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Reviews in educational psychology

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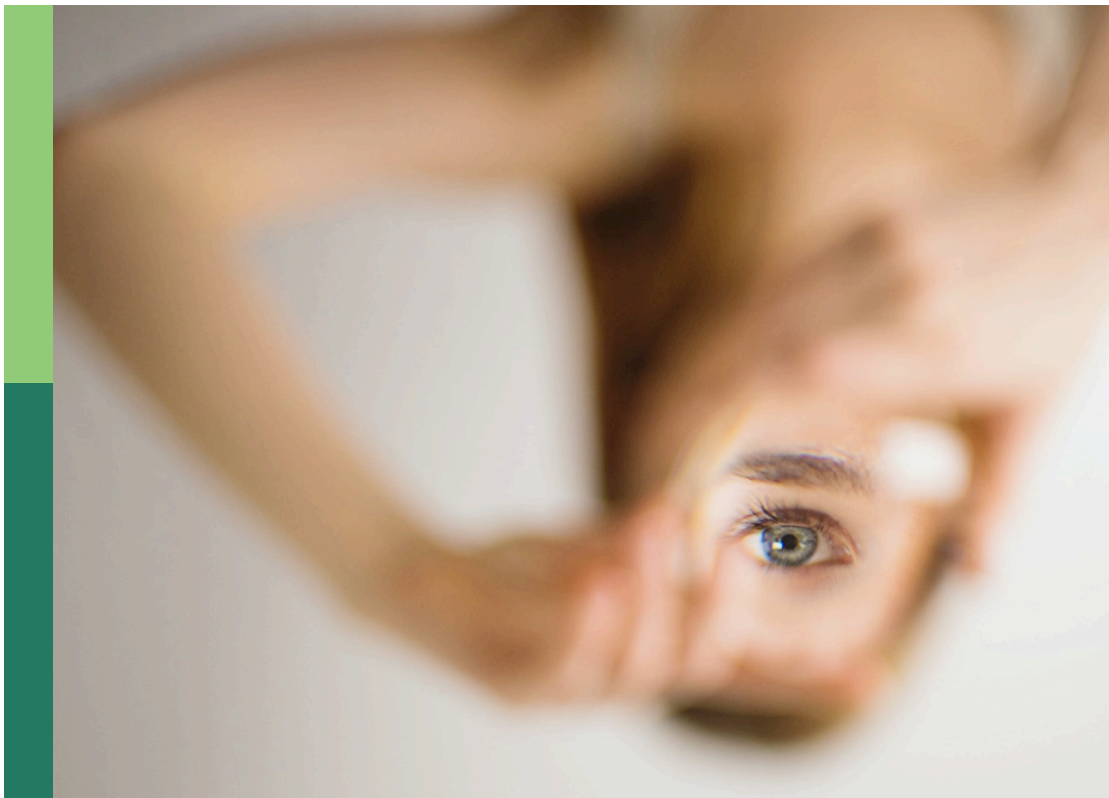

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Reviews in educational psychology

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Editorial: Reviews in educational psychology

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Editorial on the Research Topic
Reviews in educational psychology

1 Introduction

The present article introduces the Research Topic "*Reviews in educational psychology*," part of the "Reviews in" series launched by Frontiers in Psychology. This initiative highlights the growing importance of synthesis studies in consolidating knowledge and advancing the maturity of the discipline (Campos et al., 2024; Jaramillo-Mediavilla et al., 2024).

Educational Psychology, as an applied field, has reached a stage where synthesizing accumulated evidence is not only valuable but necessary. This collection showcases the diversity of review formats—systematic, theoretical, scoping, meta-analytical—and includes a comprehensive systematic review of reviews, reflecting a shift toward second-order syntheses that integrate large bodies of prior research.

Although the focus is on reviews, a small number of original studies are also featured. These contributions, some based on expert consensus or large-scale data analysis, complement the review findings by offering empirical insights into key constructs and emerging research trends.

The distribution of articles by typology and year illustrates both the scope of contributions and the growing methodological variety in the field. Together, these works demonstrate how diverse approaches—qualitative, quantitative, and mixed—contribute to a cumulative, theory-informed understanding of psychological processes in education (DeCuir-Gunby and Schutz, 2024; Kumar and DeCuir-Gunby, 2023), as summarized in Figure 1.

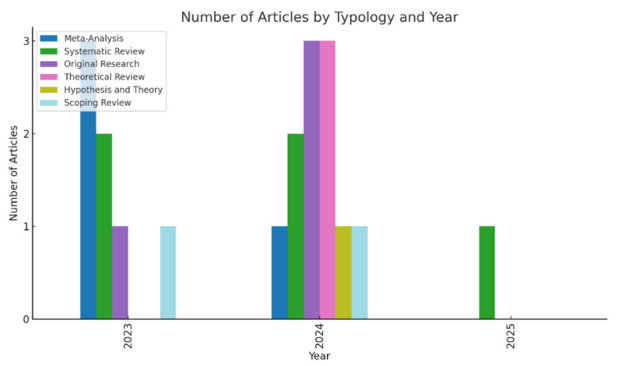

FIGURE 1
Articles published in Special Research Topic by Typology and Year.

2 Scientific contributions

2.1 Reviews

In a context where the number of systematic reviews and meta-analyses has grown exponentially, a new layer of synthesis is necessary to organize the accumulated knowledge. This is precisely the aim of Díaz-Burgos et al., who conducted a systematic review of reviews encompassing 392 review studies focused on digital education and the Sustainable Development Goals (SDGs). Their work not only identifies common review typologies, regional gaps, and emerging digital tools, but also highlights the relevance of structured strategies such as PICOC or SALSA in guiding transparent and rigorous synthesis processes. By mapping current trends and research voids, this study reinforces the value of second-order syntheses as essential tools to support inclusive policies and sustainable educational practices.

Following this, several systematic reviews address key psychological constructs from diverse perspectives. Kuznetsova et al. synthesized 104 studies on giftedness, identifying cognitive, physiological, and psychological traits—especially strong performance in motivation and executive functioning—that distinguish gifted students. Taking a more experimental focus, Wang S et al. reviewed 53 studies on fixation in problem-solving and creativity, concluding that overcoming fixation substantially enhances performance in closed-ended tasks. In another vein, Wu et al. examined 18 studies on student anxiety during the COVID-19 pandemic, showing that physical activity and mindfulness-based strategies are highly effective in reducing stress. Additionally, Yu synthesized 49 studies on foreign language anxiety, primarily in English as a Foreign Language (EFL) contexts, and emphasized the need for broader methodological and geographical diversity in future research.

Theoretical reviews in this issue contribute valuable conceptual advances. Bonilla-Sánchez explored neurodevelopmental disorders through qualitative neuropsychological assessment, offering a culturally sensitive alternative to traditional diagnostic models. Similarly, Stoltz et al. compared theories of consciousness development by Piaget, Vygotsky, and Steiner, integrating developmental, cultural, and holistic perspectives to enrich contemporary educational theory. In a more applied domain, Wang D and Li conducted a mini-review on career construction theory, highlighting assessment tools such as narrative methods, interviews, and digital interventions, with implications for increasingly personalized professional guidance.

Scoping reviews in this monograph examine structural and psychological aspects in doctoral experience. Hurtado et al. identified, across 32 studies, multiple factors influencing doctoral student retention—including individual, academic, socioeconomic, and institutional dimensions—proposing a multifactorial approach. In a related line, Wang Y and Li reviewed 30 studies on the impostor phenomenon among doctoral students, revealing its widespread prevalence and its impact on academic performance and psychological wellbeing. Both studies underscore the urgent need for tailored institutional support to ensure success in advanced academic stages.

Finally, the collection includes several meta-analyses that provide robust evidence on impactful educational interventions. Cochon Drouet et al. analyzed 43 studies on the Jigsaw method, identifying heterogeneous effects on achievement, motivation, and social relations, and offering context-sensitive implementation guidelines. Fan et al. conducted a meta-analysis of 30 studies examining parental involvement in student creativity, reporting a modest yet significant positive effect moderated by factors such as age and cultural background. Also focusing on learning processes, Shao et al. synthesized 46 studies on scaffolding in self-regulated learning (SRL), highlighting the effectiveness of composite tools and intelligent pedagogical agents. Zheng et al. explored the role of emotions in SRL through a meta-analysis of 23 studies, proposing a multimodal framework where positive emotions act as facilitators and negative emotions as barriers to effective self-regulation strategies. Finally, de la Fuente and Martínez-Vicente proposed a theoretical model linking stress and psychological wellbeing, outlining predictive, mediating, and functional components that may inform future intervention studies or theoretical syntheses (Table 1).

Although the main focus of this Research Topic lies in review studies, several original research articles have been included due to their strong thematic alignment with the constructs and challenges identified through synthesis work. López Martínez et al. employed a Delphi method with 16 international experts to identify key indicators of verbal creativity—such as fluency, originality, and elaboration—thus offering assessment criteria that can guide future empirical research and systematic inquiry. Similarly, Romero-González et al. evaluated an active Home Literacy Environment program for children aged 6 to 8, demonstrating significant improvements in reading motivation, family relationships, and academic outcomes. While not reviews, these studies contribute grounded, context-rich evidence to key educational psychology domains addressed in the broader collection.

Other original studies in the monograph provide conceptual or methodological contributions that complement the review-based focus. Ünal et al. examined Turkish teachers' personal values and emotional responses to rational and non-rational truths, offering novel insights with implications for teacher training and

TABLE 1 Overview of *Reviews in educational psychology*.

Paper	Year	Country	N	Construct	Objectives	Results	Add value
Systematic reviews of reviews							
Díaz-Burgos et al.	2025	Spain, Portugal, USA, Taiwan	392 reviews	Review methodology, digital education, SDGs	Synthesize review trends and gaps in educational psychology	Identifies typologies, regions, and digital evolution patterns	Supports inclusive and sustainable review-based research practices
Systematic reviews							
Kuznetsova et al.	2024	Finland, Russia, Canada	104 studies	Giftedness, intelligence, cognitive traits	Compare gifted vs. non-gifted children's characteristics	Gifted outperform peers in cognition, motivation, brain activity	Useful for developing assessments and gifted education programs
Wang S et al.	2023	Japan	53 studies	Fixation in creativity/problem solving	Analyze fixation types, sources, and effective defixation methods	Fixation impedes closed problems; within-frame helps open problems	Encourages tailored strategies to overcome creativity blocks effectively
Wu et al.	2023	Malaysia, China	18 studies	COVID-19 impact on student anxiety	Assess pandemic-induced anxiety and effectiveness of interventions	Physical activity and mindfulness effective; information reduces anxiety broadly	Encourages targeted coping strategies for sustained mental health interventions
Yu	2024	China	49 studies	Foreign language anxiety (FLA)	Review trends, methodologies, and findings in FLA research	EFL context dominant; mainly quantitative and mixed methods; high Chinese representation	Suggests future focus on diverse contexts and qualitative explorations
Theoretical reviews							
Bonilla-Sánchez	2024	Mexico	Not specific	Neurodevelopmental disorders and school learning	Present clinical cases of qualitative neuropsychological intervention	Qualitative assessment identifies strengths, weaknesses, and dynamic brain functions	Alternative to classical models using cultural–historical neuropsychology
Stoltz et al.	2024	Brazil, Germany	Not specific	Consciousness development	Compare educational models of consciousness development	Integrates developmental, cultural, holistic perspectives	Enriches educational theory with integrative theoretical models
Wang D and Li	2024	China	22 studies	Career construction theory tools and interventions	Present assessment tools, interventions, and future trends for career counseling	Effective tools include interviews, narrative methods, digital counseling strategies	Proposes further research on digital interventions and standardization
Scoping reviews							
Hurtado et al.	2024	Spain, Colombia	32 studies	Doctoral student retention factors	Identify factors affecting doctoral student retention and dropout	Individual, academic, socioeconomic, institutional factors interact	Proposes multifactor approach for doctoral student permanence
Wang Y and Li	2023	China	30 studies	Impostor Phenomenon among doctoral students	Review research on characteristics, impacts, measurement of impostor phenomenon	Impostor feelings prevalent, impact academic and psychological outcomes	Emphasizes need for targeted support and measurement refinement
Meta-analysis							
Cochon Drouet et al.	2023	Switzerland	43 studies	Achievement, motivation, social relations, self-esteem	Analyze effects of Jigsaw method on educational outcomes	Heterogeneous effects found across learning and social indicators	Provides implementation guidelines and identifies moderating variables
Fan et al.	2024	China	30 studies	Parental involvement and student creativity	Analyze parental involvement's effect on creativity in students	Small but significant positive effect on creativity development	Highlights moderators like age, cultural background, and involvement type
Shao et al.	2023	China	46 studies	Self-regulated learning, SSRL, scaffolding	Analyze effects of learning scaffolding on regulation and performance	Scaffolding improves strategies, composite tools most effective	Advises diverse scaffolding for SRL and collaborative learning
Zheng et al.	2023	USA, Canada	23 studies	Emotions in self-regulated learning (SRL)	Investigate role of trait and state emotions in SRL framework	Proposes integrated framework; positive emotions facilitate effective SRL strategies	Recommends multimodal methods for deeper emotion–SRL relationship understanding

(Continued)

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TABLE 1 (Continued)

Paper	Year	Country	N	Construct	Objectives	Results	Add value
Hypothesis and theory							
de La Fuente and Martínez-Vicente	2024	Spain	Not specific	Stress and psychological wellbeing	Propose conceptual model for stress and wellbeing management	Defines predictive, mediating and final functional model factors	Applicable across education, health, organizational and digital contexts
Original researches							
López Martínez et al.	2024	Spain	16 experts	Verbal creativity indicators in writing tasks	Identify valid indicators for assessing verbal creative thinking	Indicators include fluency, originality, elaboration, flexibility, refinement	Provides assessment criteria for verbal creativity in education
Romero-González et al.	2023	Spain	54 participants	Home Literacy Environment, motivation, affective bonds	Assess effects of active Home Literacy Environment program	Program enhances reading, motivation, family relationships	Highlights importance of active family-school collaboration
Ünal et al.	2024	Finland	Not specific	Teacher values and emotions (rational/non-rational truth)	Examine relationships between values, truth types, and teacher emotions	Non-rational truth linked to anxiety; rational truth to self-direction/enjoyment	Highlights value-emotion link implications for teacher wellbeing
Wang et al.	2024	China	1,638 articles	Early reading trends via dynamic topic modeling	Analyze early reading research trends and topic evolution over time	Identified 11 topics; foundational skills and autism notably increased	Highlights emerging research directions, aiding future academic inquiries

Analyses were primarily conducted using the PRISMA methodology, with the exception of Theoretical Reviews, Hypothesis and Theory and Original Researches.

professional wellbeing. Wang T et al. conducted a large-scale bibliometric analysis of 1,638 articles using dynamic topic modeling to identify evolving themes in early reading research—an approach that, while empirical, serves to map trends typically targeted by scoping reviews.

3 Conclusions

Collectively, these contributions reflect the evolving and multifaceted landscape of educational psychology research, highlighting critical issues such as creativity, emotional regulation, literacy, teacher values, and mental health in education. Each study enriches our understanding and provides practical implications, ultimately guiding educators, researchers, and policymakers toward more informed and effective practices. This compilation underscores the necessity for ongoing interdisciplinary collaboration, robust research methodologies, and continuous innovation to address educational challenges in an ever-changing global context.

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Emotions in self-regulated learning: A critical literature review and meta-analysis

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Emotion has been recognized as an important component in the framework of self-regulated learning (SRL) over the past decade. Researchers explore emotions and SRL at two levels. Emotions are studied as traits or states, whereas SRL is deemed functioning at two levels: Person and Task × Person. However, limited research exists on the complex relationships between emotions and SRL at the two levels. Theoretical inquiries and empirical evidence about the role of emotions in SRL remain somewhat fragmented. This review aims to illustrate the role of both trait and state emotions in SRL at Person and Task × Person levels. Moreover, we conducted a meta-analysis to synthesize 23 empirical studies that were published between 2009 and 2020 to seek evidence about the role of emotions in SRL. An integrated theoretical framework of emotions in SRL is proposed based on the review and the meta-analysis. We propose several research directions that deserve future investigation, including collecting multimodal multichannel data to capture emotions and SRL. This paper lays a solid foundation for developing a comprehensive understanding of the role of emotions in SRL and asking important questions for future investigation.

KEYWORDS

emotions, self-regulated learning, meta-analysis, review, framework

1. Introduction

Students experience a variety of emotions, which can be either beneficial or detrimental to their learning processes and performance. Positive emotions have a considerable impact on students' academic achievement and can ultimately lead to success in the academic domain (Pekrun et al., 2009). In contrast, negative emotions may impede students' academic processes. For example, negative emotions (e.g., anger, anxiety, and boredom) have been found to be negatively associated with students' motivation, learning strategies, and cognitive resources (Pekrun et al., 2002). Given the impressive growth of research on emotions in education, the notion of emotions has been incorporated into various education theories, especially the theoretical frameworks of self-regulated learning (SRL).

Self-regulated learning (SRL) refers to thoughts, feelings, and behaviors that learners plan and adjust to attain learning goals (Zimmerman, 2000). SRL theories account for the cognitive, metacognitive, motivational, and emotional processes and strategies that characterize learners' efforts to build sophisticated mental models during learning (Pintrich, 2000; Winne and Perry, 2000). Although theorists emphasize different aspects of SRL, the majority of them include emotions as one component of SRL (Boekaerts, 1996;

Efklides, 2011). Emotions are generally considered contributing factors that enhance or undermine the use of superficial learning strategies or deep strategies in SRL. A growing number of empirical studies provide general support for the significance of emotions in SRL by examining the effects of emotions on SRL strategies (e.g., Pekrun et al., 2010). However, both theoretical inquiries and empirical evidence about the role of emotions in SRL are still in a state of fragmentation. The field still needs a comprehensive framework that explains the complex connections between emotions and SRL. This paper addresses two research questions*: (1) What theories can be found to explain the complex relationships between academic emotions and SRL? and (2) what empirical evidence exists to support the relationships between academic emotions and SRL*? Our goal is to synthesize the current theoretical frameworks and empirical evidence with the purpose of proposing a model that underpins the link between academic emotions and SRL in individualized learning environments.

2. Academic emotions: What are they?

Academic emotion is an important dimension of self-regulated learning that researchers should consider when focusing on within-individual factors influencing learning (Ben-Eliyahu, 2019). Academic emotions are no longer just disruptions that learners should avoid or suppress (Shuman and Scherer, 2014). Academic emotions can be beneficial and harmful, pleasant and unpleasant, and activating and deactivating, depending on the specific emotions and situations.

2.1. Taxonomy of emotions

Researchers generally agree to categorize emotions according to the focus of objects (stimulus of emotions), valence (positive or negative), and degree of activation (activating or deactivating). Based on the focus of objects, emotions in the learning context can be distinguished as *achievement emotions, epistemic emotions, topic emotions, and social emotions* (Pekrun and Linnenbrink-Garcia, 2012). This review focuses on individual emotions, i.e., achievement and epistemic emotions that occur in individualized learning environments rather than social emotions that arise in group learning environments.

Achievement emotions are emotions that pertain to achievement activities or outcomes that are typically judged by competency-based standards, including anxiety, enjoyment, hope, pride, relief, anger, shame, hopelessness, and boredom (Pekrun, 2006). *Epistemic emotions* are triggered by knowledge and knowledge-generating qualities in cognitive tasks and activities (Trevors et al., 2016; Pekrun et al., 2017). For instance, when personal knowledge conflicts with external knowledge, namely cognitive incongruity, emotions may be activated by the epistemic nature of the task (Muis et al., 2015a). This kind of cognitive incongruity may cause surprise, curiosity, enjoyment, confusion, anxiety, frustration, or boredom. There are overlaps between achievement and epistemic emotions (Pekrun and Stephens, 2012). For example, a student's enjoyment can be an achievement emotion if it focuses on personal success or an epistemic emotion if it stems from a cognitive incongruity in knowledge. Achievement emotions and epistemic emotions are pervasive in different learning situations and have significant influences on learning (Sinatra et al., 2015). To better understand how these types of emotions can be evaluated in SRL, Rosenberg (1998) suggested that we must also consider the levels and organization of emotions.

2.2. Trait emotions and state emotions

According to Rosenberg's (1998) seminal work, emotions can be distinguished as traits and states. Trait emotions reflect a relatively general and stable way of responding to the world. In contrast, state emotions are characterized as episodic, experiential, and contextual and can be influenced by situational cues (Goetz et al., 2015). These differences can also be applied to the educational context, where one can differentiate trait-like academic emotions from state-like emotions (Pekrun et al., 2002). Trait-like emotions are typical course-related emotional experiences pertaining to a specific course, an exam, or a class. In contrast, state-like emotions are momentary emotional experiences within a single episode of academic life (Ahmed et al., 2013). The differences between trait and state emotions can be traced back to the factors influencing emotions. Trait emotions are derived from memory and are influenced by students' subjective beliefs and semantic knowledge (Robinson and Clore, 2002). For example, students who do not have abundant knowledge of a specific situation may report more emotions than those with sufficient or similar knowledge. On the other hand, memory plays a less significant role in state emotions (Bieg et al., 2013), where the intra-individual variance of state emotions is influenced more by the students' interactions between the learning content and environment in a single learning episode. Consequently, these distinctions between trait-like and state-like emotions are essential in understanding the inconsistent self-report emotion measurements that often occur when people are asked to self-report feelings they generally experienced in a course versus those they are currently experiencing (Robinson and Clore, 2002). Furthermore, these distinctions can also help us to better understand the role of emotions in SRL.

3. SRL: Two levels of development

Self-regulated learning (SRL) researchers evaluate self-regulated learners based on their theoretical orientations. Winne (1997) first distinguished between an aptitude and an event in terms of the property of SRL. An aptitude is a person's relatively enduring attribute aggregated in multiple learning activities. For example, a student who reports their habit of memorizing everything in learning can be predicted as a learner who is more inclined to use memorizing strategy. However, this does not mean the student will use a memorizing strategy in every SRL event. An event is a transient and continuous learning state that has a clear starting point and endpoint. Completing a task and finishing an exam are all examples of event-like SRL. Greene and Azevedo (2009) further identified 35 event-like SRL processes at the micro level, e.g., re-reading, reviewing notes, and hypothesizing.

Moreover, Efklides (2011) articulated the difference between the Person level SRL, represented by personal characteristics, and the Task × Person level SRL, guided by the monitoring features of task processing. In sum, there exist two levels of SRL: Person level SRL (or aptitude-like SRL) and the Task × Person level SRL (or event-like SRL). The underlying premise for this claim is that different learning contexts, including the nature of tasks and the structure of subjects, can influence how learners regulate their learning process (Poitras and Lajoie, 2013). The claim calls for attention to the acknowledgment of the two levels of SRL while reviewing the theoretical and empirical evidence regarding the role of emotions in SRL.

4. What do SRL models say about emotions in SRL?

The answers to the role of emotions in SRL have changed over time because of changing conceptualizations of SRL and the development of SRL models. However, emotions are consistently viewed as an important dimension in SRL (Lajoie, 2008). SRL models paved the way for understanding the role of emotions in SRL. In order to address our first research question regarding emotion and SRL theories, we reviewed five SRL models recognized by Panadero (2017) who argued that all have a consolidated theoretical and empirical foundation. Moreover, the five SRL models are all seminal theories and they are well-recognized in the literature. Järvelä and Hadwin's (2013) socially shared regulated learning model was not included, as individualized learning is the focus of this paper. **Table 1** presents our review of these six SRL models, focusing on what emotions are generated and how emotions affect SRL.

Based on the social cognitive paradigm, Zimmerman (1990) acknowledged the existence of emotions and their role in SRL. He described self-satisfaction as a combination of emotions ranging from elation to depression. However, he did not specify which emotions were included in the umbrella of self-satisfaction feelings. Pintrich (2000) extended Zimmerman's (1990) model and discussed emotions in the context of test anxiety. In Pintrich's (2000) model, task or contextual features were proposed as factors that might activate test anxiety, and emotion regulation strategies were used to manage test anxiety. This model recognized both the generation and effect of emotions. However, the model only identified test anxiety as an emotion, failing to address other types of emotions that might affect learning. Boekaerts (1996, 2011) gradually shifted her theory from cognition and motivation to emotion and emotion regulation (Panadero, 2017). In her dual-processing model, emotions were proposed as a result of the dual processing of appraisals toward the learning situation (Boekaerts, 2011). If the learning situation were appraised as congruent with personal goals, positive emotions toward the task would be triggered. In contrast, negative emotions would be triggered if the learning situation was appraised as threatening well-being because of task difficulty or insufficient support. The dual processing model highlighted the importance of emotions in SRL but did not specify the type of emotions and the outcomes of emotions in SRL. Winne and Hadwin (1998) emphasized how conditions, operations, products, evaluations, and standards (COPES) could influence the four phases of SRL tasks (i.e., task definition, goals and planning, studying tactics, adaptations). Emotion was not explicitly referred to in this model (Panadero, 2017). The discussion about motivational factors could be an allusion to emotions. Learning feelings may influence the relationship between cognitive conditions and actual operations. In contrast, the metacognitive and affective model of self-regulated learning (MASRL) provided insight into the interactions of metacognition, motivation, and affect in SRL. This model puts more emphasis on the affect in SRL and refers explicitly to the two levels of SRL. As mentioned before, MASRL presented a Person level of SRL functioning, as well as a Task × Person level of SRL events in task processing (Efklides, 2011). We will discuss further how this model describes the relationship between emotions and SRL at two levels.

At the Person level, decisions about what SRL strategies to choose are made based on stable personal characteristics and habitual representation of situational demands (Efklides et al., 2018). Emotion is a relatively stable characteristic of the individual, namely trait emotions. Efklides (2011) describes three extreme scenarios pertaining to how emotions may interact with SRL at the Person level. In the first positive scenario, learners predict success with appropriate SRL strategies and positive emotions. In the second negative scenario, learners predict failure with inappropriate SRL strategies and negative emotions. In the third scenario, learners underestimate or overestimate personal competency; consequently, their emotional reactions and effort expenditure do not match learning outcomes. More specifically, if a student underestimates their mathematics skills, for example, they would emotionally feel anxious and spend more effort learning math, resulting in successful learning outcomes. By contrast, a student who overestimates his effort would experience positive emotions, exert insufficient effort, and have unsuccessful outcomes. These estimated efforts and emotions, restored at a general level, provide cues for subsequent specific tasks (Efklides, 2006).

In a specific task, SRL happens in the form of dynamic events at a Task × Person level. According to this model, task features (e.g., complexity) are objective and independent of a specific learning context but intersect with the person's attributes and must be considered jointly. The MASRL model proposed three phases of SRL that align with Zimmerman's (2000) proposition of SRL phases (i.e., *forethought, performance, and self-reflection*). The *forethought phase* may involve two types of cognitive processes. The first type is an automatic and unconscious cognitive process, which can be generated when dealing with familiar, fluent, and effortless tasks (Efklides, 2011). When processes are automatic, emotions are neutral or moderately positive without conscious control processes and increased physiological activity (Carver and Scheier, 1998). The second type of cognitive process is analytic and can be triggered by the task's structure, novelty, and complexity (Alter et al., 2007). Negative emotions may appear with increased arousal (Efklides, 2011). On the other hand, emotions such as surprise and curiosity may be generated depending on the uncertainty and cognitive interruption that occurs during this phase (Bar-Anan et al., 2009). At the *performance phase*, negative or positive emotions may also change according to the fluency of processing and the rate of progress (Ainley et al., 2005). When tasks are completed, and outcomes are produced at the *self-reflection phase*, positive or negative emotions accompanying the outcomes of the task are triggered or enhanced.

5. Academic emotions and SRL: What does the empirical evidence tell us?

To address the second research question (i.e., empirical evidence regarding the role of emotions in SRL), we conducted a comprehensive literature search *via* the PsycINFO, ERIC, and Web of Science databases. The search syntax was ("self-regulated learning" OR "self-regulation" OR "metacognition") AND ("emotion" OR "affective" OR "anxiety" OR "positive emotions" OR "negative emotions"). The search ended up retrieving 205 articles. We then applied these five inclusion criteria to screen articles: (1) The study must be published in English; (2) The study measured specific self-regulated learning strategies or self-regulated learning processes; (3) The study measured discrete emotions; (4) The study was conducted in a specific learning setting, including an exam, a task, a course, or a specific training program; (5) The study reported the correlation between specific SRL strategies/processes and discrete emotions. Only 23 studies that meet these five criteria are included.

As can be seen in **Appendix A**, these 23 empirical studies examined the relationship between emotions and SRL strategies. By analyzing the summary of the 23 included studies (**Appendix A**), we find anxiety, enjoyment, frustration, and boredom are the most frequently examined academic emotions. Metacognitive strategy is most frequently examined in SRL. We then coded these five variables to synthesize the correlation between the four academic emotions and metacognitive strategies. Particularly, there were 14 studies focusing on anxiety, 11 studies on enjoyment, 7 studies on frustration, and 10 studies on boredom. The number of studies was statistically sufficient, based on the rule of a minimum of five independent studies for reliable estimation in the small-sample meta-analysis (Fisher and Tipton, 2015).

We adopted a random-effects model (Hedges and Vevea, 1998) since the studies in our review differed in methodological characteristics. Among the positive emotions, we found that enjoyment was positively related to metacognitive strategies (r = 0.42) (see **Table 2**). As displayed in the forest tree of enjoyment in **Figure 1**, we found positive relationships between enjoyment and metacognitive strategies in all studies. In addition to enjoyment, pride also positively predicted cognitive and metacognitive strategies (Ahmed et al., 2013).

In terms of negative emotions, anxiety and frustration are generally negatively related to metacognitive strategies ($r = -0.075$ and $r = -0.12$, respectively). However, mixed findings have also been identified across studies. For instance, Muis et al. (2015a) and Peng et al. (2014) found positive relationships between anxiety and metacognitive strategies. Frustration was found to be both positively and negatively related to metacognitive strategies (Artino and Stephens, 2009; Artino and Jones, 2012; Marchand and Gutierrez, 2012; Cho and Heron, 2015). Surprise, curiosity, and confusion are epistemic emotions that produce the most inconsistency in terms of valence categorization, meaning that for learners, they are sometimes pleasant and sometimes unpleasant when experiencing these three epistemic emotions (Noordewier and Breugelmans, 2013). In our meta-analysis, we found boredom negatively related to metacognitive strategies in most of the studies ($r = -0.31$). Curiosity and confusion either positively or negatively predict SRL depending on the depth of strategy use (Muis et al., 2015b). In other words, surprise, curiosity, and confusion can have different effects on shallow processing strategies, deep processing strategies, cognitive strategies, and metacognitive strategies.

The empirical studies provide evidence about the relationship between trait emotions and SRL strategies. Specifically, the majority of the empirical studies focused on examining how academic emotions affect SRL strategies at the Person level (see **Appendix A**). This emphasis is partly because researchers initially conceptualized SRL as a relatively stable individual inclination, which led to trait-like measures of SRL strategies that have dominated the literature (Boekaerts and Cascallar, 2006). The methodological and ethical issues regarding collecting online data also restrict the exploration of emotions and SRL as states and events (Schutz and Davis, 2000).

To sum up, previous SRL models and empirical studies are not sufficient to reveal the underlying mechanisms of emotions in SRL. One reason is that existing SRL models put unequal emphasis on emotions and SRL. It is worth mentioning that the MASRL model took a crucial step toward a better understanding of emotions in SRL. The model emphasizes both the static and dynamic characteristics of emotions at the two levels of SRL. Nevertheless, the MASRL model provides no clues about how emotions are generated and how the complex interplays of emotions

TABLE 1 The role of emotions in self-regulated learning (SRL) models.

References	SRL models	Generation of emotions	Effects of emotions
Zimmerman (1990)	Three Cyclical Phases Model	Self-satisfaction in the self-reflection phase	Proactive learners: further efforts to learn; Reactive learners: reduce motivation and efforts to continue
Pintrich (2000)	Four Phases of SRL Model	Anticipatory emotions: test anxiety and fear in the forethought stage	Emotion occurs in the reaction and reflection phase
Boekaerts (1996, 2011)	Adaptive Learning Model	Emotions triggered by appraisal	Influence cognition; Emotion regulation to deal with emotion
Winne and Hadwin (1998)	COPES		The feelings accompanying learning can influence the relations between cognitive conditions and operations
Efklides (2011)	Metacognitive and affective Model of Self-regulated learning (MASRL)	Perceived control and value beliefs influence emotions	Emotions interact with motivation and metacognition in two levels of SRL

As described above, these SRL models reveal a long-established interest in emotion as a key component in SRL. MASRL is the most pertinent theoretical framework that demonstrates an intersection of emotions and SRL with the acknowledgment of the two levels of SRL (i.e., Person and Task × Person level). These models provide some basic assumptions regarding the role of emotions in SRL. In this paper, we critically analyze empirical evidence to find if the literature supports or refutes these theoretical arguments.

TABLE 2 Meta-analysis results.

Emotion	*k*	*N*	*r*	95% CI		*r*-range	Test of heterogeneity		
				LL	*UL*		*Q*	df (Q)	*p*
Anxiety	14	5184	−0.075	−0.23	0.085	−0.44∼0.38	376.76	11	< 0.0001
Enjoyment	9	3362	0.42***	0.32	0.53	0.04∼0.56	42.46	8	< 0.0001
Frustration	7	1396	−0.12*	−0.23	−0.013	−0.062∼-0.28	21.42	6	0.0015
Boredom	10	1902	−0.31***	−0.42	−0.19	−0.57∼0.01	30.37	7	< 0.0001

N, sample size; *LL*, lower limits; *UL*, upper limits; *CI*, confidence interval; *$p < 0.05$, ***$p < 0.001$.

and SRL influence learning outcomes. In terms of empirical evidence, previous studies only addressed the relationships between emotions, SRL strategies, and learning outcomes. Many questions are still unanswered, for instance, (a) what academic emotions will be generated in the SRL process? (b) what are the effects of different emotions in SRL, (c) how do emotions change in different stages of SRL?, and (d) what are the relationships between emotion and SRL at the Task × Person level? An integrated framework is needed to illustrate the role of emotions in SRL better. To substantially advance this field of research, we contend that this framework should address the generation and effects of emotions in SRL. It should provide explanations of the reciprocal relationships between emotions and SRL. Furthermore, the two levels of SRL (i.e., Person and Task × Person level) should be considered to demonstrate how trait and state emotions unfold in different SRL phases, e.g., forethought, performance, and self-reflection.

6. Toward an integrated framework for understanding emotions in SRL

In this study, we proposed an integrative framework of emotions in SRL (ESRL) (**Figure 2**). The ESRL framework was developed based on the previous conceptualizations of emotions and SRL. It retains the important contributions of previous SRL models. As shown in **Figure 2**, the framework focuses on the generation and effects of emotions in SRL at two levels (i.e., Person and Task × Person level). In the center of the ESRL framework are the propositions that SRL is an aptitude influenced by trait emotions at the Person level. Moreover, SRL is also an event in a specific task that has dynamic state emotions unfold during different phases at the Task × Person level.

6.1. Antecedents of academic emotions

Individual characteristics, environmental factors, control appraisals, and value appraisals are the antecedents of academic emotions at both the Person and Task × Person levels. According to the Control Value theory (CVT), individual antecedents include intraindividual differences such as gender and achievement goals (Pekrun and Perry, 2014). Environmental antecedents (e.g., autonomy support and feedback) are factors that characterize general learning environments. Either trait or state emotions can be triggered depending on the specificity of these antecedents. When control appraisals are conceptualized as the general perception of a learning situation, such as attending online courses (You and Kang, 2014) or a math course (Villavicencio and Bernardo, 2013), control appraisals can predict how students generally feel (trait emotions) in these similar situations. In contrast, when control appraisals are conceptualized as the perception of a specific learning task, for example, solving a math problem (Muis et al., 2015b), control can influence students' emotions during the problem-solving process (i.e., state emotions). From the perspective of CVT, generalized control-value beliefs can be linked to trait emotions. They can also influence momentary appraisals and state emotions (Pekrun and Perry, 2014).

Furthermore, the majority of the literature in educational psychology has focused on the effect of task features (i.e., task novelty, complexity, and structure) on the occurrence of emotions, especially epistemic emotions (D'Mello and Graesser, 2012; Muis et al., 2018). These task features are objective and independent of a specific learning context but intersect with the person's attributes and must be considered jointly (Efklides, 2011). Foster and Keane (2015) focused on how new, novel or unique information may trigger surprise if the individual perceives the information as unexpected. D'Mello et al. (2014) proposed that complexity is a crucial antecedent to confusion during learning. Silvia (2010) argued that the complexity of the task would also predict either curiosity or confusion after the surprise toward novelty. In addition to curiosity and confusion, boredom and anxiety are the consequences of task novelty, complexity, and structure. For example, a generally highly competent student may still feel anxious when solving a difficult math question (i.e., task complexity). A student who usually feels bored in a face-to-face math class may be curious about a novel math question that is presented in an innovative way (i.e., task novelty and structure). All the emotions arise from appraisals of uncertainty stemming from task novelty, complexity, or structure (Ellsworth and Scherer, 2003). It is the cognitive disequilibrium underlying uncertainty that plays a critical role in triggering dynamic epistemic emotions (D'Mello and Graesser, 2012). Compared with the dynamic appraisal process of state emotions and ever-changing task attributes, however, trait emotions are relatively stable to interact with SRL.

6.2. Interaction between emotions and SRL at the person level

Trait emotions have reciprocal relationships with SRL strategies. Trait emotions are a decontextualized and stable way of reporting feelings (Goetz et al., 2016), while SRL strategies include all the components of SRL, namely cognitive strategies,

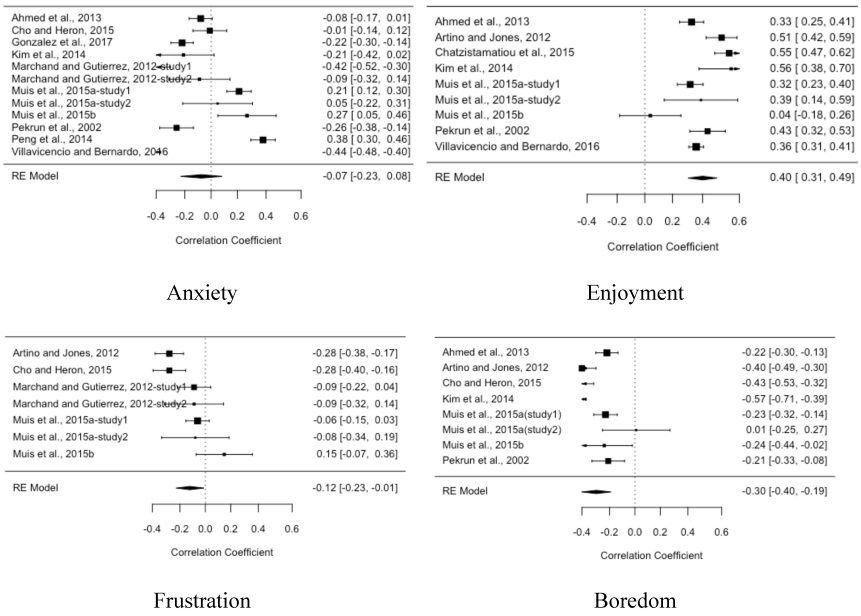

FIGURE 1
The forest tree of anxiety, enjoyment, frustration, and boredom.

metacognitive strategies, emotional strategies, and motivational strategies (Warr and Downing, 2000; Ferla et al., 2009). In the interaction between emotions and SRL, trait emotions are presented as an emotional loop or cycle that monitors the strategies or efforts exerted in SRL (Efklides et al., 2018; Ben-Eliyahu, 2019). On the one hand, trait emotions may interfere with students' prioritization of SRL strategies. Results from empirical studies support these propositions. Positive emotions (e.g., enjoyment, pride) are positively related to students' usage of cognitive strategies and metacognitive strategies (Pekrun et al., 2002; Artino and Stephens, 2009; Ahmed et al., 2013; Villavicencio and Bernardo, 2013, 2016; Mega et al., 2014; Chatzistamatiou et al., 2015; Chim and Leung, 2016). Villavicencio and Bernardo (2013, 2016) examined the relationship between academic emotions, self-regulation, and achievement in a math course and found that both enjoyment and pride were positively correlated with self-regulation. In terms of negative emotions, boredom, frustration, and anxiety were generally negatively associated with SRL strategies (Pekrun et al., 2002; Kim et al., 2014; Mega et al., 2014; Peng et al., 2014; Gonzalez et al., 2017). More interestingly, researchers found that SRL strategies also influenced students' trait emotions. For example, Ben-Eliyahu and Linnenbrink-Garcia (2013) examined how self-regulated emotion strategies would influence students' emotions in academic courses. Results suggested that self-regulated emotions were differentially employed based on course preference, which consequently influences students' emotions in the course. Furthermore, students who heavily rely on ineffective strategies show prolonged frustration, boredom, and confusion (D'Mello and Graesser, 2012; Sabourin and Lester, 2014; Azevedo et al., 2017). The cyclical effects between emotions and SRL strategies generate long-term effects on student learning outcomes, including persistence (Drake et al., 2014), procrastination (Rakes and Dunn, 2010), and academic achievements (Peng et al., 2014; Gonzalez et al., 2017).

6.3. State emotions function at the Task × Person level

Achievement emotions and epistemic emotions are the dominant emotions triggered in a specific task (Pekrun and Stephens, 2012), where these emotions dynamically influence three phases of the SRL cycle (Efklides, 2011). Research provides support for the dynamic emotional changes throughout SRL processes. Anticipatory feelings start from the beginning of a learning activity (i.e., forethought), even though these feelings may be more salient in the self-reflection phase of SRL (Usher and Schunk, 2018). Within the SRL cycle, individuals experience emotions in proportion to the challenges they are facing (Usher and Schunk, 2018). The structure, complexity, and novelty attributes of a task reflect the challenges, which have become the catalyst of academic emotions (Muis et al., 2018). In other words, task analysis in the *forethought phase* predicts the initial emotions students may feel. It is reasonable to anticipate confusion when facing unfamiliar structures, anxiety when facing complexity, and curiosity when facing novelty. In addition to the *forethought phase*, task fluency in the *performance phase* contributes to discrete emotions. In two studies by Winkielman and Cacioppo (2001), students showed more negative emotions in reaction to processing fluency. Fulmer and Tulis (2013) examined students' fluency and emotions multiple times in a reading task. A latent growth curve showed that positive emotions decline with a decrease in reading fluency. Finally, self-evaluation in the *self-reflection phase* can also affect a change of emotions (Efklides et al., 2018). Learners judge their learning situations by comparing them with performance standards established by themselves and others (Usher and Schunk, 2018). There is no doubt that students experience different emotions even when they have similar performances. A low-performing student may experience more happiness and even pride in the

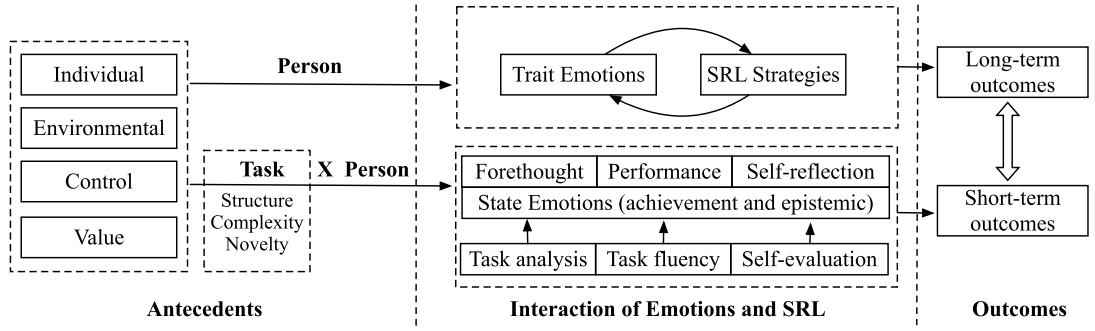

FIGURE 2
The role of emotions in self-regulated learning (ESRL).

self-reflection phase if they consider themself to outperform what they expected. As discussed above, emotions are dynamic and change throughout the three SRL phases, which can influence the effort individuals put toward a task or create an obstacle to further progress in the SRL tasks. Feelings of happiness and pride may lead to renewed efforts, while anxiety and frustration may lead to task avoidance or withdrawal (Usher and Schunk, 2018). Consequently, the short-term learning outcomes will be influenced, including achievements and learning gains, in this SRL event.

6.4. Interaction between the two levels of SRL

Self-regulated learning (SRL) is a life-long learning process where students need to plan for each session, each semester, and each training period (Efklides et al., 2018). The short-term learning outcome of one section determines if students will persist with learning or quit on their attempt in the next session. Repeated engagement or disengagement with similar tasks provides consistent information about self-efficacy in a task domain and updates the domain-specific self-concept (Efklides, 2011). Indeed, Metallidou and Efklides (2001) found that self-ratings of confidence and personal estimates of mathematical performance predicted competence at the Person level. It is possible that the short-term perseverance or withdrawal of effort will transfer into long-term outcomes that will be relatively stable over time. From the Task × Person level to Person level, the short-term outcomes of a specific SRL event will gradually influence long-term SRL outcomes. On the other hand, long-term learning outcomes will be transformed into more stable individual characteristics to affect SRL at the Task × Person level. These individual characteristics can be prior knowledge, motivation, and self-efficacy, which will affect how students appraise a specific task. Efklides and Tsiora (2002) conducted a longitudinal study to examine the mechanism between SRL at the Task × Person level and Person level. They found self-concept at the Person level influenced SRL at the Task × Person level. Therefore, from the perspective of life-long learning, we assume the existence of long-term interaction between the two levels of SRL, even though empirical evidence to support this argument is sparse.

7. Future directions that build upon the integrative framework

Future research should progress beyond the singular study of relations between emotions and SRL at the Person level. As proposed in our framework, the dynamic relationships between emotion and SRL exist at the Task × Person level. Therefore, it is crucial for future research to examine how emotions unfold in different phases of SRL using advanced methodologies. For example, the high sampling rates of physiological and behavioral measures make it possible to capture the components of SRL with high granularity. Further research in examining emotions and SRL at the Task × Person level could provide insights into the dynamics of SRL, which will consequently inform instruction and the scaffolding for SRL.

Another fruitful area of research resides in the longitudinal research that examines the long-term interplays between the Task × Person and the Person levels of SRL. For example, if students are trained to have proper task analysis skills at the beginning of a specific task, will this kind of training influence their general SRL strategies? Do students transfer the strategies across different contexts and gradually develop them into trait-like personal inclinations? If so, what factors can promote or prohibit this kind of influence? Do trait emotions influence state emotions? Do achievements and motivations associated with a specific task accumulate to influence students' general persistence and procrastination in learning? Answering these types of questions can provide educators and researchers with tools for designing SRL training programs that can affect learners in the long run.

The third area in need of investigation is how the structure, difficulty, and novelty of a task are related to control-value appraisals and collectively influence academic emotions and SRL. Task difficulty is likely a well-explored direction in task analysis; however, task structure and novelty need further exploration. For example, different emotions and SRL patterns

may be triggered by an exam that starts with easy questions or an exam that starts with difficult questions. Thus, a better understanding of the influence of task structures and novelty would contribute to the design of a task that is beneficial for SRL.

Additionally, empirical studies are needed to verify the antecedents of emotions across the three SRL phases. As discussed in our ESRL model, task analysis in the forethought phase, task fluency in the performance phase, and self-evaluation in the self-reflection phase triggers the occurrence and changes of academic emotions. More studies are needed to empirically explore these possibilities. More importantly, researchers can delve into the real-time modeling and visualization of the factors influencing emotions so that corresponding strategies or interventions can be incorporated to optimize the whole learning process. For example, it would be interesting to provide instructors with a dashboard that displays how students' task fluency evolves and students' experience of academic emotions over time. In doing so, teachers can provide students with effective emotional or instructional support in real-time.

It is also important to highlight the necessity of using multimodal multichannel data to study SRL for future research. Researchers currently use four types of methodological approaches to studying SRL: (a) self-report measures (i.e., self-report questionnaires, structured dairy, think-aloud/emote aloud, interview); (b) behavioral measures (i.e., facial expressions, body posture, eye-tracking); (c) physiological measures; and (d) computer trace log files. However, each of these four types of measures has its strengths and weaknesses. For example, self-report has its strength in examining SRL at the Person level. However, many self-report measures are static and not capable of capturing the dynamic changes of SRL at the Task × Person level. In contrast, computer log files are powerful in keeping track of SRL at the Task × Person level. However, researchers have to overcome the challenge of making reliable inferences from the trace data.

In response to the drawbacks and strengths of the current methodologies, we argue that researchers need to use multimodal multichannel data when examining the relationship between emotions and SRL at both levels. Self-report measures can be the focus of trait measures at the Person level, whereas physiological measures and trace data can contribute to the situational measures at the Task × Person level. Furthermore, when adopting multichannel data to examine the relationships proposed in the ESRL model, researchers must pay attention to the challenges regarding data analysis and data interpretation. Alignment is the major challenge of analyzing multiple data streams, especially when the starting times are different or the sampling rate varies across devices and methods. For example, it is obvious that physiological sensors need to be attached before an actual data collection process. Consequently, the physiological time stamps start earlier in data collection than in computer log files if both are used for measuring SRL events. In a similar vein, the eye-trackers capture data continuously at 60–120 Hz, but EDA occurs at 8–20 Hz, which means that transformation is necessary when using multimodal multichannel data to analyze different data channels. In terms of data interpretation, it is problematic when researchers cannot make consistent predictions related to specific indices of a method. For example, fixation duration has been interpreted as both cognitive engagement and emotional arousal. These mixed interpretations can cause misleading findings in the literature.

8. Conclusion

There is remarkable progress in the theoretical development of SRL toward a holistic understanding of learning or problem-solving process that underscores academic emotions. Although limited empirical studies are available, contemporary literature clearly suggests the complex relationships between academic emotions and SRL. However, this field of study is still scattered and fragmented, given the many ambiguities and arguments about the nature of the two constructs (i.e., academic emotions and SRL). In this study, we contended that emotions could be studied as either traits or states and SRL functions at both Person and Task × Person levels. By reviewing predominant SRL models and analyzing relevant empirical studies, we proposed an integrative framework to explain the role of trait and state emotions in SRL. Specifically, the proposed framework illustrates what the antecedents of emotions are and how they influence academic emotions and consequently SRL and learning outcomes. Moreover, the framework explains how trait emotions influence SRL strategies at the Person level and how state emotions unfold in different phases of SRL at the Task × Person level. We discuss future research directions that build upon our framework, which will advance this field of study considerably. We acknowledge that there is still a long way to go to pinpoint the complex interplays between emotions and SRL. The proposed framework in this study lays a solid foundation for developing a comprehensive understanding of the role of emotions in SRL and asking important questions for future investigation.

Author contributions

JZ: conceptualization, investigation, and writing–original draft. SLa: writing–reviewing and editing, supervision, and funding acquisition. SLi: writing–reviewing and editing. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Appendix

APPENDIX A Studies of the relationships between emotions and self-regulated learning (SRL) strategies.

References	Sample	Age	Subjects	Emotions	SRL strategies	Emotion measure	SRL measure	Relationships
Ahmed et al. (2013)	495	12.8	Math	anxiety, boredom, enjoyment, pride	shallow: rehearsal deep: elaboration, organization metacognitive: planning, monitoring, and evaluation	AEQ	MSLQ	Anxiety – Metacognitive; Boredom – Shallow, Metacognitive; Enjoyment ++ Deep, Metacognitive; Pride ++ Shallow, Deep, Metacognitive;
Artino (2009)	481	20.5	Online aviation	boredom, frustration	elaboration metacognitive	AEQ	MSLQ	Boredom – metacognition; Frustration ++ metacognition;
Artino and Jones (2012)	302	20.5	Online aviation	boredom, enjoyment, frustration	elaboration metacognitive	AEQ	MSLQ	Boredom – elaboration, metacognition; Enjoyment ++ elaboration, metacognition; Frustration ++ metacognition;
Ben-Eliyahu and Linnenbrink-Garcia (2013)	250	18.99	General	positive activated, positive deactivated, negative activated, negative deactivated	ERS: reappraisal, suppression, rumination	PANAS	Gross and John (2003)	Reappraisal ++ positive; Reappraisal – negative; Suppression – positive activated; Suppression ++ positive deactivated; Rumination ++ negative; Rumination – positive;
Burić and Sorić (2012)	365	16	Test	hope, hopeless	Volitional strategies: self-efficacy enhancement, negative-based incentives,	AEQ	AVSI	self-efficacy enhancement – hopeless; self-efficacy enhancement ++ hope; negative-based incentives – hope; negative-based incentives ++ hopeless;
Chatzistamatiou et al. (2015)	344	11–12	Math	enjoyment	cognitive: memorization, deep comprehension metacognitive: metacognition, reflection	Price and Mueller (1981)	Dermitzaki and Efklides (2003)	enjoyment ++ cognitive, metacognitive;
Chim and Leung (2016)	180	NA	English language	boredom anxiety enjoyment, anger, Shame, Pride, hopelessness	memory strategy, goal setting, self-evaluation, seeking assistance, environment structuring, learning responsibility, organization	AEQ	Magno (2010)	enjoyment, pride, hope ++ All except environment structuring; anxiety, anger, shame hopelessness ++ All except environment structuring; boredom – all except environment structuring;
Cho and Heron (2015)	229	21.64	Online math	test anxiety, boredom, frustration	metacognitive, CT	AEQ, MSLQ	MSLQ	Boredom – metacognitive, CT; Frustration – metacognitive, CT;
Gonzalez et al. (2017)	520	16.81	Physics	hope, anxiety	metacognitive: planning, monitoring, evaluation	AEQ	Physics Metacognitive Inventory	hope ++ planning, monitoring, evaluation; anxiety – planning, monitoring, evaluation;
Kim et al. (2014)	72	16.7	Online math	boredom, anxiety enjoyment, anger, shame, pride, hopelessness	cognitive strategy self-regulation	AEQ	MSLQ	boredom, anger, shame, hopelessness – self-regulation; enjoyment, pride – self-regulation, cognitive strategy; boredom – cognitive strategy;

(Continued)

APPENDIX A (Continued)

References	Sample	Age	Subjects	Emotions	SRL strategies	Emotion measure	SRL measure	Relationships
Van Nguyen et al. (2015)	623	20.92	Medical students	depression, anxiety, stress	rehearsal, elaboration, CT, organization, metacognitive, time and study environment, help seeking, peer learning, and effort regulation	DASS	MSLQ	help-seeking – depression; time and study environment ++ depression;
Kesici et al. (2011)	320	21.28	Statistics	anxiety	rehearsal, elaboration, CT, organization, metacognitive, time and study environment, help seeking, peer learning, and effort regulation	STARS	MSLQ	effort regulation, help seeking strategies ++ anxiety;
Marchand and Gutierrez (2012)	291	33.5	Research methods course	hope frustration, anxiety	learning strategies	AEQ	(Greene et al., 2004)	hope, anxiety ++ learning strategies; frustration – learning strategies;
Mega et al. (2014)	5805	22.46	General	positive emotions, negative emotions	SRL strategies: organization, elaboration, self-evaluation, metacognition	emotion questionnaire	MSLQ	positive emotions ++ SRL strategies; negative emotions – SRL strategies;
Muis et al. (2015a)	439	21.77	climate change	surprise, curiosity, enjoyment, confusion, anxiety, frustration, boredom	metacognitive, elaboration, CT, rehearsal	EEQ	MSLQ	Surprise – CT; Boredom – rehearsal; curiosity, confusion, enjoyment ++ metacognitive; curiosity, anxiety ++ CT; curiosity, enjoyment ++ elaboration; enjoyment ++ rehearsal;
Muis et al. (2015b)	79	11	Math	surprise, curiosity, enjoyment, confusion, anxiety, frustration, boredom	planning and goal setting, shallow strategies deep strategies metacognitive strategies	EEQ	think-aloud	curiosity, anxiety, frustration ++ shallow; surprise, confusion – shallow; surprise, confusion, boredom – deep; surprise, boredom – planning and goal setting; curiosity, anxiety ++ metacognitive; boredom – metacognitive;
Pekrun et al. (2002)	230	NA	General	enjoyment, hope, anger, anxiety, boredom	elaboration, rehearsal, self-regulation	AEQ	MSLQ	enjoyment, hope ++ elaboration; anger, anxiety, boredom – rehearsal; enjoyment, hope ++ self-regulation; anxiety, boredom – self-regulation;
Peng et al. (2014)	438	15–16	Test	anxiety	metacognitive strategies	TTSQ	TTSQ	anxiety ++ metacognitive;
Villavicencio and Bernardo (2013, 2016)	1345	16.49	Math	anxiety, enjoyment, pride	self-regulation	AEQ	MSLQ	enjoyment, pride ++ self-regulation
Lajoie et al. (2018)	43	24.5	Clinical reasoning	positive activating, negative activating, positive deactivating, negative deactivating)	SRL processes (forethought, performance, self-reflection)	Medical emotions	Log file	Forethought – negative activating emotions Performance – negative deactivating emotions Self-reflection positive activating emotions
Rienties et al. (2019)	1035	First-year	Introductory math, statistic	Epistemic emotions, achievement emotions	SRL strategies	EES, AEQ	Vermunt's student learning pattern (ILS)	Emotions differ among SRL groups

(Continued)

APPENDIX A (Continued)

References	Sample	Age	Subjects	Emotions	SRL strategies	Emotion measure	SRL measure	Relationships
Taub et al. (2021)	65	21.8	Biology (circulatory system in Metatutor)	surprise, contempt, confusion, frustration	Metacognitive judgments	Facial expressions	Self-report	Surprise – metacognitive accuracy Frustartion ++ Cognitive accuracy.

++ refers to positive relations and – refers to negative relations.

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Effects of regulated learning scaffolding on regulation strategies and academic performance: A meta-analysis

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Education research is increasingly focused on fostering self-regulated learning (SRL) and socially shared regulation of learning (SSRL) among students. However, previous meta-analyses have rarely focused on the specific types of regulated learning scaffolding. Therefore, this meta-analysis examines the effects of different types of regulated learning scaffolding on regulation strategies and academic performance. A total of 46 articles met the inclusion criteria and were included in the final analysis. The findings showed that overall, regulated learning scaffolding had a moderate effect (g=0.587). In addition, moderation analyses were performed using a random effects model that focused on four types of scaffolding. The results showed that overall, composite tools had the greatest effect, while the most useful scaffolding for SRL and SSRL were group awareness tools (g=0.61) and composite tools (g=0.53), respectively. In terms of learning outcomes, composite tools had the greatest effect on regulation strategies, while intelligent pedagogical agents had the greatest effect on academic performance. We also performed a meta-regression analysis to identify the moderators that had the greatest influence on the effects of regulated learning scaffolding. The results showed that grade level, academic subject, and cooperation all had a significant impact. In conclusion, these findings provide evidence for validating the effectiveness of four regulated learning scaffolding and for discovering their function for SSRL, and presented some practical implications of our findings.

KEYWORDS

regulated learning scaffolding, SRL, SSRL, regulation strategies, academic performance, meta-analysis

1. Introduction

Self-regulated learning (SRL) is a crucial element in the student learning process (Jansen et al., 2019) that is essential for the cultivation of students' lifelong learning competence and employability (Bruijn-Smolders et al., 2016; Theobald, 2021). Students must regulate their own behavior and cognition effectively and in a timely manner if they are to achieve positive learning outcomes (Duffy and Azevedo, 2015). In addition, meaningful learning requires group members' active interaction and the co-construction of shared goals and strategies (Zheng et al., 2017; Zabolotna et al., 2023). Therefore, it is necessary to focus on not only individual learning but also socially shared regulation of learning (SSRL) (Hadwin et al., 2011; Zheng et al., 2017). Rogat and Linnenbrink-Garcia (2011) identified the strong link between SRL and SSRL, and

highlighted the contextualized nature of students' experiences during shared activities. Previous studies have also shown that high levels of SSRL are associated with reduced social loafing and improved problem-solving (Panadero and Järvelä, 2015), and play a critical role in collaborative learning (Zheng et al., 2017).

However, students often lack the necessary regulated learning knowledge, and fail in their SRL and SSRL (Lin, 2018). For instance, they are unable to manage self-regulation processes and activities spontaneously (Bannert and Reimann, 2012), perform poorly in terms of time and study management (Theobald, 2021), and have difficulty in collectively regulating cognitions, emotions, metacognitions, and behaviors (Zheng et al., 2017). Hence, it is necessary to use scaffolding to support regulated learning (including SRL and SSRL), given that SRL and SSRL have a mutual influence on collaborative learning (Grau and Whitebread, 2012). Despite a wealth of empirical studies exploring the effects of various scaffolding on regulation strategies and academic performance (Troussas et al., 2021; Azevedo et al., 2022), such as scripts (Chen et al., 2014; Raes et al., 2016), intelligent pedagogical agents (Duffy and Azevedo, 2015), and group awareness tools (Lin, 2018), there is no consensus about the scaffolding's effects. Therefore, it is necessary to examine the functions of various regulated learning scaffolding using meta-analysis. Moreover, previous meta-analysis has not yet focused on the type of regulated learning scaffolding, i.e., the macro level (the type of regulated learning scaffolding) rather than the micro level (such as functions, delivery forms, and so on). This research intended to focus on four regulated learning scaffolding and explored their respective effects at a macro level. Further, although there were many meta-analyses on SRL scaffolding, those on SSRL scaffolding remained scarce. Scholars have not previously verified the function of the regulated learning scaffolding on SSRL using meta-analysis. Thus, the first goal of this meta-analysis was to investigate the overall effectiveness of regulated learning scaffolding. The second goal was to explore the specific effects of scaffolding on the type of regulated learning (SRL/SSRL) and learning outcomes (regulation strategies and academic performance). The third goal was to identify the factors influencing the effectiveness of various scaffolding.

2. Literature review

2.1. Self-regulated learning and socially shared regulation of learning

SRL is defined as an "active, constructive process whereby students set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features of their environment" (Pintrich, 1999). Students who engage in SRL take control of their own learning process (Jansen et al., 2019), which can generally be divided into three phases: preparation, performance, and appraisal (Panadero et al., 2017). Learners analyze the task and set goals in the preparation phase, supervise and control the learning process in the performance phase, and reflect on the process to facilitate subsequent learning in the appraisal phase (Theobald, 2021).

Socially shared regulation of learning has attracted increasing attention with the enrichment of collaborative learning scenarios and tools. Collaborative learning provides opportunities for shared knowledge construction and productive interactions (Dillenbourg, 1999). Shared regulation occurs when groups of learners regulate their learning together, such as when they construct shared task perceptions or shared goals, and thus SSRL can be defined as a process in which a group of learners co-construct plans or align their monitoring perceptions to establish a shared evaluation of learning (Järvelä et al., 2013), regarding learning as the co-construction of knowledge.

Numerous researchers have found empirical evidence of SRL as a widespread social phenomenon (e.g., Volet et al., 2009; Järvelä et al., 2013), and previous review studies have consistently shown that SRL is related to higher levels of student achievement (Dignath et al., 2008; Sitzmann and Ely, 2011; Boer et al., 2014). Numerous studies of SSRL have focused on how groups regulate their collaborative work and how this affects their learning experience as a group (Järvelä et al., 2013; Panadero and Järvelä, 2015), and have found that the type of regulation that develops over time is related to the degree of collaborative success. Thus, SRL and SSRL have become important topics in current research.

2.2. The effects of scaffolding on the type of regulated learning and learning outcomes

The current meta-analysis focusses on regulated learning scaffolding. Scaffolding can be defined as the process of supporting learning efforts in an open learning environment (Zheng, 2016). They can be platforms, scripts or tools (Troussas et al., 2013; Zheng, 2016; Lin, 2018; Krouska et al., 2019). In this regard, "regulated learning scaffolding" refers to the process through which self-regulated learning and socially regulation of learning efforts are supported. In recent years, more and more researchers have focused on regulated learning scaffolding to facilitate students' regulating strategies and academic performance (Janssen et al., 2007; Lin, 2018; Yilmaz-Na and Sönmez, 2023). Among these, four types of scaffolding can be classified based on their functions: scripts (Azevedo et al., 2004), group awareness tools (Lin et al., 2016; Lin, 2018), intelligent pedagogical agents (Duffy and Azevedo, 2015; Jones et al., 2018), and composite tools (Janssen et al., 2007; Zheng et al., 2017). Scripts are scaffolds that provide collaborators with task-related interactive instructions, which can be represented in different ways and tailored to specific learning objectives, and can implicitly or explicitly specify the collaboration roles and the sequences of activities (Kollar et al., 2006). Group awareness tools provide tacit guidance in understanding group members' learning activities, participation status, and contributions by visually presenting member activities to other group members or teams in a computer-supported collaborative learning (CSCL) environment (Lin, 2018). An intelligent pedagogical agent is a virtual agent that is embedded in a computer-based learning environment and provides instruction through verbal and non-verbal forms of communication using images of animated or human-like figures (Lin et al., 2020). Composite tools are those that combine two or more types of scaffolding. Different types of regulated learning scaffolding have different delivery modes, and can be either direct or indirect, fixed or adaptive, hard or soft, and embedded or non-embedded (Devolder et al., 2012).

Numerous studies have found that regulated learning scaffolding can improve students' academic writing (Teng, 2022), monior and understand their learning (Moos and Azevedo, 2008), and enhance

regulation strategies (Lin, 2018). For instance, Azevedo et al. (2004) pointed out that adaptive scaffolding can regulate students' learning by activating prior knowledge, monitoring their understanding using various strategies, and engaging in adaptive assistance. Duffy and Azevedo (2015) found that students' use of self-regulatory strategies was significantly improved by the support of an intelligent pedagogical agent. However, other studies have suggested that regulated learning scaffolding does not always work as well as expected, and might have little influence on students' learning (Malmberg et al., 2015; Raes et al., 2016). For example, Malmberg et al. (2015) showed that a low-performing team failed to identify the challenge using learning tools. Similarly, Raes et al. (2016) found that a collaborative script only had a marginal effect on socially shared regulation. Scholars have also found that regulated learning scaffolding has inconsistent effects on SRL and SSRL. For example, Lin (2018) found that the experimental group (group awareness) and the control group did not differ significantly in relation to unbalanced SSRL, but differed noticeably in relation to SRL. Similarly, Teng (2022) and Manlove et al. (2006) reported contrasting findings regarding the role of scripts, with Teng (2022) finding that scripts did not have a significant effect on SRL, while Manlove et al. (2006) identified a positive effect of scripts on SSRL. Therefore, there is a lack of consensus on the effects of regulated learning scaffolding, raising the question of what relationships exist among regulation strategies, academic performance, and regulated learning scaffolding. Thus, a meta-analysis is needed.

Some previous meta-analyses have examined the effects of regulated learning scaffolding on academic performance and regulation strategies and found small to medium effects. For example, Guo (2022) examined the effects of metacognitive prompts on students' self-regulated learning (SRL) and learning outcomes. Results found that metacognitive prompts significantly enhanced SRL activities ($g = 0.50$) and learning outcomes ($g = 0.40$). Given the importance of specific regulation strategies on student academic performance varies (Theobald, 2021), however, Guo's meta-analysis did not spotlight specific levels of regulation strategies. Theobald (2021) further focused on the relationship between regulated learning scaffolding and specific regulation strategies, and results revealed that SRL training programs can effectively enhance academic performance ($g = 0.37$), motivation ($g = 0.35$), regulation strategies (e.g., metacognitive strategies ($g = 0.40$), and resource management strategies ($g = 0.39$)) among university students. However, this meta-analysis was restricted to university students. Similarly, Jansen et al.'s (2019) meta-analysis also tested the effectiveness of SRL interventions for university students. Zheng (2016) examined the functions of scaffolding in relation to both K–12 and university students, and found a moderately positive effect on academic performance ($g = 0.438$). However, this meta-analysis only included 29 studies, and most studies were focused on (biased toward) higher education. Several other meta-analyses also didn't simultaneously concern K12 and higher education, such as Dignath et al. (2008) and de Boer et al. (2018), both of which examined only primary and secondary school. Thus, there is a need to test the effectiveness of regulated learning scaffolding using a larger database that includes more diverse student samples.

Further, most previous meta-analyses have not examined the effectiveness of various types of regulated learning scaffolding, such as scripts, group awareness tools, intelligent pedagogical agents, and composite tools, at the macro level, instead focusing on the mechanisms, functions, delivery forms, and number of scaffolding (Zheng, 2016; Guo, 2022), that is, micro-level issues. However, different types of macro-level scaffolding have specific micro-level characteristics. Therefore, it is necessary to view regulated learning scaffolding from a macro-level perspective. Besides, we can further explore which type of scaffolding is most effective for different outcome variables. Moreover, there has been no meta-analysis of SSRL scaffolding, despite previous studies finding that SSRL is positively linked to academic performance (Panadero and Järvelä, 2015). Most meta-analyses only focused on SRL scaffolding, such as Theobald (2021) and Guo (2022). Thus, given the high degree of relevance of SSRL to academic performance, it is also important to test the effectiveness of scaffolding in relation to SSRL.

2.3. Moderators of regulated learning scaffolding' effectiveness

Characteristics included in previous regulated learning review studies have been incorporated into this review as moderators, and are described below.

2.3.1. Types of regulated learning scaffolding

Scripts are a critical component in students' learning (see Chi et al., 1994, 2001). Several studies have found that when students learn about complex topics with scripts, they are better able to regulate their learning and gain a conceptual understanding of the topic (Hill and Hannafin, 1997; Greene and Land, 2000; Azevedo and Cromley, 2004). *Group awareness* is defined as up-to-date information obtained by an individual in the group on the activities and situations of others that can be used for coordinating and completing a part of a group task (Yilmaz and Yilmaz, 2019). Group awareness tools can be used to increase a group's collective actions and visualize social interactions (Kreijns et al., 2002), thereby increasing the effectiveness of collaboration (Janssen and Bodemer, 2013), and providing students, particularly those with a low level of SRL, with the opportunity to observe and emulate role models (Lin et al., 2016). *Intelligent pedagogical agents* are actuated by users in a virtual environment and have been developed for educational purposes (Yilmaz and Cakmak, 2011). A review of previous studies revealed that the use of a pedagogical agent in online learning environments had a positive effect on learning processes and outcomes such as motivation (Dinçer and Doğanay, 2017), achievement (Yilmaz and Cakmak, 2012), and behavioral intentions (Guo and Goh, 2016). Several studies have confirmed the positive effects of pedagogical agents on self-regulation skills and metacognitive awareness (Molenaar et al., 2011; Yilmaz et al., 2018). However, another study found that metacognitive scaffolding provided by a pedagogical agent did not have a significant effect on either group performance or individual domain knowledge (Molenaar et al., 2011). Thus, it is necessary to examine the effects of these regulated learning scaffolding on regulation levels, regulation strategies, and academic performance in an effort to determine which regulated learning scaffolding has the greatest effect.

2.3.2. Cooperation

In cooperative learning, students share responsibilities, ideas, and thoughts to promote metacognitive reflection and motivation (Chiu and Kuo, 2009). Prior meta-analyses have reported inconsistent results

including a negative impact (e.g., Boer et al., 2014) and no impact for primary school students but a positive impact on comprehension and conceptual understanding for secondary school students (e.g., Dignath et al., 2008). A meta-analysis of university students by Theobald (2021) found that collaborative learning elevated SRL training effects on metacognitive strategies. However, it remains unclear whether the effects would be greater if students worked collaboratively rather than individually.

2.3.3. Academic subject

Each subject area constitutes a distinct context that can potentially influence students' SRL (Wolters and Pintrich, 1998; Patrick et al., 2007). Further, students' use of cognitive and metacognitive strategies might be based on the learning domain (Wolters and Pintrich, 1998). However, whether the academic subject shapes regulated learning and its association with achievement has received relatively little attention (e.g., Wolters and Pintrich, 1998). Instead, most studies exploring the outcomes of regulated learning have focused on a single subject area (Dent and Koenka, 2016). Therefore, integrating these findings enables us to test whether the academic subject has a moderating effect.

2.3.4. Grade level

Self-regulated learning has been described as an "inherent aspect of learning" (Winne, 1995, p. 186), and students' ability to undertake SRL develops with age (Paris and Newman, 1990). In elementary school, students have only a vague understanding of academic tasks (e.g., Meyers and Paris, 1978), and rarely monitor or reflect on their task performance (e.g., Skinner et al., 1988). Following the transition to middle school, variations in achievement are more closely related to variations in SRL (Brookhart, 1994; McMillan and Workman, 1998). SRL continues to develop during adolescence, with metacognitive monitoring and reflection improving significantly (Keating, 1990; Ryan and Pintrich, 1997). It can be seen that students' grades are closely related to their regulated learning ability. Therefore, a meta-analysis can be used to explore how regulation levels, regulation strategies, and academic performance are influenced by grade level and academic subject.

2.4. The current meta-analysis

In current meta-analysis, we aimed to investigate the impact of regulated learning scaffolding on regulation strategies and academic performance. Empirical studies in the past decade that examined various regulated learning scaffolding's effect were evaluated. The findings offered insights into the overall effectiveness of regulated learning scaffolding as well as the respective roles of SRL scaffolding and SSRL scaffolding. In addition, they provided directions for determining the most effective scaffolding for different outcome categories and key factors to consider when implementing scaffolding in the future. Specifically, three research questions were raised in this study:

1. What is the overall effect of regulated learning scaffolding?
2. Which kinds of regulated learning scaffolding are most effective in improving regulated learning (SRL/SSRL) and learning outcomes (regulation strategies and academic performance)?
3. How are the effects moderated by cooperation, grade level, and academic subject?

The first research question examined the effect of regulated learning scaffolding on overall outcome categories, as well as on the sub-category (type of regulated learning and learning outcome). We predicted that regulated learning scaffolding would have a moderate effect on both overall outcome categories and the sub-category.

The second research question examined more specifically the effects of different type of regulated learning scaffolding (scripts, group awareness, intelligent pedagogical agents, composite tool), and clarified what is the most effective scaffolding for different outcome categories. We anticipated that overall, composite tools would have the greatest effect. For SRL and SSRL, the most useful scaffolding may be group awareness tools and composite tools, respectively. In terms of learning outcomes, scripts and intelligent pedagogical agents would have the greatest effect on regulation strategies and academic performance, respectively.

The third research question involved moderator analysis. We assumed that regulated learning scaffolding would have the greatest impact on primary school learners, collaborative learners, and natural science learners, respectively.

3. Method

3.1. Literature search

The meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for reporting meta-analytical findings (Moher et al., 2009). The PRISMA consists of a 27-item checklist (such as, title, abstract, method, results, discussion and so on) and a four-phase flow diagram (identification, screening, eligibility and included). Research should strictly follow this process to improve the reporting of systematic reviews and meta-analyses. The identification of relevant studies was conducted via the online databases Web of Science, Elsevier Science Direct, and Proquest, and covered articles published in English from January 2000 to December 2021. Review articles and conference papers were excluded. The following search terms were used:

Abstract: (self-regulated learning OR socially shared regulated learning OR regulat* learning OR SRL OR SSRL) AND abstract:(tool OR scaffold OR group awareness OR script OR pedagogical agent) AND abstract:(achievement OR performance OR level OR strategy).

3.2. Criteria for inclusion and exclusion

First, because the meta-analysis focused on the ways in which regulated learning scaffolding affects students' academic performance and regulation strategies, at least one type of regulated learning scaffolding had to be used and the studies had to report on at least one of the following outcomes: students' regulation strategies and academic performance. Studies that didn't focus on regulated learning scaffolding or didn't pay attention to these two types of outcome variables will be excluded.

Moreover, the studies had to target in-school or online students, including pre-K children, primary school students, junior and senior high school students, and higher education students. Studies focused on pre-service teachers, children with disabilities, or other adult learners were excluded.

Only empirical studies were selected, and they had to include a control group and an experimental group. Excluding surveys, one-group pretest-posttest designs, and qualitative studies. In addition, studies had to contain sufficient information (N, M, SD) to enable the computation of effect sizes.

3.3. Selection of studies

Figure 1 shows the flow diagram for the literature selection process. In the first step, 3,391 articles were identified from the database search ($n = 3{,}373$) or a backward and forward search of the literature ($n = 18$). Then we removed duplicate studies ($n = 242$). This preliminary search yielded 3,149 articles. After collecting articles, we reviewed titles and abstracts to remove studies that didn't fit any of the above three inclusion criteria, resulting in 2,790 articles being deleted, and 359 articles being retained for the next step. Next, we thoroughly scrutinized the full texts of these articles. Then, 313 articles that did not meet the requirements of the meta-analysis were deleted. Thus, 46 studies met all inclusion criteria and were included in the meta-analysis.

3.4. Coding of outcome categories and moderating variables

Two outcome categories were set: type of regulated learning and learning outcomes. The type of regulated learning was classified into SRL and SSRL, and the learning outcomes were academic performance and regulation strategies. Based on the classification of regulation strategies in previous studies, we classified regulation strategies into three lower-level categories. *Cognitive strategies* refer to how to learn and integrate new knowledge into existing structures, such as rehearsal, elaboration, and organization (Weinstein and Mayer, 1985). *Metacognitive strategies* refer to the monitoring and controlling of the application of cognitive strategies (Flavell, 1979), and encompass goal-setting, planning, monitoring, and reflection. *Resource management strategies* refer to the integration of internal (attention, emotion, and motivation) and external (environment, time, and management) resources (Pintrich, 1999). Numerous studies have been conducted on learners' use of regulation strategies. For example, Dignath et al. (2008) found that self-regulation strategies can be improved through training. Järvelä et al. (2008) pointed out that students adopt and activate new motivation strategies to fit specific challenges in socially shared learning, and strong shared regulation groups are more likely to activate cognitive and metacognitive strategies (Järvelä et al., 2013). Outcomes other than academic performance were mostly assessed by questionnaire.

Four moderating variables were coded. *Types of regulated learning scaffolding.* We divided the regulated learning scaffolding into four categories: (1) scripts, (2) intelligent pedagogical agents, (3) group awareness tools, and (4) composite tools. We then coded whether the regulated learning scaffolding were used consistently. *Cooperation.* Based on whether students had adopted collaborative learning, we divided learning into two categories: (1) individual learning, and (2) collaborative learning. *Academic subject.* Four subject areas were considered: (1) social sciences, (2) natural sciences, (3) engineering and computer science, and (4) language acquisition. *Grade level.* We divided education into three levels: (1) primary education, (2) secondary education, and (3) higher education.

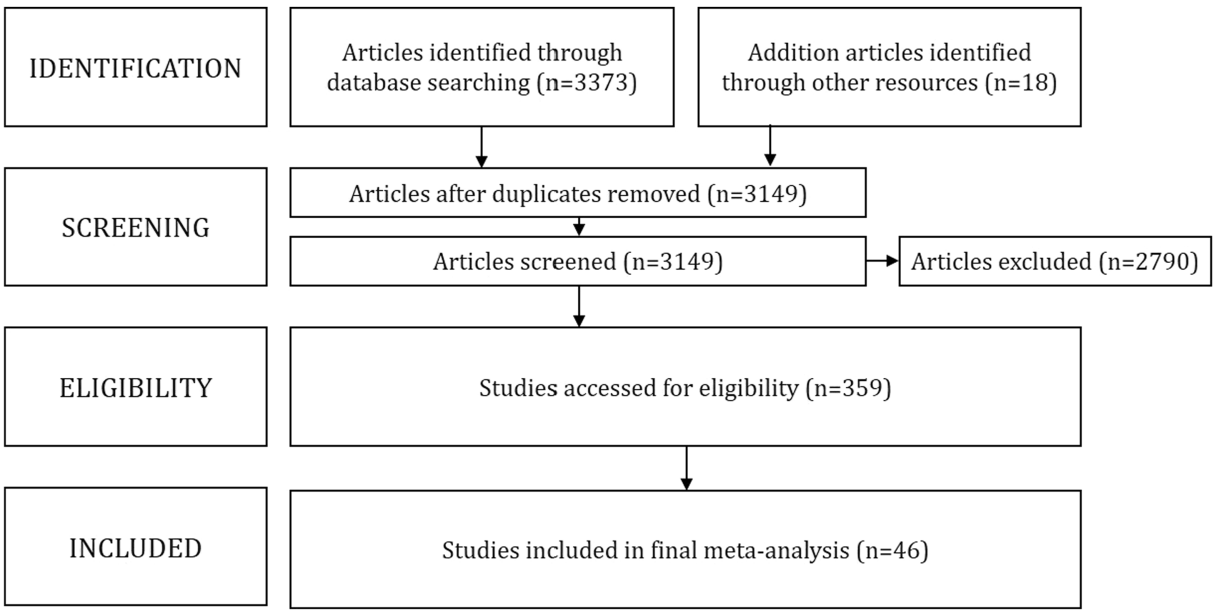

FIGURE 1
Literature selection process.

A detailed overview of the coding of outcome categories and moderating variables is presented in Table 1 and Figure 2.

Each study was independently coded by two raters based on the coding schemes and the inter-rater reliability calculated by Cohen's kappa was 0.89, which was regarded as reliable. In response to discrepancies, the two raters discussed and resolved the problem.

3.5. Data analysis

To calculate the effect sizes, we used comprehensive meta-analysis (CMA) software developed by Biostat. The effect size was calculated based on the sample sizes, mean outcome scores, and standard deviations for both the experimental group and the control group (standardized mean differences). If one study adopted multiple tests to examine academic performance, the effect sizes were averaged to obtain one representative effect size for each study using CMA software. However, Cohen's d has a slight upward bias, especially in small samples. Hedges (1981) proposed removing this bias by using correction factor J. Thus, we set Hedge's g as the main indicator to determine the size of the effect, with effect sizes of 0.30, 0.50, and 0.80 corresponding to a small, medium, or large effect, respectively.

TABLE 1 Overview of outcome categories and moderating variables included in the meta-analysis.

Category	Variable
Outcome categories	
Type of regulated leaning	SRL
	SSRL
Learning outcome	Academic performance
	Regulating strategies
	Cognitive strategies
	Metacognitive strategies
	Planning & goal setting
	Monitoring
	Reflection & evaluation
	Resource management strategies
Moderator variables	
Type of regulated learning scaffolding	Script
	Intelligent pedagogical agent
	Group awareness
	Composite tool
Grade level	Primary education
	Secondary education
	Higher education
Cooperation	Individual learning
	Collaborative learning
Academic subject	Social sciences
	Natural sciences
	Engineering and computer
	Language acquisition

First, we combined the overall effect of regulation using a random-effects model because we assumed that the size of the effect could vary from study to study (Borenstein et al., 2011). The confidence interval (CI) of the pooled effect size was set at 95%. In addition, publication bias was checked using the funnel plot and Egger's linear regression test. Then, we compared the size of the effect of scaffolding on different types of regulated learning and learning outcomes. Next, moderator analysis was conducted to examine the effects of different types of regulated learning scaffolding on the subgroups (Karadag et al., 2015), and obtained the following information: (a) the mean, standard errors, and 95% confidence intervals of the effect size for each category, and p values to indicate whether each effect size was significantly different from zero; and (b) the p values to indicate whether the effect size of each category was significantly different from the effect size of another category. Finally, we ran a simultaneous meta-regression with multiple independent variables to examine how different characteristics explain the effects of regulated learning scaffolding. In this analysis, the effect size was the dependent variable, and grade, academic subject, and cooperation were the independent variables.

4. Results

4.1. Descriptive results

We examined 46 peer-reviewed journal articles published between 2010 and 2021, of which 37 examined the effects of scaffolding on SRL activities and nine examined the effects of scaffolding on SSRL activities. Overall, 138 effect sizes were reported, of which 34 related to academic performance and 104 related to regulation strategies.

The heterogeneity tests for regulation strategies and academic performance were significant and there was a moderate amount of variance in the effect sizes ($Q = 846.502$, df = 137, $p = 0.000$; $I^2 = 83.82$). Thus, the hypothesis of homogeneity was rejected, suggesting the necessity of moderator analyses in an effort to ascertain the variables that might explain the heterogeneity and to select a random effects model. Using a random effects model, these analyses showed that regulated learning scaffolding had moderately positive effects. The average weighted effect size was Hedges' g = 0.587 (SE = 0.056). Table 2 presents the number of studies (k), effect size (g), standard error (SE), variance, confidence intervals, z value, p value, and test of heterogeneity in effect size.

Regarding the type of regulated learning, we calculated the overall effect for SRL and SSRL (Table 3). The average weighted effect size was Hedges' g = 0.603 (SE = 0.066) for SRL and $g = 0.530$ (SE = 0.108) for SSRL.

Regarding learning outcomes, the greatest effect size was associated with regulation strategies ($g = 0.617$, $p < 0.001$), followed by academic performance ($g = 0.500$, $p < 0.001$). In terms of specific regulation strategies, the largest average effect sizes were obtained for resource management strategies ($g = 0.826$, $p < 0.001$) and metacognitive strategies ($g = 0.546$, $p < 0.001$), while the smallest effect size was in relation to cognitive strategies ($g = 0.326$, $p < 0.1$). Regarding specific metacognition regulation strategies, the effect sizes ranged from 0.369 (monitoring) to 0.769 (reflection and evaluation) (Table 4).

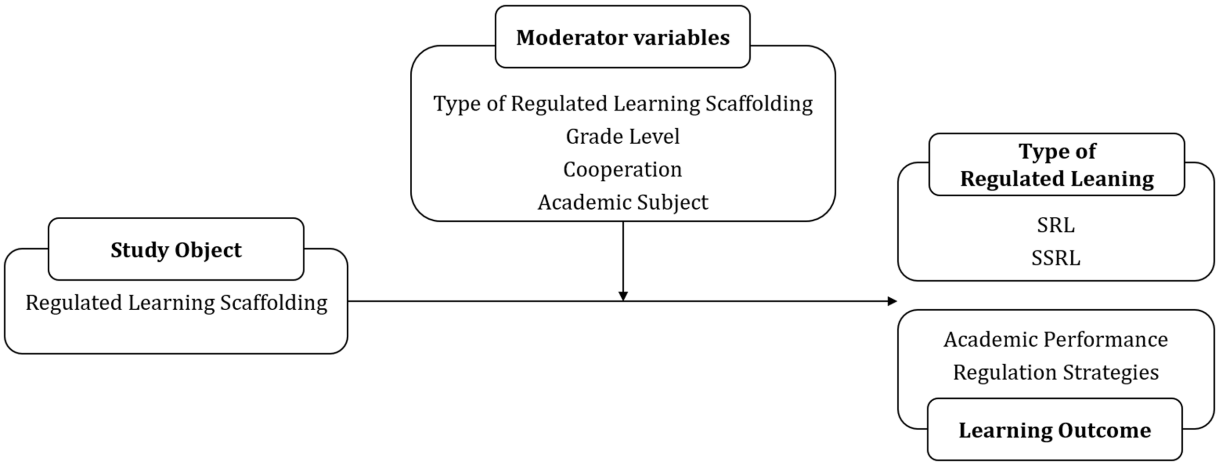

FIGURE 2
Overview of study objects, outcome categories, and moderating variables.

TABLE 2 Overall effect sizes.

	k	g	SE	Variance	95%CI		Z	*p*	Heterogeneity		
					Lower	Upper			Q	df	*p*
Random	138	0.587	0.056	0.003	0.476	0.692	10.412	0.000	846.502	137	0.000

K, Number of effect sizes; g, Hedges' g effect size; SE, standard error; CI, confidence interval.

4.2. Publication bias

Studies with larger samples and significant results are more likely to be published than those with smaller samples and non-significant results (Borenstein et al., 2011). This results in publication bias, which may lead to bias in the sample set selected for inclusion in a meta-analysis. In this study, examination of the funnel plot (see Figure 3) showed that the effect sizes were distributed symmetrically around the mean effect size, with no concentration of effect sizes on either side. The results of Egger's regression test for funnel plot asymmetry rejected the presence of publication bias ($t=1.27$, $p=0.10$). Taken together, the funnel plot and Egger's regression test results suggested that the observed overall effect sizes were not an artifact of publication bias.

4.3. Regulated learning scaffolding' effects by outcomes

Regarding the effects of different types of regulated learning scaffolding, the greatest effect size was associated with composite tools ($g=0.700$, $p<0.001$), followed by group awareness tools ($g=0.604$, $p<0.001$), intelligent pedagogical agents ($g=0.542$, $p<0.01$), and scripts ($g=0.525$, $p<0.001$) (Table 5).

4.3.1. Scaffolding' effects by type of regulated learning

As shown in Table 6, the impact of various scaffolding varied between SRL and SSRL. For SRL, group awareness tools had the greatest effect ($g=1.298$, $p<0.001$), while for SSRL, composite tools had the greatest effect ($g=0.871$, $p<0.001$).

4.3.2. Scaffolding' effects by learning outcome

The effects of regulated learning scaffolding also varied in relation to different learning outcomes (see Tables 7–9). For academic performance, intelligent pedagogical agents were the most useful tool, with an effect size of 0.558 ($p<0.01$), while for regulation strategies, most of the regulated learning scaffolding had a moderate effect ($g>0.50$), with composite tools having the greatest effect ($g=0.750$, $p<0.001$). In terms of sub-categories, all regulated learning scaffolding had a moderate effect in relation to cognition strategies ($g<0.40$), with scripts having the greatest effect ($g=0.406$, $p<0.1$). Surprisingly, the effect of intelligent pedagogical agents was negative ($g<0.00$). In terms of resource management strategies and metacognitive strategies, group awareness tools ($g=1.844$, $p<0.01$) and composite tools ($g=0.737$, $p<0.01$) had the greatest effects. Regarding specific metacognitive strategies, composite tools, intelligent pedagogical agents and group awareness tools, respectively, had the greatest effect on planning and goal-setting, monitoring, and reflection and evaluation.

4.4. Moderator analyses

To facilitate a meaningful interpretation of the results, we included the other moderating variables in the meta-regression. As can be seen from Table 10, the categorical variables were dummy coded and used as predictors in the meta-regression. For example, of the three grade levels (primary school, junior and senior high school, and higher education), we used higher education as the reference variable and included the other two predictors in the meta-regression.

In the full model, only junior and senior high school was not statistically significant ($p=0.427>0.1$). The effect size of primary

TABLE 3 Effect sizes by type of regulated learning.

	k	g	SE	Variance	95%CI		Z	*p*	Heterogeneity test
					Lower	Upper			
SSRL	34	0.530	0.108	0.012	0.319	0.742	4.920	0.000	$Q = 0.335$
SRL	104	0.603	0.066	0.004	0.475	0.732	9.185	0.000	$p = 0.562$

K, Number of effect sizes; g, Hedges' g effect size; SE, standard error; CI, confidence interval.

TABLE 4 Effect sizes by learning outcome.

	k	g	SE	Variance	95%CI		Z	*p*	Heterogeneity
					Lower	Upper			
Academic performance	34	0.500	0.102	0.010	0.299	0.700	4.882	0.000	Q = 0.923
Regulation strategies	104	0.617	0.068	0.005	0.485	0.750	9.144	0.000	$p = 0.337$
Cognition strategy	21	0.326	0.063	0.004	0.202	0.450	1.898	0.058	Q = 3.501
Recourse management strategy	13	0.826	0.077	0.006	0.674	0.977	3.879	0.000	$p = 0.321$
Metacognition strategy	51	0.546	0.039	0.002	0.470	0.622	6.547	0.000	
Planning and goal setting	23	0.649	0.163	0.026	0.331	0.968	3.992	0.000	Q = 6.903
Monitoring	16	0.369	0.075	0.006	0.221	0.516	4.893	0.000	$p = 0.067$
Reflection and evaluation	11	0.769	0.219	0.048	0.340	1.198	3.514	0.000	

K, Number of effect sizes; g, Hedges' g effect size; SE, standard error; CI, confidence interval.

school was larger by a 0.723 standard deviation unit than the effect size of higher education. The effect sizes of social science, natural science, and language acquisition were greater than those of engineering and computer science. When collaborative learning was included, the effect size was larger than that when only individual learning occurred by 0.531 standard deviation unit.

5. Discussion

5.1. Overall effect

Consistent with our hypothesis, the findings of this meta-analysis of 46 studies indicate that regulated learning scaffolding has a moderately positive effect ($g = 0.587$) on regulated learning. This is consistent with the results of a previous study by Schmid et al. (2014), who found that the overall weighted average effects of technology use on achievement were significant, and is also in line with the results of a previous meta-analysis that found a positive overall effect of SRL scaffolding on academic performance (Zheng, 2016). One difference is that the current study focused on regulated learning scaffolding rather than training programs or scaffolding mechanisms, enabling us to examine the effects from a macro perspective.

We further explored the effects of scaffolding on SRL and SSRL, and as anticipated, provided the first evidence of the effects of scaffolding on SRL ($g = 0.603$), supporting the findings of previous meta-analyses. As Theobald (2021) pointed out, SRL training programs could be used to enhance students' academic performance, SRL strategies, and motivation. This corroborated the findings of a study by Stevenson et al. (2017), which confirmed the positive effect of concept mapping technologies on SRL. However, one distinction is that the current study focused on four types of regulated learning scaffolding (i.e., group awareness tools, scripts, intelligent pedagogical agents, and composite tools), which enabled us to obtain a more comprehensive understanding of the effects of various technologies. Another distinction is that this meta-analysis adds to previous research in this area by showing that regulated learning scaffolding also has a positive effect on SSRL ($g = 0.530$). Numerous studies have demonstrated that learners often fail to achieve socially shared regulation during collaborative learning (Zimmerman and Schunk, 2011; Kirschner and Erkens, 2013) because it is more difficult to regulate at the group level than at the individual level (Winne et al., 2013). Thus, external support is essential for facilitating SSRL (Järvelä et al., 2015). The results of this study support the use of regulated learning scaffolding for SSRL. Zheng et al. (2017) proposed and developed a collaborative learning tool using a socially shared regulation approach, and measured its effectiveness in relation to participants' learning achievement, group performance, and socially shared regulation frequency.

We also examined the effects of regulated learning scaffolding on learning outcomes (academic performance and regulation strategies). Consistent with predictions, our results supported the findings of previous meta-analyses that regulated learning scaffolding had a moderate effect on academic performance (Zheng, 2016) and a small to moderate effect on regulation strategies (Theobald, 2021). The results showed that regulated learning scaffolding had the greatest effect on regulation strategies. This confirmed the finding of Jansen et al. (2019), who found that the effects of interventions were greater in relation to regulation strategies than in relation to academic performance. One possible reason is that regulation strategies moderate the relationship between regulated learning scaffolding and academic performance (Jansen et al., 2019), and thus regulated learning scaffolding possibly weaken some effects on academic performance. Another possible reason is that regulation strategies are difficult to measure. Some researchers have argued that self-reporting and questionnaires, which have been used to measure regulation

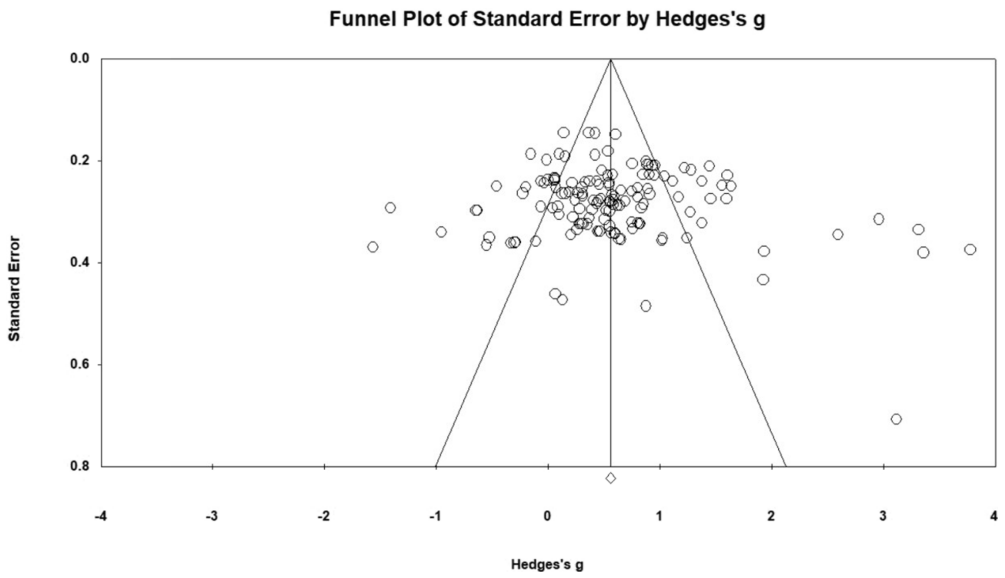

FIGURE 3
Funnel plot of standard errors by Hedges' g effect sizes.

TABLE 5 Overall effectiveness of various regulated learning scaffolding.

	k	g	SE	Variance	95%CI		Z	*p*	Heterogeneity test
					Lower	Upper			
Script	69	0.525	0.079	0.006	0.370	0.680	6.628	0.000	Q = 1.977
Group awareness	26	0.604	0.165	0.027	0.280	0.927	3.653	0.000	
Intelligent pedagogical agent	10	0.542	0.203	0.041	0.144	0.939	2.670	0.008	*p* = 0.578
Composite tool	33	*0.700*	0.099	0.010	0.506	0.895	7.062	0.000	

Italics indicate that it is the largest value. K, Number of effect sizes; g, Hedges' g effect size; SE, standard error; CI, confidence interval.

strategies in numerous studies, are not always effective (Azevedo and Cromley, 2004). Thus, this inaccurate measure probably resulted to the high value of the regulation strategies. Regarding the sub-categories, the effects of regulated learning scaffolding on cognitive strategies were smaller than those on resource management and metacognitive strategies. This result is consistent with that of Theobald (2021), and might be because students' cognition is difficult to change over a short study period, which means more extensive intervention and time should be taken. In terms of metacognitive strategies, the results showed that regulated learning scaffolding had a positive effect on planning and goal-setting, as well as reflection and evaluation, but had little effect on monitoring. Therefore, future research should investigate ways to enhance monitoring.

5.2. The effect of regulated learning scaffolding

In terms of different types of regulated learning scaffolding effects, consistent with hypothesis, we found that composite tools had the greatest overall effect. Composite tools integrate numerous features of other tools, such as question guides, visual diagrams, constructive modules, templates, animated or human-like communication, and visual and auditory hints (Manlove et al., 2006; Zheng et al., 2017). Various functions can be arranged to appear at the right moment to support students' diverse needs, encourage group participation, remind students to regulate and monitor themselves, stimulate their interest in learning with animations or diagrams, and promote their cognitive and metacognitive development with a variety of materials (Bellhäuser et al., 2016). Further, the cognitive theory of multimedia learning states that student learning is enhanced by the presentation of both words and pictures rather than only words (Meyer, 2009). Therefore, when using composite tools, students can obtain access to more materials and integrate visual and verbal representation, thereby simultaneously promoting students' regulated learning through both channels. This might explain why composite tools had the greatest effect. Below, results are discussed separately for two aspects: the type of regulated learning and the learning outcome.

5.2.1. The effect of scaffolding by type of regulated learning

Regarding the type of regulated learning, as expected, the most useful scaffolding for SRL is the group awareness tool. Pintrich (2000) stated that learners could only undertake SRL effectively if they were motivated and persistent in their learning activities. Group awareness provides maximum sensory stimulation to students without cognitive load. Expressed in the

TABLE 6 Scaffolding' effects by type of regulated learning.

	SRL				SSRL			
	k	g	SE	*p*	k	g	SE	*p*
Script	67	0.528	0.082	0.000	2	0.439	0.175	0.012
Group awareness	8	*1.298*	0.381	0.001	18	0.303	0.136	0.026
Intelligent pedagogical agent	10	0.542	0.203	0.008				
Composite tool	19	0.602	0.113	0.000	14	*0.871*	0.192	0.000

Italics indicate that it is the largest value. K, Number of effect sizes; g, Hedges' g effect size; SE, standard error.

TABLE 7 Scaffolding' effects by learning outcome.

	Academic performance				Regulation strategies			
	k	g	SE	*p*	k	g	SE	*p*
Script	18	0.518	0.146	0.000	51	0.529	0.095	0.000
Group awareness	5	0.267	0.350	0.445	21	0.682	0.190	0.000
Intelligent pedagogical agent	4	*0.558*	0.504	0.268	6	0.544	0.183	0.003
Composite tool	7	0.501	0.115	0.000	26	*0.750*	0.125	0.000

Italics indicate that it is the largest value. K, Number of effect sizes; g, Hedges' g effect size; SE, standard error.

form of pictures, diagrams, and text, it allows students to observe their own progress and status, as well as those of their peers, their own group, and other groups at any time, and reminds them to cooperate with each other. Pintrich (1999) also noted that social comparison/peer comparison led students to employ more cognitive and self-regulatory strategies, and that group awareness provided more opportunities and conditions for social comparison than other scaffolding. In addition, Zimmerman's (2000) model included four aspects of developmental self-regulation: observation, emulation, self-control, and self-regulation. Group awareness fits this pattern precisely. Firstly, students obtain a basic understanding of SRL by observing the learning behavior trajectory of others (observation). Then, students can emulate the role models they have observed, comparing themselves with others and gradually practicing the skills independently (emulation, self-control). Finally, students gradually acquire self-regulation skills through repeated practice (self-regulation) (Lin et al., 2016).

While the composite tool had the greatest effect on SSRL, Järvelä et al. (2015) emphasized three design principles for supporting SSRL: awareness, social space, and sharing in interaction, prompting regulation. These principles suggest that scaffolding supporting SSRL should both enhance learners' awareness of their own and others' learning processes, that is, they can jointly set goals and monitor their learning progress, and provide a shared space in which they can set group norms, interaction rules, and roles to promote collaboration and socioemotional interaction, as well as enabling them to identify challenging learning situations and typical learning patterns, in other words, to focus on the process of collaboration in real time. Based on such principles and features, there is no doubt that the composite tool is the most compatible and effective option.

5.2.2. The effect of scaffolding by learning outcome

Regarding learning outcomes, a *script* is the most effective scaffolding for cognitive strategies. Scripts can stipulate the sequence and type of learning activities, and collaboration roles to help group members collaborate and solve problems (Wang et al., 2017). Scripts can take many forms, such as a teacher's oral presentation, role assignment, question prompts, peer feedback, and worked examples. They are structured, elaborative, and enlightening, and can take the form of social scripts, content-oriented (epistemic) scripts, communication-oriented (collaborative) scripts, and metacognition scripts (Noroozi et al., 2012). Changes in cognitive strategies are difficult to achieve, and must be accompanied by deep processing of new knowledge and connections to prior knowledge, requiring the long-term support of procedural tools. Given the advantages of scripts, this is probably why they are the most effective scaffolding in relation to cognitive strategies. Previous studies have found that scripts enable students to anchor newly acquired knowledge within prior knowledge (Broadbent et al., 2020), stimulate the activation of learning strategies, and enhance deeper processing of information (Bannert et al., 2015).

Group awareness is the most useful scaffolding for resource management strategies, as well as reflection and evaluation. Group awareness tools enable the interactive activities of each team to be visualized, including the number of individual contributions, evaluations, replies, and "likes" (Lin, 2018). Visualization strengthens social interaction and communication by enhancing motivation, triggering reflection, and monitoring individual contributions (Janssen et al., 2007), enabling the formation of a learning community (Hu et al., 2002). This mechanism enables group awareness to help students to realign their tactics for subsequent learning activities, identify problems, reflect on the entire learning process, manage their time, and foster motivation (Janssen et al., 2007; Järvelä et al., 2013; Lin, 2018). Thus, resource management (e.g., effort management, motivation regulation, and time and study management), as well as reflection and evaluation, are best facilitated by group awareness tools.

Intelligent pedagogical agents are the most effective scaffolding for academic performance and monitoring. One reason is that agents are designed to scaffold learning processes in a timely manner by providing feedback and prompts in response to learners' behavior, progress, and self-evaluation (Duffy and Azevedo, 2015). Therefore, agents can monitor the overall learning process by prompting students to set goals, paying attention to time, progress, and group participation, and facilitating self-reflection, resulting in improved academic performance and monitoring. In addition, Jones et al. (2018) found that higher levels of personalization and adaptive scaffolding had a greater impact on regulation strategies and learning gains. There is no doubt that intelligent pedagogical agents are more adaptive than the other scaffolding. However, they have a negative effect on cognitive strategies. One reason is that it is difficult for agents to enhance cognitive strategies (Theobald, 2021). Another reason might be the small number of articles which is not representative.

Composite tools have the greatest effect on regulation strategies, metacognition, and planning and goal-setting. We predicted that the

TABLE 8 Scaffolding' effects by sub-category.

	Cognition strategy				Recourse management strategy				Metacognition strategy			
	k	g	SE	*p*	k	g	SE	*p*	k	g	SE	*p*
Script	15	*0.406*	0.241	0.092	6	0.525	0.212	0.014	23	0.494	0.113	0.000
Group awareness	5	0.232	0.216	0.283	3	*1.844*	0.648	0.004	9	0.572	0.312	0.067
Intelligent pedagogical agent	1	−0.001	0.238	0.997					2	0.406	0.170	0.017
Composite tool					4	0.475	0.138	0.001	17	*0.737*	0.163	0.000

Italics indicate that it is the largest value. K, Number of effect sizes; g, Hedges' g effect size; SE, standard error.

TABLE 9 Scaffolding' effects by metacognitive strategy.

	Planning and goal setting				Monitoring				Reflection and evaluation			
	k	g	SE	*p*	k	g	SE	*p*	k	g	SE	*p*
Script	10	0.486	0.246	0.048	8	0.437	0.127	0.001	4	0.581	0.176	0.001
Group awareness	6	0.183	0.182	0.313	1	0.216	0.244	0.376	2	*1.920*	1.035	0.064
Intelligent pedagogical agent					1	*0.439*	0.241	0.069	1	0.372	0.240	0.121
Composite tool	7	*1.314*	0.308	0.000	6	0.282	0.114	0.014	4	0.519	0.279	0.063

Italics indicate that it is the largest value. K, Number of effect sizes; g, Hedges' g effect size; SE, standard error.

most useful scaffolding for regulation strategies may be scripts. However, results were contrary to predictions. Reasons for this may be that composite tools have multiple functions, including providing prompts to engage in metacognitive monitoring, presenting group information through graphs and tables, searching for information, making notes, and summarizing or providing video and discourse prompts (Janssen et al., 2007; Zheng et al., 2017). Supported by multiple functions, students can be motivated to set goals, perceive group member status, monitor their own progress and that of their peers, and reflect on their own performance, thereby promoting regulation strategies, metacognition, planning, and goal-setting. For example, Manlove et al. (2006) designed a tool incorporating goal lists, visualization trees, hints, prompts, cues, and templates to support the three phases of learning: planning, monitoring, and evaluation. This was consistent with Zheng et al.'s (2017) results, which demonstrated that the socially shared regulation-embedded CSCL tool (composite tool) contributed to the awareness and frequency of collective regulation. The reason for the prominence of planning and goal-setting is probably because it is the most frequently used feature of the composite tool (Manlove et al., 2006; Alvarez et al., 2022).

5.3. Other moderators of the effects of regulated learning scaffolding

The results of the meta-regression showed that all three moderator categories had a significant effect on learners' regulation strategies and academic performance. Consistent with predictions, regulated learning scaffolding has a greater impact on primary school learners, collaborative learners, and social science, natural science, and language learners than on higher education learners, individual learners, and engineering and computer science learners, respectively.

5.3.1. Grade level

These results are inconsistent with our general perception of the situation. One reason is that higher education students are more difficult to improve their academic performance (Hattie et al., 1996), and their regulation level, learning habits, and preferences are relatively stable, which makes it more difficult to improve their learning behavior. Conversely, younger students obtain more benefits from regulated learning scaffolding and are subject to a greater effect in relation to the use of strategies (Dignath et al., 2008), confirming the results of previous studies (Hohn and Frey, 2002). This could be because younger students are more open to acquiring new strategies (Dignath et al., 2008), and the impact of the application of regulated learning scaffolding might be more obvious, while older learners are more proficient in the use of technology-based tools, and thus are more difficult to influence. Another reason could be that this meta-analysis only included a small number of studies on primary education students, and the focus was mainly on SRL, while the number of studies on higher-education students was larger and included both SRL and SSRL.

5.3.2. Cooperation

This might be because communication and interactions among learners make the use of regulated learning scaffolding more effective, thereby increasing their impact on collaborative learning, consistent with the findings of numerous previous studies. Another reason might be the limited amount of research on individual learning, which means more and more studies focus on collaborative learning.

5.3.3. Academic subject

Unexpectedly, regulated learning scaffolding had less impact on engineering and computer science than on other academic fields. One reason could be that learning in engineering and computer science is

TABLE 10 Results of meta-regression of moderating variables.

Model		Full model			
Variables coded	Predictors	Regression coefficient	Standard error	*p*	
	Intercept	−0.199	0.175	0.258	
Grade level (reference: higher education)	Primary school	0.723	0.204	0.000	$Q = 13.46$, $p = 0.001$
	junior and senior high school	−0.134	0.168	0.427	
Academic subject (reference: engineering and computer)	Social science	0.492	0.171	0.004	$Q = 15.78$, $p = 0.001$
	Natural science	0.747	0.195	0.000	
	Language acquisition	0.582	0.188	0.002	
Cooperation (reference: individual learning)	Collaborative learning	0.531	0.122	0.000	

largely dependent on independent inquiry and practice, while learning in other fields requires more interaction and expression, thereby increasing the effect on regulated learning. There is also the possibility that engineering and computer science students are required to be proficient in the use of regulated learning scaffolding, enabling them to largely eliminate the influence of these scaffolding and focus on the learning content, thereby reducing the influence of regulated learning scaffolding on their learning outcomes.

5.4. Limitations

Despite this study yielded fruitful results, it also had some limitations. First, not every article addressed all moderator variables that may have an effect on our results, so we only chose some variables that appeared in the majority of articles, such as scaffolding type, collaboration, grade level, and academic subject. That is to say, some moderator variables were not considered, such as the delivery forms of scaffolding and feedback. With the increase of empirical studies, future meta-analyses could incorporate more moderator variables. Second, the sample size of our study is somewhat limited, containing only 46 articles. Although 138 effect sizes were reported, the number divided to each subcategory is small. For example, the effect size on SSRL is only 34 and on intelligent pedagogical agents is only 10. So, due to the small number, insignificant study-level results need to be interpreted with caution. Future studies could include more articles for meta-analysis with the increase of research.

5.5. Implications and future research

In summary, we investigated the overall effect of regulated learning scaffolding, identified which kinds of regulated learning scaffolding (including group awareness tools, scripts, intelligent pedagogical agents, and composite tools) were most effective in improving regulated learning (SRL and SSRL) and learning outcomes (academic performance and regulation strategies), and analyzed which moderators had the greatest effects. In this section, we discuss several practical implications of our findings and provide suggestions for future research.

Given that regulated learning scaffolding has a positive impact on both regulated learning and learning outcomes, it follows that they can assist students in enhancing both their academic achievement and regulation strategies. Therefore, we suggest that practitioners should implement regulated learning scaffolding to support learners' engagement in regulation activities, as well as their achievement. In addition, research has shown that various regulated learning scaffolding are most effective in relation to different outcome variables. For example, the most effective scaffolding for academic achievement is a script, while the most effective scaffolding for regulation strategies is a composite tool. Therefore, to support student learning, teachers should select different scaffolding based on the target outcome to maximize the impact and achieve the dual goals of promoting both academic achievement and regulation strategies.

Moreover, grade level, academic subject, and cooperation should be considered when selecting regulated learning scaffolding to improve regulation strategies and academic performance. The critical period for developing students' regulatory skills is during primary school, when their academic performance and regulation strategies are most likely to be developed. Natural science students' abilities can also be maximized with the support of regulated learning scaffolding, and cooperative learning can enhance their effectiveness. Thus, in the future practice of regulated learning, we should pay attention to the construction of a collaborative environment and collaborative learning activities, and use different regulated learning scaffolding based on the academic field and level of education.

Finally, because some information was missing from the studies included in this meta-analysis, a number of moderators, such as the delivery forms of scaffolding and the number of scaffolding, could not be examined, but might have contributed to variations in the effect sizes. Therefore, future studies should investigate the impact of these moderators. Further, the limited number of empirical SSRL studies meant that our meta-analysis included relatively few studies on SSRL. There is a strong link between SRL and SSRL, both of which can significantly improve the in-group climate, as well as individual academic performance, and thus future research should focus more on SSRL, exploring how regulated learning scaffolding might be used to better support SSRL, and providing more data for future meta-analyses.

6. Conclusion

The use of regulated learning scaffolding enhanced both SRL and SSRL, as well as academic performance and regulation strategies. This study also explored the effect of four types of regulated learning scaffolding and identified which types were most effective in improving regulated learning and learning outcomes. Results showed that overall, composite tools had the greatest effect, while the most useful scaffolding for SRL and SSRL were group awareness tools and composite tools, respectively. In terms of learning outcomes, composite tools had the greatest effect on regulation strategies, while intelligent pedagogical agents had the greatest effect on academic performance. In addition, the moderating effects of grade, academic subject, and level of cooperation were analyzed, and the results of our meta-regression showed that all three had a significant moderating effect on the impact of regulated learning scaffolding. Thus, it is suggested that the use of regulated learning scaffolding in a collaborative learning environment should be considered to promote academic performance and regulation strategies. Further experimental work is needed to clarify the contextual factors that may moderate the effectiveness of regulated learning scaffolding, but the present findings are encouraging for those looking to utilize regulated learning scaffolding to enhance learning. Given the importance of SRL and SSRL, the demand for regulated learning scaffolding will not diminish, and thus future research should pay more attention to the effects of various regulated learning scaffolding on SSRL.

Author contributions

JS, YC, XW, and XL contributed to conception and design of the study. JS presented the initial ideas, and then our group discussed together to clarify the ideas and determine the outline. Then JS coordinated the planning, organized and analyzed the data, and wrote most of the manuscript. YC and XW collected and analyzed data and wrote part of the article separately. XL gives certain modifications. YL responsible for idea alignment and financial support. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Effects of the Jigsaw method on student educational outcomes: systematic review and meta-analyses

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Introduction: Cooperative learning methods are particularly interesting for building more inclusive schools; however, they have not been widely implemented. Among cooperative learning methods, the Jigsaw strategy is attractive for teachers, as it seems to be easy to implement and follow its four-step teaching structure; in addition, this method is believed to improve students' socialization and learning. To identify the effects of the Jigsaw method accurately, a systematic review of studies that have tested the effects of this method on important student educational outcomes was proposed and completed using a meta-analytical approach.

Methods: A total of 69 Jigsaw studies were analyzed, and three major outcomes were retained following inductive and deductive thematic analyses: learning (including achievement and motivation), social relations, and self-esteem (including academic self-esteem and social self-esteem). When possible, complementary meta-analyses were conducted to quantify the Jigsaw effects on achievement ($n = 43$), motivation ($n = 5$), social relations ($n = 4$), and academic self-esteem ($n = 4$).

Results: The primary results of our review focused on the inconsistency of Jigsaw effects and the high degree of variability among studies with regard to all retained student educational outcomes (i.e., achievement, motivation, social relations, and academic self-esteem) with the exception of social self-esteem, for which only three studies concluded that the Jigsaw method had positive effects. Moreover, homogeneous results were observed within studies. Our review highlights several factors that may explain this variability among studies: the sample size, the diversity of students in the classroom, and the type of content taught.

Discussion: The moderating roles of these factors must be tested empirically, as they suggest ways of implementing the Jigsaw method more efficiently.

KEYWORDS

achievement, cooperative learning, learning, motivation, self-esteem, social relations

1. Introduction

Building more inclusive schools is a primary objective in international educational guidelines (UNESCO, 2009; ONU, 2015), and cooperative learning methods have been highlighted as one of the most effective ways to promote inclusion (Fabes et al., 2018; Farmer et al., 2019; Juvonen et al., 2019). Cooperative learning refers to a set of situations in which individuals interact and learn together (Johnson and Johnson, 1989; Slavin, 2011), and this form of learning has emerged as a promising pedagogical practice (Dyson and Casey, 2012). It permits students to engage collectively, viewing their peers as a fundamental learning resource. In this way, cooperative

pedagogies offer interesting perspective on the improvement of both socialization and learning (for reviews, see Casey and Goodyear, 2015). There is a significant gap between the mass of scientific evidence in favor of cooperative learning and actual classroom practices. According to Pianta et al. (2007), in American schools, <10% of class work takes the form of group work. This fact may be due to teachers' lack of confidence with regard to implementing this approach (Abrami et al., 2004), the complexity of cooperative learning principles (Buchs et al., 2017), a lack of training, ora concern about changing practices (Sabourin and Lehraus, 2008). Among cooperative learning methods, the Jigsaw method (Aronson et al., 1978) is an attractive method for teachers, as it proposes a four-step teaching structure that seems to be easy to follow. Jigsaw is thus one of the most popular and frequently studied cooperative learning methods. The purpose of the current paper is (1) to propose a systematic review of extant research on the Jigsaw method in education, (2) to identify the effects of the Jigsaw method on important student educational outcomes precisely and comprehensively, and (3) to highlight the limits of previous Jigsaw research and propose directions for future research and practical guidelines for the implementation of the Jigsaw method.

Originally developed by Aronson et al. (1978), the Jigsaw method aims to reduce intergroup prejudices in schools (Williams, 2004). After making some observations, Aronson et al. (1978) concluded that intergroup aggressiveness was due to the competitive classroom environment. Their idea was to create situations that would involve cooperative interracial interactions in which students would be dependent on one another to learn the material in a manner similar to assembling a jigsaw puzzle, with each member supplying an essential piece (Roseth et al., 2019). Thus, improving social relations among children was the first aim of the Jigsaw method. The Jigsaw method has evolved since 1978. Now, several models exist (see Table 1). Jigsaw I, which is the basis of each model, features four steps. (1) Students belong to a Jigsaw group. These groups exhibit within-group heterogeneity (i.e., sex, students' cognitive, social and motor levels) and between-group homogeneity and include 3–8 students each. (2) "Students join temporary "expert" groups consisting of students who have been assigned the same subset of material" (Roseth et al., 2019, p. 150). This step provides less competent students with the opportunity to learn how to understand and teach their material from more competent peers (Aronson and Patnoe, 2011; Roseth et al., 2019). (3) Students return to their original Jigsaw groups, where they are responsible for teaching and explaining the skills they have learned to their group members with the aim of making them competent as well. (4) Home group students work together to produce a final joint work through integration and evaluation.

Several meta-analyses have focused on the effects of cooperative learning on three important educational outcomes: achievement (Johnson et al., 2000; Kyndt et al., 2013; Stanczak, 2020), social relations and self-esteem (Slavin, 1990; Johnson et al., 2007; Kyndt et al., 2013). As cooperative learning can be defined in terms of situations in which teachers structure group work with the objective of maximizing social and cognitive gains (Buchs and Butera, 2015), these meta-analyses have included studies based on the Jigsaw method. First, as socialization is the primary objective of cooperative learning methods, Johnson et al. (2007) meta-analyzed the effects of cooperative learning on interpersonal relationships and self-esteem by examining 95 studies. These authors found that cooperative learning promotes greater liking among students than does competing with others [effect size (*ES*) = 0.68] or working on one's own in an individualistic manner (*ES* = 0.55) (Johnson et al., 2007). The results regarding self-esteem showed that cooperation promotes higher self-esteem than does competitive (*ES* = 0.47) or individualistic (*ES* = 0.29) behavior (Johnson et al., 2007). Nevertheless, numerous studies have been conducted since 2007, and this meta-analysis did not focus specifically on the Jigsaw method. Subsequently, Hattie (2017) produced a "mega-analysis" synthesis of the effects of cooperative learning on achievement and social relations, in which context the Jigsaw method was included among the top 10 most effective academic interventions, with an estimated ES of $d = 1.20$. This estimation is based on one meta-analysis of 11 studies conducted in Turkey between 2005 and 2012, with an average sample size of 109 participants (Stanczak et al., 2022). Such a large ES is unusual (Cheung and Slavin, 2016; Kraft, 2020; Patall, 2021) if we consider the first studies on the Jigsaw method (Johnson and Johnson, 2002) and the mean estimates in educational psychology (i.e., $d = 0.33$, see Schäfer and Schwarz, 2019). In addition, from this perspective on achievements pertaining to the Jigsaw method and cooperative learning, Slavin (2015) highlighted the importance of the motivational perspective. Nevertheless, to our knowledge, no review or meta-analysis has investigated the motivational effects of the Jigsaw method. Stanczak (2020) focused exclusively on the effects of the Jigsaw method. He conducted a meta-analysis of studies published between 2000 and 2019 that have tested the effects of the Jigsaw method on achievement in various academic domains. His results indicated a positive and large ES, $g = 0.88$, 95% CI [0.51; 1.25]; however, they were primarily characterized by a very large dispersion

TABLE 1 Historical evolution of the Jigsaw method.

Version of the Jigsaw method	Creators	Characteristics
Jigsaw I	Aronson et al. (1978)	Students alternate between working in the homegroup and the expert group; their roles and resources are complementary
Jigsaw II	Slavin (1986)	The structure is the same as that of Jigsaw I with the addition of a group reward based on the sum of individuals' performance in the group
Jigsaw III	Stahl (1994)	A quiz group is added before step 4 (correction)
Jigsaw IV	Holliday (2000)	A quiz and a test are added between each step
Subject Jigsaw	Doymus (2007)	This version is specific to the sciences (i.e., physics and chemistry); each student can see all the contents of the pre-expert step

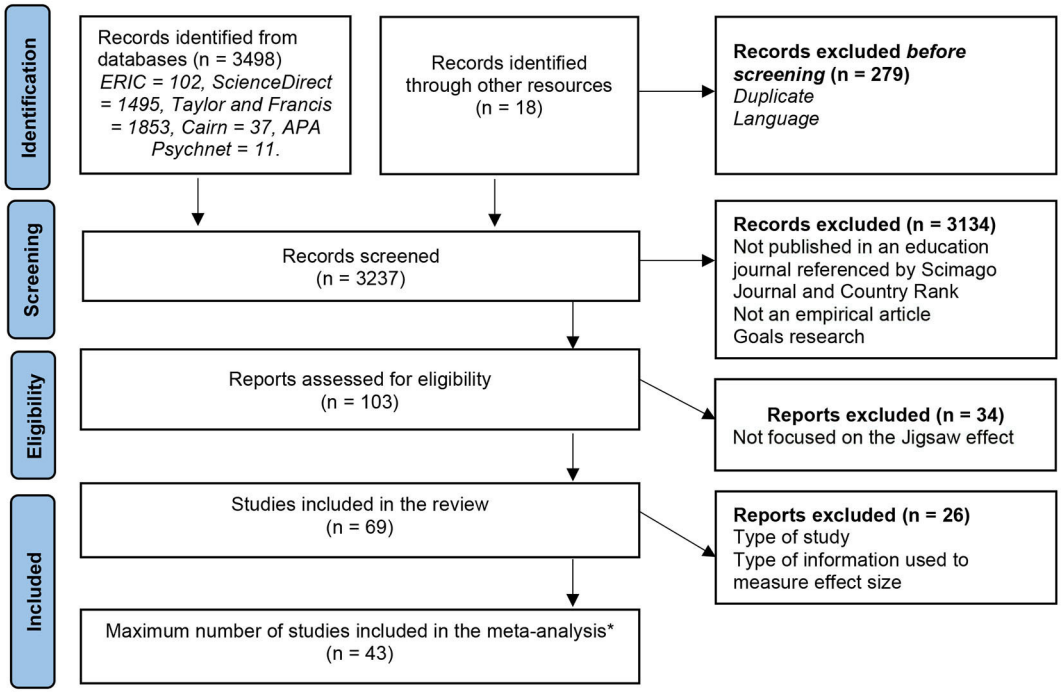

FIGURE 1
Prisma flowchart of the identification process of the systematic review and meta-analysis. *Only the achievement meta-analysis included the maximum of the studies retained ($n = 43$).

and significant heterogeneity, $Q(\text{df} = 19) = 265.86$, $p < 0.001$; $I^2 = 92.85\%$.

In summary, beyond achievement outcomes, other important outcomes, such as social relations, self-esteem, and motivation, must be investigated to identify the effects of the Jigsaw method more effectively and help practitioners make good decisions. Moreover, according to the theoretical relations among those outcomes, such a comprehensive approach can lead to a better understanding of the observed variability among studies pertaining to the effects of the Jigsaw method on achievement. This perspective also requires the identification of factors that could modify these Jigsaw effects.

To explain this variability in achievement more effectively and understand the effects of the Jigsaw method on important educational outcomes, several factors observed in the described methodologies were retained in this paper as potential moderators of the Jigsaw effects: the sample size, the duration of implementation, the discipline taught, the age of participants, and the diversity of students in the classroom. This choice relies on the possibility of observing these factors in the methodologies of the studies reviewed as well as theoretical and empirical considerations. First, the sample size is a potential determining factor. Indeed, ES estimates based on small samples are more sensitive to sampling error, which affects their precision and increases the likelihood of extreme estimates (Kühberger et al., 2014). Power analyses can be performed to estimate the number of participants required per experimental condition. These power calculations were performed by considering a minimum ES of interest of $\delta = 0.40$ at a threshold of $\alpha = 0.05$ (Maxwell, 2004; Stanczak et al., 2022), and the results indicated that 176 participants were needed to yield a 95% chance of detecting a medium effect ($\delta = 0.50$), 140 participants for a 90% chance and 102 participants for an 80% chance. The duration of implementation is another factor that potentially influences the effect of the Jigsaw method. Indeed, efficient classroom implementation of the Jigsaw method requires preparation, adaptation and habituation. It takes time for students to familiarize themselves with the procedure (Aronson et al., 1978; Aronson and Patnoe, 2011; Roseth et al., 2019), and peer groups are more complex to establish and organize than individual procedures in which students work alone (e.g., Aydin and Biyikli, 2017; Roseth et al., 2019). Time allows the procedure to be routinized and potentially to be more effective. A recent study (Cochon Drouet et al., 2022) observed the influence of implementation time on the effects of the Jigsaw method. Concerning disciplines, some meta-analyses (Lou et al., 1996; Kyndt et al., 2013) have reported more positive effects of cooperative learning on "scientific" disciplines than others. However, in the meta-analysis conducted by Stanczak (2020) on the effect of the Jigsaw method on achievement, no significant differences between studies conducted in one scientific discipline and those conducted in another discipline were detected. It is possible to explore the teaching content using the Jigsaw method, as it breaks down the teaching objectives into subcategories on which the expert groups can work (Aronson and Patnoe, 2011). Student age can be a potential factor. Indeed, Kyndt et al. (2013) observed differences across students' ages, with higher effects of cooperative learning being found at the primary and tertiary levels than at the secondary level. However, no explanation of the origin of these differences was given. Finally, student

diversity (i.e., student heterogeneity in terms of achievement or sex) is also a potential factor. Cohen (1994) explained that diversity can be problematic for cooperation in class. Excessive diversity can be detrimental to mutual understanding, but it can also be a source of progress and social cohesion, with diversity being viewed as an asset (Peyrat, 2009).

To legitimate the Jigsaw method in actual and future pedagogical practices, we must go beyond the intuitive notion that the method should work and identify its effects more precisely. A previous study reported promising results regarding specific achievement outcomes (e.g., Stanczak, 2020), but practical decisions must consider all educational outcomes of the Jigsaw method from a comprehensive perspective. Moreover, the large dispersion and significant heterogeneity among studies on students' achievement observed by Stanczak (2020) must be analyzed in more depth. We must evaluate whether this variability can also be found in other educational outcomes and identify the potential factors that could explain such hypothetical variability among studies. These factors leading to the differential impacts of Jigsaw on important educational outcomes are also crucial to improve the Jigsaw method. Therefore, the purpose of the current paper was (1) to propose a review of the extant research on the Jigsaw method in education, (2) to identify the effects of the method on each student's important educational outcomes, and (3) to improve our understanding of the heterogeneity of these effects with the aim of proposing directions for future research and guidelines regarding the implementation of the Jigsaw method. In other words, two research questions were raised in this study:

1. What effects does the jigsaw method have on different educational outcomes?
2. Do the results regarding different outcomes exhibit heterogeneity? If so, why?

To achieve these goals, a systematic review was conducted to identify the educational outcomes empirically associated with the Jigsaw method. When possible, we proceeded to perform a complementary meta-analysis of each identified outcome variable with the aim of quantifying the observed Jigsaw effects and their variability across studies. Finally, we tried to identify the factors that could explain such potential variability. Based on previous research and theoretical propositions, our examination of the literature focused more deeply on the five following factors: the sample size, the discipline taught, the age of the students, the duration of implementation, and the diversity among the students.

2. Methods

The systematic review and meta-analyses followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for reporting meta-analytical findings (Moher et al., 2009). The identification of relevant studies was conducted by reference to the following databases: *ERIC, ScienceDirect, Taylor and Francis, Web of Science, Cairn,* and *APA Psychnet*. The keyword "Jigsaw" was used, and the combination of the following keywords was used with the Boolean connector "AND": Jigsaw AND Education. The whole process was implemented in April 2023.

2.1. Systematic review

Only published or accepted peer-reviewed scientific education research articles that were written in English or French, contained the keywords "Jigsaw" and "Education" in the body of the article, included information about the research goal (excluding theoretical studies and reviews) and were published in an education journal referenced by Scimago Journal and Country Rank (SJR) were considered for the review. Abstracts and conference papers were not included.

Figure 1 shows the flow diagram for the literature selection process. The full screening process followed the Prisma guidelines (Page et al., 2021). The first step of the review consisted of checking all retained references ($n = 3{,}237$) to eliminate duplicates. In the second step, the titles and abstracts of the selected articles were examined to determine applicability, and the full texts were read carefully to determine whether they conformed to the inclusion criteria. The sample was thus reduced to 103 references. In the third step, as recommended by Scott et al. (2018), we verified the quality of these 103 studies. The studies included in this review were checked by the first and second authors. Two criteria were consulted. First, the study in question should present a well-defined argument that establishes a connection between theory and research, showcasing a logical and coherent line of reasoning. It should effectively elucidate the relevant theoretical foundations and previous research, contributing to the formulation of the research question(s). Second, the study should present its findings and makes claims that align with and are supported by the methods used in the research.

Consensus was reached between the two coders to delete 34 studies from this set of 103. Ultimately, 69 studies were included in this review. The variables used in the coding procedure are detailed in Table 2.

Subsequently, these 69 studies were analyzed using a two-step process. First, the studies were categorized based on the following parameters: year of publication, sample size, academic level of students, discipline, geographic location, and duration of implementation. Second, a more in-depth content analysis of the studies' methods and results facilitated the identification of several themes and subthemes. Both inductive and deductive thematic analyses were used as described by Fereday and Muir-Cochrane (2006). The identification of themes and grouping into major themes were performed by two researchers, and the results were compared until consensus was reached. Finally, three major educational outcomes and certain subthemes were identified by reference to the extant research on some of the effects of the Jigsaw method: learning (encompassing motivation and achievement), social relations, and self-esteem (including academic self-esteem and social self-esteem).

2.2. The meta-analyses

The first step of this meta-analytical approach consisted of checking all statistical information contained in the 69 studies included in the systematic review. Studies that met all the following inclusion criteria were selected for the meta-analyses.

TABLE 2 Description of the studies retained in this review.

Date of publication (year)	*N*	Percent
1975–1980	2	2.90
1980–1985	3	4.35
1985–1990	1	1.45
1990–1995	2	2.90
1995–2000	1	1.45
2000–2005	1	1.45
2005–2010	19	27.54
2010–2015	12	17.39
After 2015	28	40.58
Sample size (n)		
>176	12	17.39
140–175	3	4.35
102–139	10	14.49
50–101	32	43.38
<50	13	18.84
Geographic location		
East	42	60.87
West	27	39.13
Grade level		
Primary school	16	23.19
Secondary school	20	28.99
University	33	47.82
Jigsaw method		
Jigsaw I	51	82.61
Jigsaw II	8	11.59
Jigsaw III	1	1.45
Jigsaw IV	3	4.35
Subject Jigsaw	6	8.69
Duration of implementation		
> 15 h	18	26.09
10–15 h	11	15.94
9–5 h	20	28.99
<5 h	16	23.19
Not mentioned	4	5.80
Discipline		
Sciences	37	53.62
Languages	9	13.04
Social sciences	10	14.49
Physical education	5	7.25
Not mentioned	8	11.59

Only empirical studies were selected. Such studies were required to include both a control group and an experimental group. Only studies that contained sufficient information (N, M, SD) to measure the computation of effect size were included. Studies featuring only surveys, studies featuring only a one-group pretest and posttest design, and qualitative studies were excluded.

The 69 studies were analyzed by the first and second authors. Consensus was reached between the two coders to delete 26 studies from this set of 69 because they did not meet all the inclusion criteria.

The same themes that had previously been identified in the systematic review were used, and regarding the theme "students' learning", two meta-analyses were performed – one meta-analysis on achievement and one on motivation. The "social relations" theme was the focus of one meta-analysis. "Self-esteem" was explored through one meta-analysis on academic self-esteem. The specific constructs of the variables are specified in the Appendix. When a meta-analysis could be conducted, each educational outcome was studied using a mixed-methods approach combining a qualitative analysis of the results and a meta-analysis of the obtained effect sizes.

Several elements were included in the data analysis. The mean and standard deviation were extracted to estimate the average ES and its dispersion using the *g* parameter developed by Hedge (Borenstein et al., 2009). First, a Cohen *d*, i.e., the standardized difference between the means of the two experimental groups (Jigsaw vs. Control) as weighted by an intrastudy standard deviation, was calculated for each study. Then, this value was corrected alongside its associated variance by a "small-sample correction" factor *J* to arrive at the Hedge parameter *g*, which can be interpreted using the benchmarks defined by Hattie (2009). Hattie (2009) defined a small ES as $\delta = 0.20$; a medium ES as $\delta = 0.40$, which was motivated by the criteria of practice signification and his estimation of a medium ES of cooperative learning of $\delta = 0.41$; and a large ES as $\delta = 0.8$. If a study reported multiple measures of the same construct, an intermeasurement correlation coefficient $r = 0.71$ was estimated based on the recommendations of Borenstein et al. (2009). This coefficient permits us to measure a variance inflation factor (VIF), which is used to correct the inflation of the variance in studies that used many measures of the same proxy. We used the "MAJOR" extension to conduct our meta-analysis with the support of Jamovi 1.1.8.0 software. As Goh et al. (2016) noted, this approach is usually conservative if few studies are available, but it offers greater generalizability. The Der-Simonian-Laird method was used for the computation of the estimate because it is one of the most frequently used approaches and is simple to implement (Veroniki et al., 2016). We estimated the homogeneity of effects using Q-statistics and I^2 (Higgins et al., 2003), which relate the observed variance to the within-study variance, with the goal of highlighting potential sources of heterogeneity.

Publication bias was examined using funnel plot asymmetry (Tatsioni and Ioannidis, 2017). This approach focuses on a plot of the estimate of ES in each study against an estimate of its precision (typically its standard error; Simmonds, 2015). In a funnel plot, smaller studies tend to exhibit larger variation in their estimated treatment effects, resulting in more scattered data points around

the mean effect. In contrast, larger studies exhibit smaller variation and cluster more closely around the mean effect (Simmonds, 2015). This pattern arises due to the inherent uncertainty associated with smaller sample sizes, which leads to a wider range of estimated effects (Tatsioni and Ioannidis, 2017). Moreover, Tables 3–6 show the role of sample size in the change in ESs (Uttl et al., 2017).

For each selected outcome, we tried to understand the heterogeneity of the results observed in both the systematic review and meta-analysis more accurately. Moderation analyses seek to test whether study groupings explain differences in heterogeneity, i.e., differences in the dispersion of Jigsaw effects (Stanczak, 2020). Five potential moderators were analyzed in depth to try to explain this heterogeneity (e.g., the sample size, the discipline taught, the age of the students, the duration of implementation, and the diversity among the students). This approach enables us to compare several studies according to a specific criterion. For reasons of statistical power and the categorical nature of some moderators, we chose to divide each moderator into two categories. In the case of continuous variables, categorical classification was performed based on the median score of our sample (Stanczak, 2020). More precisely, concerning the duration of implementation, in our sample, we used the median duration in hours (i.e., $\Delta t = 9$) to categorize "short" or "long" durations of implementation and test the moderating effect by reference to Jigsaw exposure duration. Concerning the sample size, the 102 participant range was chosen according to the power of the studies. Concerning the discipline taught, the sciences were separated from other disciplines. Concerning the students' age, schoolchildren were separated from students in higher education. Finally, no quantitative exploration of moderation was performed with regard to students' diversity due to overly heterogeneous criteria.

3. Results

This section presents the results first of the systematic review, second of the meta-analyses, and third regarding the factors that could explain the heterogeneity in results.

3.1. Systematic review

Table 2 shows a general description of the selected studies, and the Appendix provides a complete description of each selected study. The number of studies increased over the period (1976–2022), and the majority of studies were published after 2000 (85.50%). The focus of these studies ranged from primary schools to universities, and 60% of the students were conducted in an Eastern context (see Table 2). The mean duration of the implementation of the Jigsaw method was 13.76 hours. The results of the systematic review of each outcome are detailed below.

3.1.1. Students' perceptions of achievement and learning

Among the 48 studies on students' achievement, 18 focused on students' perceptions of achievement and learning with respect to the Jigsaw method (e.g., Aydin and Biyikli, 2017; Er, 2017). Seven studies involved interviews, and 13 entailed open-ended items in questionnaires. Some studies showed improvements in perceived achievement or learning. For example, in the study conducted by Aydin and Biyikli (2017), 33% of students reported that tasks were perceived easier in the Jigsaw condition. The interviews conducted by Tarhan et al. (2013) revealed that "83% of students thought that since they were responsible for their own learning (i.e., mastery climate), they were meeting the lesson's objectives" (p. 196). These qualitative results support the positive effect of the Jigsaw method on learning.

3.1.2. Students' motivation

Six studies measured intrinsic and extrinsic motivation in scientific disciplines (Hänze and Berger, 2007; Berger and Hänze, 2009, 2015; Roseth et al., 2019; Sanaie et al., 2019; Costouros, 2020). Their results are detailed in the meta-analysis section. Three other studies used other motivational constructs (Ural et al., 2017; Blajvaz et al., 2022; Cochon Drouet et al., 2022). For example, Ural et al. (2017) showed a positive Jigsaw effect on motivation to learn ($g = 0.6$), and Cochon Drouet et al. (2022) obtained mixed results regarding physical education, including significant positive or negative effects of the Jigsaw method on situational interest and motor engagement according to the type of sport taught in the context of physical education as compared to the control condition. Berger and Hänze (2015) also showed that the type of content taught using the Jigsaw method in the context of physics modified teachers' quality of teaching and their intrinsic motivation. The more demanding the content is, the higher the cognitive load faced by the student, and the more this factor hinders motivation.

3.1.3. Students' social relations

In terms of student social relations, the Jigsaw effect appeared to be inconsistent. Indeed, some studies obtained positive results, others obtained negative results, and one yielded mixed results. More precisely, positive effects of the Jigsaw method on social relations were found in 11 studies (Blaney et al., 1977; Bridgeman, 1981; Ziegler, 1981; Desforges et al., 1991; Lazarowitz et al., 1994; Walker and Crogan, 1998; Hänze and Berger, 2007; Göçer, 2010; Theobald et al., 2017; Oakes et al., 2019; Costouros, 2020; Chang and Benson, 2022). For example, in Desforges et al. (1991 study), the Jigsaw method led to more positive interpersonal attitudes and more empathy. The study conducted by Theobald et al. (2017) found positive effects on students' social relations.

The study conducted by O'Leary et al. (2019) presented mixed results with regard to social relations depending on students' ability level. Indeed, in this study, which focused on the context of physical education, some students recognized that high-ability classmates could help their lower-ability peers learn (O'Leary et al., 2019). However, the results also showed that the low ability of students negatively impacted their social relationships. For example, one student in this study stated that "two of us worked truly well, and the other one (a low practical ability student), I truly struggled to connect with. I was trying to determine where he was at and where he felt comfortable and to get him more involved" (O'Leary et al., 2019, p. 723).

TABLE 3 Estimated effect sizes and characteristics of students' achievement.

Study	Effect size	Confidence intervals	Sample	Study weight	Population	Discipline	Duration (hours)	Percent boys
Göçer (2010)	4.29	[3.88, 4.70]	60	1.90	SS	Literature	3	NM
Yapici (2016)	2.65	[2.38, 2.92]	53	2.12	SS	Sciences	11	NM
Tarhan et al. (2013)	2.57	[2.33, 2.81]	61	2.15	SS	Physics	8	NM
Gömleksi'z (2007)	2.38	[2.09, 2.67]	66	2.09	UNI	English	28	NM
Koc et al. (2010)	1.90	[1.76, 2.04]	106	2.39	UNI	Chemistry	16	NM
Doymus (2008b)	1.75	[1.36, 2.14]	68	1.93	UNI	Chemistry	10	NM
Abed et al. (2020)	1.49	[1.36, 1.61]	80	2.43	SS	Mathematics	8	0
Doymus et al. (2010)	1.47	[1.33, 1.61]	122	2.39	UNI	Chemistry	5	NM
Tarhan and Sesen (2012)	1.39	[1.13, 1.64]	38	2.19	UNI	Chemistry	1.15	NM
Aydin and Biyikli (2017)	1.31	[1.17, 1.45]	63	2.39	UNI	Physics	12	NM
Akkus and Doymuş (2022)	1.18	[0.56,1.80]	68	2.27	PS	Sciences	NM	52.70
Er (2017)	1.14	[0.85, 1.43]	46	2.09	SS	Social sciences	12	58.70
Kilic (2008)	1.13	[0.69,1.57]	80	2.48	UNI	Pedagogy	NM	NM
Artut and Tarim (2007)	1.09	[0.97, 1.21]	71	2.43	UNI	Mathematics	36	NM
Karacop and Doymus (2013)	1.09	[0.91, 1.27]	115	2.31	UNI	Chemistry	5	44.40
Namaziandost and Gilakjani (2020)	1.09	[0.89, 1.25]	50	2.31	SS	English	20	100
Doymus (2008a)	1.04	[0.88, 1.20]	36	2.35	UNI	Chemistry	9	NM
Sahin (2010)	0.97	[0.87, 1.07]	80	2.48	UNI	Turkish	24	NM
Doymus (2007)	0.96	[0.86, 1.06]	108	2.48	UNI	Chemistry	12	NM
Sahin (2011)	0.86	[0.74, 0.98]	71	2.43	PS	Writing	24	45.00
Hornby (2009)	0.76	[0.58, 0.94]	44	2.31	UNI	Education	2	NM
Van Dat (2016)	0.54	[0.10, 0.98]	80	2.48	UNI	Management	18	60.00
Koç et al. (2016)	0.53	[0.35, 0.71]	71	2.31	SS	Sciences	20	6.8
Wilson et al. (2017)	0.46	[0.36, 0.56]	94	2.48	UNI	Pharmaceutic	12	38.30
Garcia (2021)	0.45	[0.01, 0.89]	80	2.48	UNI	Informatics	14	93.75
Arslan (2016)	0.38	[0.24, 0.52]	56	2.75	SS	Turkish	12	51.80

(Continued)

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TABLE 3 (Continued)

Study	Effect size	Confidence intervals	Sample	Study weight	Population	Discipline	Duration (hours)	Percent boys
Sagsoz et al. (2017)	0.34	[−0.18, 0.86]	50	2.39	UNI	Dentistry	3	NM
Ghaith and El-Malak (2004)	0.27	[0.09, 0.45]	48	2.31	SS	Reading	15	60.40
Roseth et al. (2019)	0.26	[0.24, 0.28]	258	2.68	UNI	Anatomy	10	32.00
Shaaban (2006)	0.23	[−0.02, 0.48]	45	2.15	SS	Reading	8	59.10
Suárez-Cunqueiro et al. (2017)	0.21	[0.13, 0.29]	109	2.53	UNI	Dentistry	12	31.20
Costouros (2020)	0.18	[−0.21, 0.57]	50	2.53	UNI	Management	48	54.00
Oakes et al. (2019)	0.15	[−0.87, 0.36]	145	2.31	UNI	Anatomy	2	23.40
Stanczak et al. (2022) study 4	0.05	[−0.18, 0.27]	74	2.48	SS	Earth and life sciences	18	48.65
Stanczak et al. (2022) study 5	0.05	[−0.14, 0.25]	101	2.53	SS	Earth and life sciences	18	43.56
Ural et al. (2017)	0.01	[−0.15, 0.17]	49	2.35	PS	Sciences	6	NM
Stanczak et al. (2022) study 2	0	[−0.22, 0.22]	313	2.68	SS	Earth and life sciences	2	46.00
Stanczak et al. (2022) study 1	−0.04	[−0.30, 0.2]	252	2.63	SS	Mathematics	2	41.66
Stanczak et al. (2022) study 3	−0.07	[−0.26, 0.11]	110	2.58	SS	Physics and chemistry	16	52.73
Berger and Hänze (2009)	−0.07	[−0.11, −0.03]	344	2.63	SS	Physics	9	67.00
Hänze and Berger (2007)	−0.24	[−0.30, −0.18]	137	2.58	SS	Physics	9	NM
Souvignier and Kronenberger (2007)	−0.48	[−0.52, −0.44]	208	2.63	PS	Sciences	15	48.10
Moreno (2009)	−0.65	[−0.79, −0.51]	87	2.39	UNI	Biology	1	63.10
$K = 42$	0.77	[0.55, 0.98]		100				

NM, Not mentioned; PS, Primary school; SS, Secondary school; UNI, University.

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TABLE 4 Estimated effect size and characteristics of students' intrinsic and extrinsic motivation.

Study	Effect size	Confidence intervals	Sample	Study weight	Population	Discipline	Duration (hours)
Sanaie et al. (2019)	2.38	[2.24, 2.52]	94	18.88	UNI	Nursing	34
Hänze and Berger (2007)	0.35	[0.29, 0.41]	137	20.19	SS	Physics	9
Costouros (2020)	−0.04	[−0.43, 0.35]	50	19.84	UNI	Management	48
Roseth et al. (2019)	−0.10	[−0.12, −0.08]	258	20.91	UNI	Anatomy	10
Berger and Hänze (2009)	−0.13	[−0.19, −0.07]	286	20.19	SS	Physics	9
$K = 4$	0.46	[−0.20, 1.13]		100			

SS, Secondary school; UNI, University.

TABLE 5 Estimated effect size and characteristics of students' relatedness.

Study	Effect size	Confidence intervals	Sample	Study weight	Population	Discipline	Duration (hours)
Hänze and Berger (2007)	0.87	[0.81, 0.93]	137	24.97	SS	Physics	9
Costouros (2020)	0.32	[−0.07, 0.20]	50	23.74	UNI	Management	48
Berger and Hänze (2009)	0.03	[−0.03, 0.09]	286	24.97	SS	Physics	9
Roseth et al. (2019)	−0.08	[−0.12, −0.04]	258	26.33	UNI	Anatomy	10
$K = 3$	0.28	[−0.15, 0.71]		100			

SS, Secondary school; UNI, University.

TABLE 6 Estimated effect size and characteristics of students' academic self-esteem.

Study	Effect size	Confidence intervals	Sample	Study weight	Population	Discipline	Duration (hours)
Hänze and Berger (2007)	0.52	[0.46, 0.58]	137	26.54	SS	Physics	9
Berger and Hänze (2009)	0.27	[0.21, 0.33]	286	26.54	SS	Physics	9
Roseth et al. (2019)	0.01	[−0.03, 0.05]	258	29.88	UNI	Anatomy	10
Costouros (2020)	−0.30	[−0.85, 0.25]	50	17.04	UNI	Management	48
$K = 3$	0.16	[−0.14, 0.46]		100			

SS, Secondary school; UNI, University.

Finally, ten studies concluded that the effect of the Jigsaw method on social relations was either inconsistent (Moskowitz et al., 1983, 1985; Santos Rego and Moledo, 2005; Berger and Hänze, 2009; Zacharia et al., 2011; Roseth et al., 2019) or negative (Bratt, 2008; O'Leary and Griggs, 2010; O'Leary et al., 2015; Aydin and Biyikli, 2017). Indeed, the study conducted by O'Leary et al. (2015) identified problems resulting from group heterogeneity. These authors observed that it was difficult for many students to teach their peers. For example, one participant noted that "students seem to lack basic skills to talk and listen to each other; teaching each other becomes almost impossible" (O'Leary et al., 2015, p. 186). Overall, 7% of students in the study conducted by Aydin and Biyikli (2017) reported conflicts within groups in which the lack of knowledge on the part of one group member negatively affected other group members. The results of the study conducted by Roseth et al. (2019) in the context of anatomy also suggested that "increasing epistemic regulation may have the unintended effect of also making social comparison more salient, as deeper engagement with the material also heightens students' sensitivity to relative differences in competence" (p. 162).

3.1.4. Students' social self-esteem

Three studies focused only on social self-esteem (Blaney et al., 1977; Lazarowitz et al., 1994; Walker and Crogan, 1998). Two studies showed a significant increase in social self-esteem in favor of the Jigsaw condition (Blaney et al., 1977; Lazarowitz et al., 1994), and one study reported nonsignificant results (Walker and Crogan, 1998). The lack of statistical information prevented us from conducting a meta-analysis on this topic.

3.1.5. Students' academic self-esteem

A positive effect of the Jigsaw method on academic self-esteem was found in two studies (Hänze and Berger, 2007; Crone and Portillo, 2013), and a nonsignificant effect was found in the four other studies (Moskowitz et al., 1983; Berger and Hänze, 2009; Roseth et al., 2019; Costouros, 2020). In the study conducted by Crone and Portillo (2013), undergraduate students had more confidence in their ability to communicate orally about psychology. The results reported by Hänze and Berger (2007) in the context of physics in secondary school showed that students with a low academic self-concept had a greater feeling of competence in the Jigsaw condition than in the direct instruction condition. Moreover, the results showed a significant interaction of the Jigsaw condition with gender, resulting in a greater feeling of competence for girls than in the traditional teaching setting in the context of physics, which is viewed as a masculine discipline (Morge and Toczek, 2009). Three studies reported no significant results.

3.2. Meta-analysis

3.2.1. Student achievement

Our meta-analysis of student achievement included 43 studies (five experiments conducted by Stanczak et al., 2022 and 38 articles on student achievement that were included in a meta-analysis, see Table 3 and Figure 2). It revealed a large ES of the Jigsaw method on achievement ($g = 0.77$, 95% CI [0.55; 0.98], $p < 0.001$). However, this meta-analysis also showed a large dispersion and significant heterogeneity [Q(df=41) $= 457.04$, $p < 0.001$, $\tau^2 = 0.48$, $I^2 = 91.03$]. Some studies (Hänze and Berger, 2007; Souvignier and Kronenberger, 2007; Moreno, 2009; 9.30% of the 43 studies, Berger and Hänze, 2009), including three with large sample sizes, even indicated significant negative ES ($g = [-0.65; -0.07]$). Among the 43 studies on student achievement included in the meta-analysis, 17 had an ES > 1 that could be of substantial concern (Cheung and Slavin, 2016). The mean sample size was 69 participants (the mean sample size of all studies in our meta-analysis was 94 participants). Among these 17 studies, 12 were conducted at universities with a focus on the sciences, and 16 were conducted in Turkey.

Figure 2 offers a visual representation of heterogeneity (i.e., publication bias).

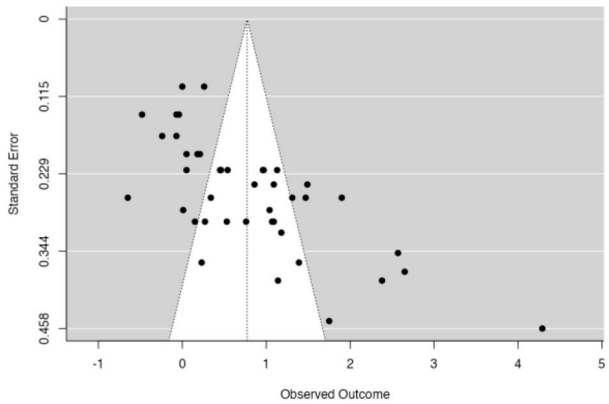

FIGURE 2
Funnel plot of the effect sizes of achievement outcomes. The outer dashed lines indicate the triangular region within which 95% of studies are expected to be located in the absence of both biases and heterogeneity (fixed effect summary log odds ratio ± 1.96×standard error of summary log odds ratio). The solid vertical line corresponds to no intervention effect (Sterne et al., 2011). The large samples are on the left, and the small samples are on the right.

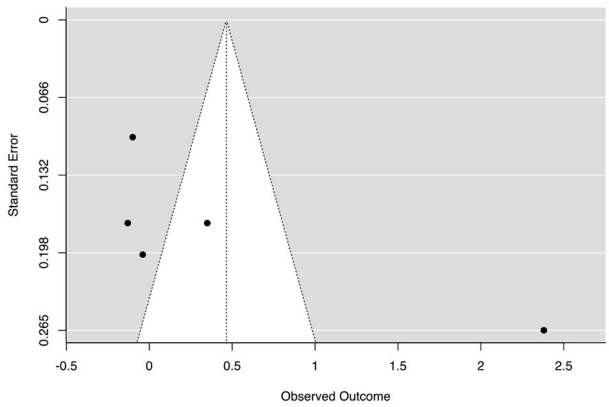

FIGURE 3
Funnel plot of the effect sizes of motivation outcomes. The outer dashed lines indicate the triangular region within which 95% of studies are expected to be located in the absence of both biases and heterogeneity (fixed effect summary log odds ratio ± 1.96×standard error of summary log odds ratio). The solid vertical line corresponds to no intervention effect (Sterne et al., 2011). The large samples are on the left, and the small samples are on the right.

3.2.2. Student motivation

With regard to the five studies that measured intrinsic and extrinsic motivation in scientific disciplines (Hänze and Berger, 2007; Berger and Hänze, 2009, 2015; Roseth et al., 2019; Sanaie et al., 2019; Costouros, 2020), a meta-analysis was possible, as Berger and Hänze (2015) used a design without control conditions. This meta-analysis revealed non-significant ESs ($g = 0.47$, 95% CI [−0.21, 1.13], $p = 0.17$; see Table 4 and Figure 3) and significant heterogeneity among these studies [Q(df = 5) $= 82.14$, $p < 0.001$, $\tau^2 = 0.55$, $I^2 = 95.1$].

Figure 3 offers a visual representation of heterogeneity (i.e., publication bias).

3.2.3. Student social relations

Among these 22 studies, only four were eligible for the meta-analysis. These four studies were conducted in the West and

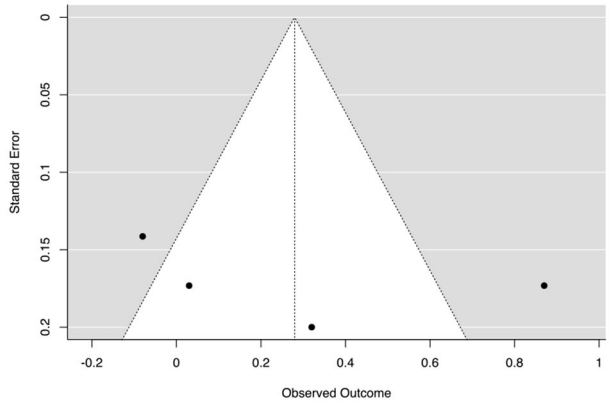

FIGURE 4
Funnel plot of the effect sizes of relatedness outcomes. The outer dashed lines indicate the triangular region within which 95% of studies are expected to be located in the absence of both biases and heterogeneity (fixed effect summary log odds ratio±1.96×standard error of summary log odds ratio). The solid vertical line corresponds to no intervention effect (Sterne et al., 2011). The large samples are on the left, and the small samples are on the right.

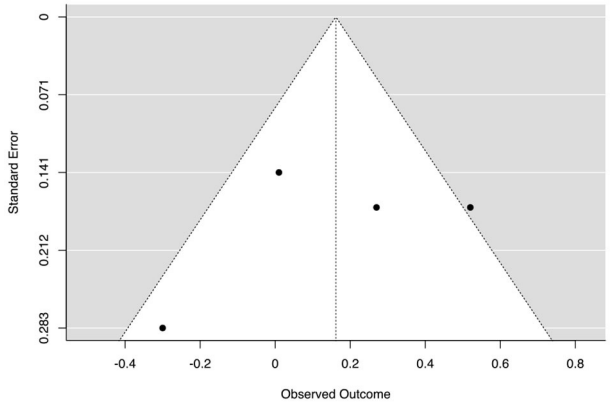

FIGURE 5
Funnel plot of the effect sizes of academic self-esteem outcomes. The outer dashed lines indicate the triangular region within which 95% of studies are expected to be located in the absence of both biases and heterogeneity (fixed effect summary log odds ratio ± 1.96×standard error of summary log odds ratio). The solid vertical line corresponds to no intervention effect (Sterne et al., 2011). The large samples are on the left, and the small samples are on the right.

measured students' perceptions of social relatedness (Berger and Hänze, 2009, $N = 286$; Costouros, 2020, $N = 50$; Hänze and Berger, 2007, $N = 137$; Roseth et al., 2019, $N = 258$). The overall ES appeared to be non-significant ($g = 0.28$, 95% CI [−0.15, 0.71], $p = 0.19$; see Table 5 and Figure 4) but to exhibit significant heterogeneity ($Q(\text{df} = 3) = 19.98$, $p < 0.001$, $\tau^2 = 0.15$, $I^2 = 88.33$). More precisely, two studies concluded that the Jigsaw method had a non-significant effect on social relatedness (Roseth et al., 2019; Table 5, Berger and Hänze, 2009), whereas two studies (Hänze and Berger, 2007; Costouros, 2020) showed a positive effect.

Figure 4 offers a visual representation of heterogeneity (i.e., publication bias).

3.2.4. Student academic self-esteem

Among the six studies, four studies were eligible for the meta-analysis (Hänze and Berger, 2007; Berger and Hänze, 2009; Roseth et al., 2019; Costouros, 2020). The obtained ESs were small and nonsignificant ($g = 0.25$, 95% CI [−0.14, 0.46], $p = 0.29$; see Table 6 and Figure 5), and heterogeneity was observed ($Q(\text{df} = 2) = 8.45$ $p = 0.04$, $\tau^2 = 0.06$, $I^2 = 64.49$).

Figure 5 offers a visual representation of heterogeneity (i.e., publication bias).

3.3. Factors that could explain the heterogeneity of the results: moderating effects

The large dispersion and significant heterogeneity of each outcome can be explained by reference to the five factors previously identified as able to influence the Jigsaw effect.

3.3.1. Sample size

For each outcome, the sample size appeared to be a factor that could explain the significant heterogeneity observed. Indeed, the ESs associated with students' achievement were larger ($Q(\text{df} = 1) = 52.78$, $p < 0.001$) in studies with sample sizes containing fewer than 102 participants (ES $_{smallsamples} = 1.01$, SE = 0.16, 95% CI [0.69; 1.33]) than in studies with sample sizes containing more than 102 participants (ES $_{largesamples} = 0.33$, SE = 0.23, 95% CI [−0.04; 0.70]). The mean sample size of studies reporting negative ESs was 224, whereas studies reporting large positive ESs had a mean sample size of 78 (Gömleksi'z, 2007; Göçer, 2010; Tarhan et al., 2013; Yapici, 2016). In addition, with regard to students' motivation, the two studies with the largest samples indicated small negative nonsignificant ESs (Berger and Hänze, 2009, $g = -0.13$; Roseth et al., 2019, $g = -0.10$), and two others reported positive significant ESs (Hänze and Berger, 2007, $g = 0.35$; Sanaie et al., 2019, $g = 2.38$) (see Table 4). The results pertaining to student motivation were similar when the four studies included in the meta-analysis were considered: the mean sample size of the studies with negative ESs was higher ($M = 277$, with the exception of Costouros (2020), which featured a sample size of 50 participants) than that of studies with positive ESs ($M = 115.5$). Moreover, the studies that found positive results regarding students' social relations had sample sizes ranging between 36 and 684 ($M = 130$). The studies that reported inconsistent results had the most important sample sizes (between 258 and 384 students, $M = 297$). Studies indicating negative effects had sample sizes ranging between 36 and 63. Finally, studies that reported positive results regarding students' self-esteem had smaller sample sizes ($N_{Moy} = 103.5$) than studies that reported non-significant results ($N_{Moy} = 268$). The studies on students' social self-esteem had consequent sample sizes (Blaney et al., 1977, p. 304; Lazarowitz et al., 1994, p. 120; Walker and Crogan, 1998, p. 103, $M = 213$).

3.3.2. The discipline taught

For each outcome, the discipline taught did not appear to be a factor that could explain the significant heterogeneity observed. Indeed, the systematic review of students' achievement indicated positive effects of the Jigsaw method in many disciplines (sciences, English, literature, economics, etc.), although 78.38% of these studies focused on scientific disciplines. Moreover, no significant difference was observed among the ESs of studies investigating scientific disciplines [$Q(\text{df} = 1) = 47.16$, $p = 0.15$]. The same tendency can be observed in students' motivation and social relations, in which context 11 studies with positive results were conducted in different disciplines (i.e., sciences, literature), while ten studies found nonsignificant and negative results (i.e., sciences, physical education). Studies on social self-esteem were conducted in different academic disciplines in primary and secondary schools, and studies on academic self-esteem were conducted in the same discipline (i.e., the sciences).

However, the content taught appeared to be a factor that could explain the significant heterogeneity observed. Indeed, with regard to students' achievement outcomes, Berger and Hänze (2009) showed that the type of content taught leads to different Jigsaw effects. More precisely, Berger and Hänze (2015) showed that the content taught impacts the quality of teaching and therefore academic performance in the context of Jigsaw-based learning. The more demanding the content is, the higher the cognitive load faced by the student, and the more this factor hinders learning. The same result can be observed with regard to students' motivation outcomes (Berger and Hänze, 2015; Cochon Drouet et al., 2022).

3.3.3. The students' diversity

For several outcomes, the students' diversity appeared to be a factor that could explain the significant heterogeneity observed. Indeed, in the study on physical education conducted by O'Leary et al. (2019), student diversity influenced the effect of the Jigsaw method on students' achievement. Indeed, those authors explained that the low ability of students negatively impacted their social and cognitive learning. Moreover, "the fact that higher-order social and cognitive learning was hampered for such students is likely to impact their psychomotor learning" with the Jigsaw method was noted (O'Leary et al., 2019, p. 724). Finally, some studies have shown that student diversity, particularly in students' ability, can impact their learning in the context of the Jigsaw method (O'Leary and Griggs, 2010; O'Leary et al., 2015, 2019) in a manner that disfavors students with low ability. The same tendency can be observed in the students' social relations and self-esteem outcomes. In fact, in three studies (O'Leary et al., 2015, 2019; Aydin and Biyikli, 2017), student diversity (e.g., ability level) was highlighted as a potential factor influencing the Jigsaw effect on students' social relations. As previously explained (see the Systematic Review section), students with low ability have more difficulty or generate more difficulties within their group. Moreover, according to Hänze and Berger (2007), students' diversity seems to be a factor that can affect the effects of the Jigsaw method on self-esteem in favor of students with low academic self-esteem as well as girls. However, no evidence was found to support the claim that student diversity (i.e., sex and status) influence the effect of the Jigsaw method on motivation (Hänze and Berger, 2007).

3.3.4. The students' age

For all outcomes, the discipline taught did not appear to be a factor that could explain the significant heterogeneity observed. Indeed, the ESs associated with students' achievement were larger $Q(\text{df} = 1) = 58.72$, $p = 0.62$. Moreover, student age did not seem to explain the effect of heterogeneity on motivation, on students' social relations, or on students' self-esteem, and the relevant results showed positive and negative Jigsaw effects at different ages (primary and secondary schools vs. universities).

3.3.5. The duration of implementation

For several outcomes, the duration of implementation did not appear to be a factor that could explain the significant heterogeneity observed. For studies on student achievement, the duration of implementation (<9 h vs. >9 h, with a median implementation time of 9 h) did not lead to different ESs [$Q(\text{df} = 1) = 53.59$ $p = 0.93$], although the mean implementation time in the studies reporting positive ESs was 11 h, while the corresponding time in studies reporting negative ESs was 6 h. A similar conclusion could be drawn with regard to the impact of the implementation duration on students' motivation; this value was approximately 10 h in both studies reporting positive ESs and in studies reporting negative ESs [with the exception of Costouros (2020), which featured a duration of 48 h].

However, for studies on social relations and academic self-esteem, the duration of implementation appeared to be a factor that could explain the heterogeneity observed. In fact, concerning the duration of the implementation, studies that focused on students' social relations and reported a positive ES featured a mean Jigsaw practice time of 15 h, while studies that reported a negative ES featured a mean of 24 h of practice. Studies on students' self-esteem that reported positive results featured a mean Jigsaw practice of 10 h, and studies that reported non-significant results featured a mean of 24 h of practice.

4. Discussion

This paper proposed a mixed method review of studies that have investigated the effects of the Jigsaw method on students' outcomes. The objectives were (1) to determine the state of the art regarding these effects on students' educational outcomes precisely, (2) to improve our understanding of these effects, and (3) to highlight future lines of research and help teachers implement the Jigsaw method more effectively.

As a first output of this review, the 69 Jigsaw studies tested effects on three important types of educational outcomes: student learning, socialization, and self-esteem. Even if social relations were the historic goal of the Jigsaw method (Aronson et al., 1978), most studies focused on achievement.

4.1. Inconsistent and heterogeneous results

The primary result of our review pertains to the inconsistency reported regarding the effects of the Jigsaw method and the large variability observed among studies with regard to all retained student educational outcomes, with the exception of social self-esteem, for which only three studies found positive effects of the Jigsaw method (Blaney et al., 1977; Lazarowitz et al., 1994; Walker and Crogan, 1998). More precisely, concerning student achievement, the mean effect observed in our meta-analysis was positive and large but exhibited strongly significant heterogeneity. This heterogeneity in the meta-analysis occurred due to the variation in results among the included studies. Indeed, as explained in the introduction, studies conducted by reference to small samples tend to report unusually large effects and thus bias meta-analytic reviews (Kraft, 2020). Moreover, Funder and Ozer (2019) explained that situations in which small-sample studies report unusually large effect sizes may be a sign that the overall reliability is not trustworthy. Cheung and Slavin (2016) confirmed this claim. In their study, these authors showed that smaller-sample studies ($n < 250$) reported twice the ESs of larger-sample studies ($n \geq 250$). Among the 17 studies reporting a large ES regarding achievement outcomes, the 16 studies from Turkey lack transparency (Stanczak, 2020), particular those that were conducted at the university. Some studies provided no information regarding the composition and selection of students included in the control and experimental groups. Nevertheless, Kyndt et al. (2013) explained that cooperative learning has stronger effects in "Eastern" societies, which are more collectivist, than in "Western" societies, which are more individualistic (Kitayama et al., 1997; Oyserman et al., 2002), and that this difference was statistically significant ($\delta = 0.38$, 95% CI [0.25; 0.53]).

Concerning the motivation outcome, the results of the systematic review and the meta-analysis were ambivalent with regard to the possibilities of positive, non-significant or negative effects, indicating an overall non-significant ES and significant heterogeneity among studies with regard to both qualitative and quantitative analyses. As motivation is an antecedent of achievement, this result is consistent with the research on achievement that was previously discussed and provides additional evidence suggesting doubt regarding studies with small samples and very large positive ESs in terms of achievement. The students' social relations and academic self-esteem outcomes exhibit the same trend. From a qualitative perspective, the results regarding social relations are divided into two categories: positive results and non-significant or negative results. This result is particularly relevant since the Jigsaw method was initially created to enhance the social relations among students and to enable them to overcome prejudice between ethnic groups (Aronson et al., 1978). Moreover, the meta-analysis conducted by Johnson et al. (2007) showed that cooperative learning promotes social relations more effectively ($ES = 0.68$) than working alone ($ES = 0.55$). We develop the reasons for this unique characteristic of the Jigsaw method later in this discussion. Concerning social self-esteem, the results were predominantly positive. These results are very different from those concerning outcomes related to social relations. However, the studies conducted to investigate these two outcomes were not the same, and differences in the results concerning these theoretically associated variables can be explained by variability among studies.

More precisely, regarding this crucial point, even if a great deal of variability among studies is observed for nearly all types of outcomes, consistency is observed within studies that measure different educational outcomes simultaneously. For example, the ESs reported by Berger and Hänze (2009) with regard to achievement and motivation are consistent and in line with the theoretical link between those variables. Some studies have also presented consistent results regarding motivation and social relations (Hänze and Berger, 2007; Berger and Hänze, 2009; Roseth et al., 2019) according to the role of affiliative need completion in motivation (Deci and Ryan, 2000). This variability among studies and consistency within studies outlines the importance of contextual factors during the implementation of the Jigsaw method: the same Jigsaw structure can have positive or negative influences on educational outcomes depending on the context.

4.2. Factors influencing the effects of the Jigsaw method on educational outcomes

For different outcomes, the sample size seems to be a factor that influences the effects of the Jigsaw method. The discipline, the age of the students and the duration of implementation do not appear to be factors that influence the effects of the Jigsaw method on students. Finally, the content taught and the students' diversity are factors that influence the effects of the Jigsaw method.

4.2.1. Sample size and the effect of the Jigsaw method

The results showed that ESs are influenced by the sample size pertaining to different outcomes: achievement, motivation and academic self-esteem. More precisely, the larger the ES is, the smaller the sample size pertaining to achievement outcomes in the meta-analysis. The positive large mean effect size appears to be driven by studies featuring underpowered small sample sizes and very high effect sizes. Studies on other educational outcomes are insufficient to support a similar analysis. However, we consistently observed that the mean sample size of studies that found that the Jigsaw method has a negative effect on motivation was higher than that of the studies that found a positive influence. For social relations and student academic self-esteem, studies reporting non-significant results had larger samples than those reporting positive significant effects. In fact, in the review, 60% of studies were underpowered, i.e., they featured a sample size <102 (Maxwell, 2004; Stanczak, 2020). Moreover, these underpowered studies often reported a large or very large positive influence of the Jigsaw effect regardless of the outcomes. Finally, the observations made here regarding the Jigsaw method accurately represent the challenges posed by the replication crisis (Cheung and Slavin, 2016).

4.2.2. Duration of implementation

In this review, the duration of the implementation did not appear to be a factor influencing the effects of the Jigsaw method

on students. This factor was not relevant in the explanation of the heterogeneity observed in the results regarding student achievement. This result corroborated of the conclusions of the meta-analysis conducted by Stanczak (2020) regarding the effects of the Jigsaw method on student achievement, which showed that the efficacy of short-duration Jigsaw methods was not significantly different from that of longer-duration Jigsaw methods. This finding is consistent with our results concerning social relations and student academic self-esteem. This observation contradicts Aronson and Patnoe's (2011) assertion that cooperation in a Jigsaw context takes time to develop before gains in learning are observed (Stanczak, 2020). An implementation that features a duration longer than 9 h may lead to fatigue, boredom and a decrease in motivation, thus reducing learning gains. Indeed, students appreciate the changes. Similarly, Lentillon-Kaestner and Patelli (2017) showed that students perceived higher pleasure when the grouping forms changed regularly during a physical education sequence. The results reported by Cochon Drouet et al. (2022) are in line with Aronson's claim. Indeed, this study showed that the Jigsaw effects on motivation and moderate to vigorous physical activity increased over time in the context of physical education (between lessons 3 to 6) regardless of whether those effects were positive or negative. The impact of the duration of implementation remains unclear and requires further investigation.

4.2.3. The type of content taught and student diversity

In this review, discipline did not appear to be a factor that could influence the effects of the Jigsaw method on students. Among the studies on achievement included in this meta-analysis, 78.38% focused on scientific disciplines, but no significant difference was observed between ESs between studies conducted in the context of a scientific discipline and those conducted in the context of other disciplines. The meta-analysis conducted by Stanczak (2020) on the effects of the Jigsaw method on achievement showed similar results. However, our review revealed that the effects of the Jigsaw method could vary with the content taught (Hänze and Berger, 2007; Berger and Hänze, 2009; Theobald et al., 2017; Cochon Drouet et al., 2022). For example, the results reported by Cochon Drouet et al. (2022) with regard to physical education showed that the effect of the Jigsaw method on student motivation can be positive or negative depending on the type of sport taught during the implementation process. By focusing on this question, Berger and Hänze (2015) highlighted the difficulty of teaching pupils some subtopics in physics using the Jigsaw method. Complex topics result in a high intrinsic cognitive load and hinder the quality of expert instruction and thus partner learning. The difficulty of teaching impacts student learning and achievement. This factor also makes it more difficult to establish positive interdependence and can undermine social relations. In summary, even if the nature of the discipline does not influence the effect of the Jigsaw method significantly, the type of content taught does. Further studies should take this point into account. However, such a conclusion highlights the important effect of context and the importance of the content taught using the Jigsaw method, which seems to influence the outcomes of implementation and could explain the observed variability in the Jigsaw effect across studies.

Consistent with these observations regarding the complexity of the content that students must learn and then teach, student diversity (e.g., level of ability, self-concept and sex) appeared to influence the Jigsaw effect on achievement, social relations, and academic self-esteem (Hänze and Berger, 2007; O'Leary and Griggs, 2010; Berger and Hänze, 2015; O'Leary et al., 2015, 2019). In fact, very often, the lower students' levels are, the more difficulties they face, especially in social relations (O'Leary et al., 2015, 2019). Thus, the fit between the complexity of the content to be taught and student ability appears to be important for avoiding problems when using the Jigsaw method and preventing negative consequences on students' achievement and relationships (O'Leary et al., 2015, 2019). When the complexity of the content taught fits with students' resources, the Jigsaw method can be more beneficial for students with low resources. For example, the study conducted by Vives (2021) showed that the Jigsaw method had benefits in terms of academic performance only for students with low self-esteem and low working memory capacity. Teachers must be specifically trained in these different elements to include all students when implementing the Jigsaw method.

4.3. Ways to improve the implementation of the Jigsaw method

The results of this review highlighted factors and conditions that enable the Jigsaw method to "work" to achieve positive effects in terms of student achievement, motivation, social relations and self-esteem. Roseth et al. (2019) emphasized the fact that the Jigsaw method is a structure that generates various types of relationships among individuals. The phases of the expert group and coteaching appear to be particularly sensible with regard to the implementation of the Jigsaw method and could be sources of heterogeneity among studies (Roseth et al., 2019).

4.3.1. The expert groups

As explained by Roseth et al. (2019), the expert phase can lead to individualistic behaviors and therefore a loss of cohesion that is unfavorable to group dynamics. Problems of status within a class can also emerge, as it is difficult for a low-ability student to master the proposed content and attain credibility as an expert, leading to problems in the expert phase that could explain the variability in the effect of the Jigsaw method between studies. To overcome this issue, Roseth et al. (2019) suggested breaking down the stages of the Jigsaw method to identify the processes when students are involved in expert or Jigsaw groups. Ensuring that students exhibit interdependence with regard to resources should be a prerequisite. The time spent in the expert group could be lengthened by a phase of preparation that can allow students to reflect on and practice how they might teach the material prior to teaching their peers in their home group; this reflection could be based on some explicit prompts such as "defend your answer", "put yourself in your friend's shoes" or "probe your groupmates for justification" (Theobald et al., 2017). Teachers can also provide specific assistance

and verify that low-achieving students are mastering the skills that they will need to teach their classmates in the coteaching phase, a point of which teachers should be made aware during Jigsaw training.

4.3.2. The coteaching phase

The coteaching step is also a phase that can lead to group problems because students must understand the content in a limited amount of time and find a way to teach it in a manner that other students can understand. The Jigsaw method is very demanding for students. Some studies in the present review highlighted the problems of conflicts associated with the coteaching step of the Jigsaw method (O'Leary and Griggs, 2010; O'Leary et al., 2015; Aydin and Biyikli, 2017). While group work can be extremely fruitful, it can also be ineffective (Slavin, 2011).

Problems that emerge during the coteaching step can lead to a negative interdependence between students and even a competence threat (Buchs et al., 2018) if the expert of the group does not play his or her role. Indeed, the informational dependence that emerges in this phase of the Jigsaw method may be problematic for learning if the information is of poor quality (Buchs et al., 2004, 2010, 2018). This kind of competence threat is likely to reduce learning (Buchs et al., 2010; Buchs and Butera, 2015) and motivation as well as to result in less-constructive interactions with others (Buchs et al., 2004, 2018; Buchs and Butera, 2009).

To complete this phase successfully, the main content chosen for group work should be divided into subcategories to ensure that all group members have equal responsibilities (Karacop and Doymus, 2013; O'Leary et al., 2015). Indeed, as is the aim of the logic of the Jigsaw method, the resources must be interdependent and complementary. "The positive relationship between a partner's competence and students' learning is found only when students work on complementary information" (Buchs et al., 2018, p. 2).

This coteaching phase must therefore be made easier or spread out over time and supervised by the teachers in greater depth. This task can include training students to teach their peers over the course of several lessons before implementing the Jigsaw method. "Ovens et al. (2012) recommend that pupils are given additional time to consider how they might teach material to their peers" (O'Leary et al., 2015, p. 189). Finally, this coteaching phase can be effective only if all pupils have satisfactorily succeeded in the expert step of the Jigsaw method.

4.3.3. Time spent training teachers

The variability obtained highlights the importance of context; the best way to control all these contextual effects is therefore for teachers to receive sufficient training to anticipate and manage the problems associated with the Jigsaw method (Drouet et al., 2020). This development entails the appropriation of these principles and their application to the teaching content. The studies included in this review remain evasive on this point, which is crucial. Bratt (2008) offered 2 days of training. Several studies have followed these recommendations (Roseth et al., 2019; Cochon Drouet et al., 2022, 2023), and future implementations would benefit from following them. The time spent training teachers could alter the effects of the Jigsaw method. Cochon Drouet et al. (2023) showed that Jigsaw training for teachers helps facilitate professional development and encourages changes in practice that are beneficial to all students, especially those facing difficulties.

5. Limitations and directions for future research

A first limitation of this review is that some studies featuring many dependent variables appear in several variable analyses (e.g., achievement, motivation, social relations) and are weighed heavily in our results, especially in our meta-analyses. Moreover, meta-analysis could not always be performed due to the lack of statistical data, the lack of studies or differences in the constructs measured regarding the same theme. Finally, some meta-analyses were conducted by reference to only a few studies. Even if meta-analyses are particularly transparent and more likely to be valid than other synthesizing techniques (Valentine et al., 2010), ES estimates drawn from small samples are more sensitive to sampling error, which affects their precision and increases the likelihood of reporting extreme estimates (Kühberger et al., 2014). Therefore, these meta-analyses must be interpreted cautiously, although they complement our systematic review.

Second, in our systematic review, we followed the PRIMA guidelines (Page et al., 2021). However, we could have followed the guidelines proposed by Risko et al. (2008) and Torgerson et al. (2005), as Scott et al. (2018) to verify the methodological quality of their studies in a systematic review in light of the seven indicators included in the Methodological Quality Questionnaire.

Third, the findings of the review should be interpreted in the context of potential publication bias (Sutton et al., 2000; Thornton and Lee, 2000). Publication bias refers to the tendency of researchers and journal editors not to publish studies that fail to find significant effects. This paper is based only on published studies, and this limitation must be considered when interpreting our results. Therefore, the inconsistency regarding the effects of the Jigsaw method on student learning, social relations and self-esteem outcomes observed in this context should be even more frequent than explained in this meta-analysis. Moreover, the mean ES measured here would certainly be even smaller if studies that were not published were considered. Future research should focus on an appropriate sample size (> 176 participants for a 95% chance of detecting the mean effect) and should further test potential moderators of the effect of the Jigsaw method. According to our observations in this review, prospects for research with large samples are increasing, particularly with regard to clearly identifying the moderating effects of student diversity and duration of implementation. It would also be interesting to analyze the problematic phases of the Jigsaw method in further detail and to test this method in the context of the adaptations of the elements highlighted previously.

6. Conclusion

The main result of our systematic review and meta-analyses pertains to the inconsistency of the effects of the Jigsaw method on students' educational outcomes, despite the fact that 69 studies

have investigated this topic. This inconsistency corresponds to a strong variability and even ambivalence among these studies, revealing that the Jigsaw method is very dependent on contextual influences. The same pedagogical structure, which is quite rigid and seemingly easy to implement, can have diverse effects depending on contextual elements. Rather than asking for and simply reproducing an invariant structure independent of the context, teachers must think carefully about possible interactions between their teaching contexts and this structure; they should also complete sufficient relevant training. Moreover, our qualitative review identified some contextual factors that modify the Jigsaw effect (i.e., the content taught, student diversity). These results can help teachers and teacher-trainers focus on the decisive element when improving the effects of the Jigsaw method.

From a methodological perspective, these results highlight the complementarity of meta-analytic and systematic qualitative review approaches with regard to investigating the Jigsaw effect. Significant meta-analytic results help confirm global results. A qualitative review helps improve our understanding of such global results. For example, if our meta-analyses clearly indicated the significant variability of the Jigsaw effect regardless of the outcomes considered (i.e., achievement, motivation, social relations and self-esteem), the quantitative test of a priori factors that could explain this variability remained inconclusive, with the exception of those pertaining to sample size. Our qualitative examination of the literature helped us identify the factors that can explain this variability more accurately. This approach helped us progress from two independent questions about the impacts of diversity and the discipline taught on the Jigsaw effect to one more heuristic focus on the fit between the complexity of the content taught and the diversity of students' resources.

Finally, in light of the significant heterogeneity of results, the very large effect size observed in some studies and the significant influence of sample sizes on Jigsaw effects, the literature on the Jigsaw method appropriately represents the challenges posed by the replication crisis (Cheung and Slavin, 2016). This result highlights the need for higher-quality studies, preregistrations and careful research questions. Beyond improving "Jigsaw implementation" *per se*, such a perspective is necessary to overcome the difficulties posed by the replication crisis. Researchers must also focus on and investigate the processes that occur during the implementation of a pedagogical structure in other contexts, especially those pertaining to the use of the Jigsaw method during the expert group and coteaching phases, which appeared in our review as potentially decisive phases with regard to the Jigsaw method's effect. Cooperative methods can promote inclusive education only if access to this cooperative learning is guaranteed to all; this goal can be achieved through thoughtful teacher training (Drouet et al., 2020).

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

OD organized the database, performed the statistical analysis, wrote the first draft, and sections of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1216437/full#supplementary-material

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The impact of COVID-19 on students' anxiety and its clarification: a systematic review

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Introduction: Since the emergence of COVID-19 in 2019, every country in the world has been affected to varying degrees. Long-term psychological pressure and anxiety will inevitably damage the physical and mental health of students. This study aimed to examine the effects of the COVID-19 pandemic on students who experienced stress and anxiety and to clarify which intervention was more effective.

Methods: A comprehensive literature search was conducted between January 2020 and December 2022 using online databases such as PubMed, Web of Science, Scopus, and Google Scholar by using the following keywords in combination: "COVID-19," "stress," "anxiety," "depression," and "intervention." The retrieved literature was screened and reviewed.

Results: A total of 2,924 articles were retrieved using subject and keyword searches. After screening through the titles and abstracts, 18 related studies were retained. Their review revealed that: (1) most studies did not use medication to control stress and anxiety; (2) the standard methods used to reduce stress and anxiety were religion, psychological counseling, learning more about COVID-19 through the media, online mindfulness courses, improving sleep quality, and physical exercise; (3) the most effective interventions were physical activity and raising awareness about COVID-19 through the media and online mindfulness programs. However, some studies show that physical activity cannot directly relieve psychological stress and anxiety.

Conclusion: Limited interventions are effective, but learning more about COVID-19 and using active coping strategies may help reduce stress and anxiety. The implications of COVID-19 are also discussed.

KEYWORDS

COVID-19, stress, anxiety, depression, coping

Introduction

Since the COVID-19 outbreak in December 2019, the virus has maintained exceptionally high transmission rates, and countries around the world have been greatly affected. According to the World Health Organization's (WHO) COVID-19 Dashboard (2022), the cumulative number of confirmed cases worldwide exceeded 600 million as of September of that same year.

Due to the continuous mutation of COVID-19, the number of confirmed and suspected cases remains high, and people are forced to live with the virus for a long time, which creates a lot of psychological anxiety and stress and seriously affects the normal lives of people around the world (Peteet, 2020).

Although the severity of COVID-19 has decreased over time and the current level of prevention and control of the epidemic in the world has also decreased, COVID-19 has not been eliminated and still poses a threat to humanity (World Health Organization, 2023a,b). As noted in the WHO's most recent official COVID-19 policy brief, the pandemic appears to be in transition after more than 3 years. However, the COVID-19 pandemic remains an acute global emergency, with the risk of the emergence of new variants and future surges remaining real (World Health Organization, 2023a,b).

According to data released by the WHO COVID-19 Dashboard of 2023, as of 7 June, there had been 6,941,095 deaths and 767,750,853 confirmed cases of COVID-19 worldwide. Furthermore, according to the WHO Coronavirus (COVID-19) Dashboard, the COVID-19 outbreak has shown unpredictable volatility in terms of weekly changes in the number of confirmed cases worldwide every week since the outbreak began, with the most recent large-scale outbreak appearing in December 2022. In just 4 weeks, the outbreak increased the number of cases worldwide by 97,976,070 (World Health Organization, 2022a,b).

It is clear from these findings that COVID-19 remains a threat to humans. To deal with the possibility of a recurrence of the virus pandemic in the future, we need to understand the various effects of COVID-19 on people's psychological states and develop effective responses.

Many psychological effects have been examined during the virus outbreak at the personal, national, and even international levels (Fawaz et al., 2023). On a personal level, people are more likely to experience fear of getting sick or dying, feeling helpless, and being stereotyped by others (Salari et al., 2020). Mental health can contribute to serious psychological crises. In fact, COVID-19 affected the mental health of medical workers and also the general population (Chakraborty and Chatterjee, 2020; Khatatbeh et al., 2021; Chen et al., 2022). For healthcare workers, the sudden increase in workload has led to a surge in work stress (Tabur et al., 2022), and the risk of infection at any time has had a negative impact on their psychology (Wu et al., 2020). Witnessing the suffering and death of patients can also have a profound impact on their mental health (Mosheva et al., 2021). In addition, the uncertainty and rapid change of the COVID-19 pandemic mean that they must constantly adapt to new job requirements, changing work processes, and protective measures, and the stress caused by this uncertainty may also increase their anxiety levels (Deliktas Demirci et al., 2021). For the general population, COVID-19 may increase health anxiety and panic, and concern over the risk of infection may cause people to over-interpret common physiological responses (Marra et al., 2020). Reduced human interaction due to fear of infection can also lead to depression and anxiety (Haider et al., 2020). In addition, financial stress and work stress also contribute to a decline in mental health (Halliburton et al., 2021). The WHO has also reported that the COVID-19 pandemic triggered a 25% increase in the prevalence of anxiety and depression worldwide (World Health Organization, 2022a,b).

University students face certain peculiarities compared to working adults. They will show emotional instability under pressure. Their psychological characteristics differ from those of the general public or even ordinary young people, and they are high-risk groups for psychological problems (Kontoangelos et al., 2020; Fusar-Poli et al., 2021). Under the influence of an external environment, psychological problems such as anxiety, depression, and post-traumatic stress disorder (PTSD) are more likely to occur (Bruffaerts et al., 2018). They face greater academic pressures and challenges, and their worries about academic performance and work prospects are more intense (Son et al., 2020). Compared with adults, they are more susceptible to the adverse effects of distance learning due to their lack of experience in time management (Singh et al., 2020). Most of the students social and interpersonal relationships exist on campus, and COVID-19 isolation has cut off most of their social ties, increased their loneliness, and led to a decline in mental health. This will last for a period of time and will not disappear quickly with the end of the epidemic (Garris and Fleck, 2022). In addition, in terms of independence and social identity, COVID-19 can also have a negative impact on independence and social identity and last for a long time (Sharaievska et al., 2022).

How to deal with the psychological problems faced by university students due to the COVID-19 epidemic has become a crucial research topic at this stage (González-Sanguino et al., 2020). The purpose of this article is to review articles on the different interventions applied to reduce the psychological impact of COVID-19 and to discuss solutions among students. First of all, such research has a long-term and global impact. A large number of studies have confirmed that COVID-19 has broad psychological effects on university students worldwide. Understanding the long-term impact of COVID-19 on the mental health of university students and adaptation strategies can provide experience and lessons for similar emergencies in the future (De Girolamo et al., 2020). Second, by evaluating the effectiveness of different mental health intervention strategies, we can determine which interventions have a positive impact on alleviating mental distress and improving the mental health of university students, which can help guide mental health professionals and policymakers in choosing appropriate intervention strategies to better support their mental health. In addition, by focusing on the mental health of college students, it is helpful to increase public awareness and attention to the mental health of college students and promote overall societal attention to mental health (Hunt and Eisenberg, 2010). There are three problems to be solved in this study: (a) To summarize the effects of COVID-19 on the psychological status of students; (b) To compare the impact of different interventions; (c) To discuss the findings and recommendations for future research in this area.

Methodology

Search strategy

A literature search was conducted using major computerized databases (e.g., PubMed, Web of Science, Scopus, and Google Scholar) and library holdings for English-language peer-reviewed articles and was reviewed by two additional co-authors. When searching the database, the selected studies were those published from the beginning of January 2020 to December 2022 (because the outbreak of COVID-19 began in December 2019, this study only looked at studies over a three-year period, from January 2020 to December 2022, when searching the databases). The keywords used in this review were

"COVID-19," "anxiety," "stress," "student," and "intervention." A manual search of the reference lists of relevant studies found in the computerized search was also performed.

Inclusion and exclusion criteria

The inclusion of articles followed a three-phase approach (Figure 1) using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2015). In the first phase, a total of 3,101 records were initially obtained through an extensive database search. A total of 178 duplicates were identified and removed in this phase. In the second phase, the titles of 2,923 records were screened, and the following records were removed: (a) those that did not refer to the terms "COVID-19" or "anxiety" or "stress" or "student"; (b) all types of literature reviews and guidelines; and (c) those that were not written in English. This process resulted in the removal of 2,496 records. In the third phase, the abstracts or full texts of the remaining 427 records were examined. Records that met the inclusion criteria were studies with an interventional design. Only 18 studies met the inclusion criteria, and the authors and co-authors assessed the quality of these 18 studies and found them to be of good quality for a systematic review and were therefore included in this review.

Categorization of studies

Results

The impact of COVID-19 on the psychological status of students

Research on the psychological status of medical college students

Early in the COVID-19 outbreak, the Association of American Medical Colleges recommended pausing all student clinical rotations while the in-person curriculum moved to virtual modalities. Medical students also reported higher levels of anxiety, stress, and exhaustion, with female students experiencing this more than male students (Mittal et al., 2021). At the College of Medicine of King Saud University, Riyad, Saudi Arabia, a total of 234 medical students found

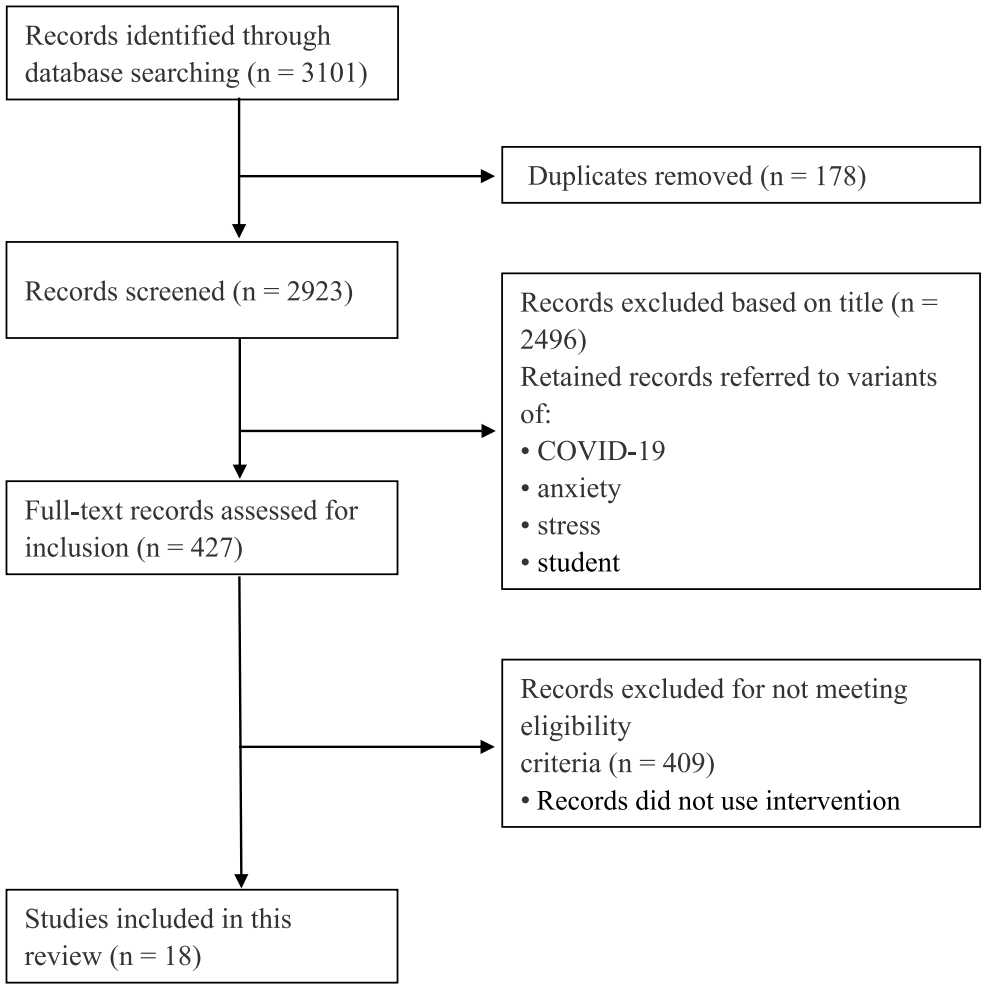

FIGURE 1
Flow diagram from identification to inclusion of studies.

that quarantine caused them to feel emotionally detached from family, colleagues, and friends and reduced their overall work performance and study time. The findings also showed that a quarter of the medical students who participated in the study felt disheartened during the quarantine period (Meo et al., 2020). In a study of 217 undergraduate medical students at a medical college in Chennai, India, there was a significant increase in both the prevalence and level of anxiety and stress (Saraswathi et al., 2020). In an Indonesian study of 1,027 medical students, 44.6% were found to be stressed, 47.8% had anxiety, and 18.6% had depression (Natalia and Syakurah, 2021).

Research on the mental state of the general student population

The psychological state of the general student population has also been a focus of researchers during the COVID-19 pandemic. A study of Bangladesh university students aged 18 to 29 years (59.5% men; mean age 21.4 ± 2 years) revealed that the estimated prevalence of depression, anxiety, and stress was 76.1, 71.5, and 70.1% for at least mild symptoms, 62.9, 63.6, and 58.6% for at least moderate symptoms, 35.2, 40.3, and 37.7% for at least severe symptoms, and 19.7, 27.5, and 16.5% for at least very severe symptoms, respectively. These data are significantly higher than before the COVID-19 pandemic (Islam et al., 2020). In a cross-sectional survey of different populations in Jordan, anxiety was highest among college students during the COVID-19 pandemic, at 21.5%, and college students were found to be at higher risk for depression (Naser et al., 2020). In another study of 69,054 high school students in France, the prevalence of suicidal thoughts, severe distress, high levels of perceived stress, severe depression, and high levels of anxiety were 11.4% (7,891 students), 22.4% (15,463 students), 24.7% (17,093 students), 16.1% (11,133 students), and 27.5% (18,970 students), respectively (Wathelet et al., 2020). Similarly, a study of 1,224 high school students in Brazil reported that the majority of undergraduates presented with symptoms of depression (60.5%), anxiety (52.5%), and stress (57.5%). These data indicated a high prevalence of symptoms of depression, anxiety, and stress in students (Lopes and Nihei, 2021). In summary, numerous studies have reported on the mental health of students during the COVID-19 pandemic, and the results show that the pandemic has caused varying degrees of mental health problems among students, indicating that the presence of COVID-19 has indeed increased psychological stress and anxiety among the student population around the world.

The effects of the different interventions

Since the outbreak of COVID-19, some research studies have tried various ways to reduce people's stress and anxiety. By collating the existing literature, the primary approaches for reducing stress and anxiety include religious practice, psychological counseling, learning more about COVID-19 through the media, mindfulness online programs, increasing the quality of sleep, and physical activity. Some of the most effective interventions include watching brief Dialectical Behavior Therapy (DBT) skill videos, regular web-based physical education to increase students' understanding of COVID-19 through social media, and about 2,500 METs of physical activity per week (Deng et al., 2020; Zhang et al., 2020; Kheirallah et al., 2021; Rizvi et al., 2022). Although the effect of some intervention methods is not significant, they play a role as effective mediating factors. These methods include: middle- and long-distance running, boosting satisfaction with distance learning, strengthening psychological resilience, enhancing social support, improving sleep quality, reducing incorrect smartphone use, and catalyzing academic satisfaction (Franzen et al., 2021; Li and Peng, 2021; Lin et al., 2021; Liu et al., 2021; Gabrovec et al., 2022; Song et al., 2022). The intervention had positive results, and effective alternatives to conventional psychotherapy included behavioral therapy and online mindfulness programs (Liang et al., 2021; Simonsson et al., 2021). Some studies have suggested that positive approach coping strategies for COVID-19 are better than negative avoidance coping strategies in improving stress and anxiety (Banstola et al., 2021; Chan et al., 2022). A review of the literature identified 18 articles related to COVID-19, anxiety, stress, and the effects of different interventions (all studies are summarized in Table 1).

Of the 18 articles included, four showed significant effects on students' stress and anxiety after the intervention (Deng et al., 2020; Zhang et al., 2020; Kheirallah et al., 2021; Rizvi et al., 2022). In a randomized clinical trial, 153 undergraduate students from a large public university in the United States completed three phases of pre-assessment, intervention, and post-assessment over six weeks during the COVID-19 pandemic. During the intervention, participants were randomized to receive animated videos of DBT skills for 14 consecutive days. All participants received ecological momentary assessments of mood, emotion management self-efficacy, and emotional tolerance four times a day. The study found that negative emotions significantly decreased and positive emotions significantly increased before and after watching the videos. There was a significant interaction between time and conditions in the development of emotional tolerance. Compared to the first two weeks, participants in the control group rated their emotions as more intolerable in the third and fourth weeks, whereas participants in the intervention group did not rate their emotions as more intolerable (Rizvi et al., 2022). This proved that DBT techniques can help college students avoid a decline in mental health and that this simple, highly scalable intervention could expand the scope of available mental health treatment.

In a Chinese study, 1,607 college students in Wuhan were asked about their mental health, exercise-related lifestyle, and other issues. The Depression, Anxiety, and Stress Scale (DASS-21) was used to evaluate their mental health. The results showed that lower DASS-21 scores were significantly associated with regular exercise, maintaining exercise habits during the COVID-19 pandemic, exercising more than 1–2 times per week, exercising for ≥1 h, and taking ≥2,000 steps (Deng et al., 2020). This proved that mental status is significantly related to regular exercise and adequate exercise time. In a similar article, a longitudinal survey of 66 college students during the peak of the COVID-19 epidemic in China showed that COVID-19 had a direct negative impact on general sleep quality. In contrast, COVID-19 mediated general negative emotions, stress, anxiety, and sleep quality. In addition, physical activity directly alleviated general negative emotions, with the greatest effect when physical activity was approximately 2,500 METs per week (Zhang et al., 2020).

In a study of all medical students in Jordan, participants self-reported increased levels of negative emotions, such as anxiety, and decreased levels of positive emotions. Nearly half of the participants reported that social media was the primary source of COVID-19 information, with a significant reduction in emotional distress after long-term use of social media for COVID-19 information (Kheirallah

TABLE 1 Literature on different interventions evaluated in this study.

Study	Participants	Instrumentation/procedure	Main outcomes
Chan et al. (2022)	A total of 202 university students in Hong Kong, 70.8% of whom were medical students	(1) Basic information about stress and psychological disorders, (2) The Ryff Scale (18 items), (3) Brief list of coping skills.	The Ryff score of the students who used proximity coping strategies was higher than that of the students who used avoidance coping strategies. Proximity coping strategies are more effective in managing stress.
Banstola et al. (2021)	A total of 144 students at the Manipal College of Medical Sciences in Pokhara, Nepal	Clinical and COVID-19 related questions; Beck Anxiety Inventory; Brief-COPE questionnaire to assess coping strategies.	The most common coping strategy was religion; adopting adaptive coping strategies helps reduce mental health problems.
Rizvi et al. (2022)	A total of 153 U.S. undergraduates. They were randomly divided into an intervention group ($n = 99$) and a control group ($n = 54$)	(1) Demographic survey, (2) Difficulties in Emotion Regulation Scale-18, (3) Ecological Momentary Assessment (EMA), (4) Intervention via brief Dialectical Behavior Therapy (DBT) skill videos.	Four assessments per day. After the intervention, negative emotions were significantly reduced, while positive emotions were significantly increased. Increased emotional tolerance. DBT technology videos can help college students avoid mental health deterioration.
Lin et al. (2021)	A total of 869 middle- and long-distance running students at a university in Guangzhou, China	(1) Civilian version of the PTSD questionnaire (PCL-C), (2) Self-rating Anxiety Scale (SAS), (3) Civilian version of the PTSD Questionnaire (PCL-C). (4) Self-rating Depression Scale (SDS).	Middle and long-distance running exercise has no direct effect on students' PTSD, anxiety, and depression, but it does have an effect on students' body scores. At the same time, body score has an effect on students' PTSD, anxiety, and depression. Furthermore, it played an interconnected role in promoting the mental health of students during the epidemic.
Deng et al. (2020)	A total of 1,607 college students in Wuhan, China, including 1,041 men and 566 women	Mental health status was assessed using the Depression, Anxiety, and Stress Scale (DASS-21).	Participants' mean scores on the DASS-21 subscale after the intervention were significantly lower than in the previous study. Lower DASS-21 scores were significantly associated with an active exercise-related lifestyle.
Gabrovec et al. (2022)	A total of 4,661 Slovenian post-secondary students, with 72.5% women, 26.7% men, and 0.8% identifying as another gender.	(1) Patient Health Questionnaire Generalized Anxiety Disorder questionnaire, (2) Perceived Stress Scale-4 10-item Connor–Davidson Resilience Scale, (3) Satisfaction with Online Study Scale (SAT-5)-5	Distance learning satisfaction and resilience can be used as protective factors to influence students' mental health. Increasing distance learning satisfaction and enhancing psychological resilience can indirectly reduce stress, anxiety, and depression. Female students need greater mental resilience to combat negative mental states.
Jain et al. (2021)	A total of 699 Indian university students, with 239 women and 460 men.	Mental health status was determined using the Coronavirus Anxiety Screening (CAS), GHQ-12, GAD-7, and PHQ-9 scales.	The prevalence of self-medication was found to be very low as compared to other studies, and a growing tendency towards homemade remedies was noted. This inclination is expected to come out as endorsements and guidelines of homemade remedies going around these days.
Li and Peng (2021)	A total of 2,640 college students in China	(1) Sociodemographic characteristics questionnaire (SCQ), (2) Coping strategy questionnaire (CSQ), (3) Social support questionnaire (SSQ), (4) Self-rating anxiety scale (SAS).	Anxiety was negatively associated with coping and social support. Social support played as a mediator in the relationships between cognitive coping, behavioral coping, and anxiety, with family support and counselor support exerting a stronger negative influence against anxiety than subjective support.
Liang et al. (2021)	A total of 52 students from Anhui Medical University in China, divided into two groups of 26 respondents, with 10 men and 16 women.	(1) PHQ-9 scale, (2) GAD-7 scale, (3) Somatic Self-rating Scale (SSS), (4) Perceived Stress Scale (PSS-10).	Dialectical behavior therapy (DBT) was more effective than traditional psychological intervention. DBT could effectively alleviate the depression and anxiety of medical students during the normalization of epidemic prevention and control.
Liu et al. (2021)	A total of 29,663 medical students in China, with 10,185 men (34.3%) and 19,478 women (65.7%)	(1) Perceived Stress Scale 14 (PSS-14), (2) Insomnia Severity Index (ISI), (3) Patient Health Questionnaire 9 (PHQ-9).	Perceived stress was associated with depression, and insomnia played a mediating role when included in the association. Interventions or strategies that improve insomnia may help reduce the severity of depression both directly and indirectly in medical students.
Seffrin et al. (2022)	A total of 40 students at the Federal University of São Paulo, with 10 men and 30 women	(1) Patient Health Questionnaire 9 (PHQ-9), (2) General Anxiety Disorder-7 (GAD-7).	Returning to online classes may mitigate the high frequency of depression symptoms observed during the social distancing measures adopted during the outbreak of COVID-19.

(Continued)

TABLE 1 (Continued)

Study	Participants	Instrumentation/procedure	Main outcomes
Simegn et al. (2021)	A total of 423 Ethiopian university students, with 272 men and 151 women	Depression, Anxiety, and Stress Scale-21	Mental health could be improved by the provision of adequate and accurate information and by increasing the self-efficacy of students.
Simonsson et al. (2021)	A total of 177 students from the University of Oxford	Outcome Measurement Information System (PROMIS) anxiety and depression scales	Participants randomized to mindfulness programs showed a greater reduction in anxiety after 8 weeks of intervention.
Song et al. (2022)	A total of 666 medical college students in Shenyang, China, with 262 men and 404 women	(1) GAD-7, (2) Smartphone addiction scale–short version (SAS-SV), (3) PROMIS Sleep Disturbance scale (short form)	Smartphone addiction may increase the likelihood of experiencing sleep disturbances, which in turn may lead to elevated levels of anxiety.
Franzen et al. (2021)	A total of 433 students from the University of Geneva with 76 men and 357 women.	(1) Hospital Anxiety and Depression Scale (HADS), (2) 14-item Cohen Perceived Stress Scale (PSS), (3) Psychological Well-Being Scale (BEP), (4) Scale of Satisfaction with Studies (SSS).	Compared to COVID-19-related stress, academic satisfaction was a stronger predictor of depression, anxiety, stress, and psychological well-being among students at the end of the academic year.
Yildirim et al. (2021)	A total of 115 Turkish university students, with 23 men and 92 women	Death Anxiety Scale (DAS)	This would be an effective method to provide training to nursing students, in order to change their negative attitudes and increase their awareness of COVID-19-related death anxiety. This training would also improve their coping skills for dealing with death anxiety and reduce the burden of anxiety.
Zhang et al. (2020)	A total of 66 college students in China, with 25 men and 41 women	(1) Short version of the International Physical Activity Questionnaire (IPAQ-S), (2) Pittsburgh Sleep Quality Index (PSQI), (3) DASS-21, (4) Buss-Perry Aggressive Questionnaire (BPAQ).	The COVID-19 death toll has had an indirect impact on general negative emotions, stress, and anxiety, with sleep quality acting as a mediator. Moreover, physical activity directly alleviated general negative emotions, and the maximum mitigation effect occurred when weekly physical activity reached approximately 2,500 METs.

et al., 2021). This was evidence that social media has a potentially positive effect on mitigating negative emotions.

Of the 18 included studies, three suggested that improving sleep quality could indirectly improve stress and anxiety in students during COVID-19 (Zhang et al., 2020; Liu et al., 2021; Song et al., 2022). In a study examining the relationship between perceived stress and depression in medical students during the COVID-19 pandemic and the mediating role of insomnia in this relationship, researchers used the Perceived Stress Scale (PSS), Insomnia Severity Index (ISI), and Patient Health Questionnaire 9 (PHQ-9) to measure perceived stress, insomnia, and depression levels. Results showed that perceived stress was significantly associated with depression. Insomnia mediated the relationship between perceived stress and depression. The indirect effect of insomnia on perceived stress was significant (Liu et al., 2021). This demonstrates that depression in medical students can be effectively reduced by improving sleep quality and relieving perceived stress. In a similar study of 666 medical students in China, anxiety was significantly associated with problematic smartphone use and sleep disturbances during the COVID-19 pandemic. Problematic smartphone use not only directly affected anxiety but also had a significant indirect effect on anxiety through sleep disturbance. Using sleep disturbance as a mediator, a significant reduction in the path coefficient of problematic smartphone use on anxiety was observed. The importance of promoting sleep health to reduce anxiety should be emphasized (Song et al., 2022).

HP Lovecraft, in "Supernatural Horror in Literature" (1927), H.P. Lovecraft wrote: "The oldest and strongest emotion of mankind is fear, and the oldest and strongest kind of fear is fear of the unknown" (Joshi and Schultz, 2001; p. 255). Therefore, among the 18 included studies, five were of the opinion that we should actively face COVID-19 and that increasing its understanding through various means would help reduce students' stress and anxiety (Banstola et al., 2021; Kheirallah et al., 2021; Simegn et al., 2021; Yildirim et al., 2021; Chan et al., 2022).

The study of 202 medical students in Hong Kong about their mental health status, stress coping strategies, and their relationship proved that respondents who adopted an approach strategy had higher Ryff scores than those with avoidant coping strategies, suggesting that approach strategies are more effective in stress management than the more dysfunctional avoidant strategies (Chan et al., 2022). Similarly, Banstola et al. (2021) suggested that adopting adaptive coping strategies helps reduce pandemic-related mental health problems. Kheirallah et al. (2021) suggested that students' use of social media to increase access to COVID-19 information had a significant effect on reducing emotional distress. Simegn et al. (2021) found that the mental health situation can be improved by the provision of adequate and accurate information and by increasing the self-efficacy of students. Yildirim et al. (2021) indicated that this would be an effective method to provide training to nursing students, to change their negative attitudes, increase their awareness of COVID-19-related death anxiety, improve their coping skills for dealing with death anxiety, and reduce the burden of anxiety. Table 2 provides a summary of the studies included in this review. Across all works, data were derived from assessments of 44,014 participants. Of these, 14,790 were men (33.60%), 26,547 were women (60.32%), and 2,677 were undetermined (6.08%). The

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TABLE 2 Summary of this systematic review.

Sample size (*n*)		Gender(*n*)	
<100	3	Men only	0
101–500	7	Women only	1
501–1,000	3	Men and Women	17
1,001–2,000	2	Undetermined	0
2,001–4,000	1	Region(*n*)	
>4,001	2	Americas	2
Participants(*n*)		Asia	11
College student	18	European	4
Medical student	9	Africa	1
Non-medical student	9	Australia	0
Intervention type(*n*)			
Improving understanding			5
Improving sleep quality			3
Physical activity			3
Other			8

number of participants ranged from 40 to 29,663. The studies included 32,973 medical students and 11,041 non-medical students.

The research included in this review covers three years (01/2020–12/2022). The participants in these studies were college students. According to the country distribution of the participants, Asia (11), the Americas (2), Europe (4), Australia (0), and Africa (1). From the perspective of the interventions used, the most common effective interventions were sustained physical exercise at a certain intensity for a period of time, maintaining good sleep quality, improving understanding of COVID-19 through multimedia, and facing COVID-19 with more positive attitudes and behaviors. In addition, regular watching of DBT skill videos may help college students avoid mental health issues.

Discussion

The COVID-19 pandemic has resulted in substantial global mental health challenges, such as increased levels of anxiety and depression symptoms (Brooks et al., 2020; Holmes et al., 2020), along with significant variation in anxiety and depression symptoms among residents of different countries (Ding et al., 2021a,b). In this review, 18 studies on anxiety and stress levels among students during the COVID-19 pandemic were identified, while also listing the effects of different interventions. The 11 studies that did not explicitly report anxiety among participants all reported higher rates of anxiety among participants; in the seven studies where anxiety was explicitly reported, the average anxiety rate was 77.99%. Hence, this shows the high level of anxiety among students due to COVID-19.

Studies have shown that students' anxiety about COVID-19 stems not only from concerns about their health but also from the health of those around them (Al-Kumaim et al., 2021). In addition, academic pressure and employment prospects during this period are also major causes of anxiety for students (Sundarasen et al., 2020). In particular, female, rural, low-income, and academically underperforming students are more likely to suffer from psychological distress (Lee et al., 2021). These key findings are of great concern given that mental health is strongly linked to student well-being, academic performance, and employment rates. During the pandemic, student mental health is in crisis and necessitates increased attention and intervention.

The primary focus of this study was to identify more effective interventions. Four of the 18 included studies reported significant reductions in student stress and anxiety. The selected interventions included: (1) Watching DBT skill videos. The results of this study showed that the simple animated DBT skill videos were easily accepted by most of the participants; the intervention showed promising results in reducing negative emotions at the time and preventing students from experiencing increased distress (i.e., finding their emotions more unbearable) as the semester progressed. This intervention is also very easy to implement (Rizvi et al., 2022). (2) 2,500 METs of physical activity per week. The results of this study showed that the persistence of COVID-19 may reduce people's sleep quality, thereby significantly increasing their negative emotions; maintaining regular exercise can help alleviate this state of mind, and engaging in physical activity (PA) of 2,500 METs per week is the most effective optimal load (Zhang et al., 2020). (3) Extending the use of social media to gain a better understanding of COVID-19 has been shown to reduce students' fear of COVID-19 and improve their negative mental state (Deng et al., 2020; Kheirallah et al., 2021).

Three of the 18 selected studies showed that due to the persistence of COVID-19, students have experienced sleep disturbance or insomnia, and the continuation of this phenomenon will lead to stress and anxiety. Improving sleep quality can indirectly help with these symptoms (Zhang et al., 2020; Liu et al., 2021; Song et al., 2022). In addition, increasing physical activity is not only beneficial in improving stress and anxiety caused by COVID-19, but it also happens to be an effective way to improve sleep quality (Piercy et al., 2018; Zhang et al., 2020). There is now a consensus that appropriately heightened physical activity can help relieve stress and anxiety, promote blood circulation, relax muscles, and improve sleep quality; multi-component exercise has a significant effect on improving people's sleep quality and physical fitness (Yang, 2019; Ai et al., 2022).

By synthesizing the results of previous studies, we have drawn a comprehensive summary that includes effective intervention methods and combined these with the current situation. Therefore, we have been able to clearly identify the most effective intervention measures. At this stage, COVID-19 is no longer an unfamiliar disease. As a result, simply getting more information about COVID-19 through social media no longer seems to be an effective way to reduce the resulting stress and anxiety. Although watching DBT skill videos is considered an effective intervention, due to the relatively small number of similar studies, it is not yet possible to provide sufficiently strong evidence. After a comprehensive comparison, it can be found that appropriate physical activity can not only directly reduce the stress and anxiety caused by COVID-19 but can also indirectly relieve these by improving sleep quality. Therefore, this can be regarded as the most effective means of intervention at this stage. Proper physical exercise can also help improve our body's immune system, increase the speed of antibody production, and improve the ability to resist viral attacks (Atzrodt et al., 2020). Therefore, more research in the future can address the need to improve sleep quality through physical activity to alleviate the perceived stress caused by COVID-19 and effectively reduce students' anxiety.

The main focus of this paper is to examine the effects of various intervention methods applied during the COVID-19 pandemic. However, there are still some limitations. Firstly, many of the included studies in the literature were cross-sectional studies, meaning that a temporal causal relationship between mental health and stress-coping strategies could not be established. The reason for this is that, although there is a large amount of research on psychological problems caused by COVID-19 at this stage, fewer articles can be retrieved with the inclusion of the keywords "student" and "intervention." Therefore, future research should focus more on the impact of COVID-19 on students' mental states and potential solutions. Second, all included studies used self-report methods to assess anxiety and depression scores, and mental health counselors were not asked to evaluate the psychological status of the participants as a form of third-party verification. Although this method simplifies the difficulty of obtaining data on the mental state of subjects, it is highly subjective and may be affected by social desirability bias. However, since all papers considered found a higher rate of anxiety in the study groups, the results are generally reliable. In addition, the participants included in the literature are all college students, so it is impossible to conclude whether the interventions applicable to college students are also applicable to students in other age groups. Similarly, the research subjects included in the literature are mostly medical students. Since these students have medical knowledge and skills, in addition to certain characteristics, it is impossible to conclude whether the interventions applicable to medical students are also applicable to non-medical students.

Conclusion

This study provides a comprehensive look at solutions to student anxiety during COVID-19. By comparing different interventions, we found that appropriate physical activity has unique benefits that not only directly reduce the stress and anxiety caused by COVID-19 but also further alleviate these feelings by improving sleep quality. Currently, the persistence and impact of COVID-19 on daily life present students with unprecedented psychological challenges. Appropriate physical activity, as a comprehensive intervention that provides both a physical and mental health response, was found to be the most effective intervention for students. Of course, we must also acknowledge the limitations of this study and recognize that physical activity, while effective, is not the only solution. A combination of other interventions is also critical when dealing with the stress and anxiety of COVID-19. Therefore, in the future response to the epidemic, we should continue to explore, research, and promote the combination of more targeted physical activities and other interventions to better help students cope with the challenges they may face during COVID-19.

Data availability statement

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/supplementary material.

Author contributions

JW, GK, HL, and YK conceptualized and designed the original study, from which the data for the analyses presented here were obtained. JW, GK, and YK completed data collection, data analysis, and initial writing. JW, GK, HL, XH, MM, AS, and YK participated in writing and commenting on the manuscript and drafted, edited, and approved its final version. All authors read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Active Home Literacy Environment: parents' and teachers' expectations of its influence on affective relationships at home, reading performance, and reading motivation in children aged 6 to 8 years

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Studies highlight the benefits of active Home Literacy Environment on learning and reading habits. This model is based on harnessing family involvement, resources and capabilities to create learning opportunities around reading, engaging in practices related to written language at home. However, it is less common to find applied research with children from the age of six, with older ages and already initiated in reading decoding. The aims are confirming and improving the expectations of families and teachers of a group of children (6–8 years old) regarding the effect of an active Home Literacy Environment program on the improvement of affective relationships between parents and children, reading performance, and children's reading motivation. The method and procedure followed included carrying out an active Home Literacy Environment program for 18 months with a group of children (aged 6 to 8 years), their families and their teachers, and measures of all variables were collected at four times, using an *Ad Hoc* instrument designed for families and teachers. The results show that participants had high expectations about the influence of the Home Literacy Environment on the improvement of all variables even before the implementation of the program, improving their expectations about its effects on positive affective relationships at home and on reading achievement after the intervention. In conclusion, we suggest the need to continue investigating the effects of the active Home Literacy Environment program applied to children aged 6 to 8 years, older than those traditionally investigated. As well as their effects on family relationships, reading ability, and reading motivation.

KEYWORDS

home literacy environment, reading, motivation, affective relationships, primary education, program

1. Introduction

The fundamental role of families in children's overall development and learning has been a focus of interest for many researchers over the years (De-La-Peña et al., 2018; among others). The first social and linguistic interactions of the child take place at home, with parents being primarily responsible for designing the right environment to foster learning opportunities, modeling desirable behavior for the young child, and providing the necessary scaffolding for building knowledge. However, the role of family in the acquisition of experiences and knowledge schemes continues throughout the child's development, transforming the environment, transmitting a positive attitude toward learning, and generating expectations that influence the child's motivation for certain tasks and activities.

At a later stage, activities carried out by teachers are added to the practices at home; teachers guide the child's learning in the school context and advise families, guiding them how to enhance learning and, even more importantly, their motivation to learn at home. On the one hand, teachers set a series of guidelines to follow and provide recommendations to families through meetings and tutorials. On the other hand, they reinforce students' achievements—individually or with family support—at home, encouraging children's interest in impressing the teacher (and their classmates), obtaining their praise and rewards, and, consequently, enhancing children's motivation for the task. Thus, a relationship is also established between the teacher and the student, associated with affective and emotional components, which requires the interest and involvement of the teacher and the student in the task (Ryan and Deci, 2017). A higher quality of these relationships is associated with higher motivation, and therefore, better academic performance, including reading performance (Roorda et al., 2017; Guay et al., 2019).

Furthermore, the influence of teachers continues beyond the school, as the child returns home and shares with his family what he has achieved, what comments the teacher has made, and how he feels, which also produces an increased sense of achievement and competence in the adults, leading them to maintain educational practices at home. Thus, directly, teachers influence their students' motivation to learn—through their attitude and reinforcement at school—and, directly and indirectly they may have an impact on families' interest in creating opportunities for increasing children's motivation, through meetings and exchanges of information (directly or through the child, with documents such as academic notes, specific records, or the schedule).

1.1. Home literacy environment

Given the deep interest of psychology in general, and cognitive psychology in particular, in the influence of the family context on children's learning, it is increasingly common to find studies and reports, both national and international, that analyze the predictive capacity of family variability in the acquisition and development of fundamental competencies and skills for the implementation of higher order processes such as reading (Ministerio de Educación y Formación Profesional, 2020; Vázquez-Cano et al., 2020, among others). Specifically, many researchers have focused on the study of Home Literacy Environment (HLE), defined as the quantity and quality of resources and skills that families possess for the creation of a context that facilitates learning opportunities, in which parents act as facilitators (Jiménez, 2012; Puglisi et al., 2017; Inoue et al., 2018; Wiescholek et al., 2018; among others); parents act as reading role models and encourage prolecting and reading activities, encouraging subsequent reading development and associated motivational aspects in children.

However, not all households are characterized as having an HLE, nor are all HLE the same and have the same effect on children's reading knowledge and motivation. Burgess (2011) distinguishes two dimensions: (i) passive HLE, which refers to the parents' skills and attitudes toward reading and their task as role models, and (ii) active HLE, which includes literacy activities carried out in the family in addition to the above. An active HLE has an apparently greater influence on the learning and development of reading, especially when formal literacy activities or *code-related interactions* are carried out, in which the child plays an active role and the task is focused on explicit learning of the written code, such as grapheme-phoneme conversion and reading comprehension strategies, as opposed to informal activities or *meaning-related interactions* that are associated with written language but do not directly manipulate it, an example of which is shared reading (Sénéchal and LeFevre, 2002, 2014). And, it is this active dimension that arouses the most interest in this study. On one hand, due to its flexible and dynamic nature, which allows adapting the model and its practices to the child's individual characteristics (linguistic and reading level of the youngest, etc.), the family's specificities (educational, linguistic, and reading levels of the adults in the household…), and their environment, in this case, the school context (socioeconomic and cultural context, the school's interest in reading frequency and habits, improving the reading ability of its students, etc.). Not only that, but it also enables tailoring practices to meet the demands of reading tasks and stimulating both basic and complex cognitive processes, including fundamental motivational aspects that foster the child's interest in reading.

1.2. Home literacy environment, reading and motivation

To understand the interaction between HLE and motivation, it is essential to delve deeper into the motivational aspects involved in children's learning, and specifically, in reading. Only then will it be possible to understand the fundamental role of HLE in the improvement and enjoyment of reading.

1.2.1. Reading as a process and behavior

Reading is a complex process that stretches beyond the academic realm as a beneficial skill for the development of brain structures and cognitive functions, as well as for activating emotions and feelings, providing insight into different ways of thinking and different perspectives, and so on (Oatley, 2016; Wolf, 2020). Reading involves perceiving and attending to stimuli, storing new knowledge, recovering and restructuring existing knowledge, anticipating and predicting, understanding the beliefs and desires of others, analyzing different points of view, analyzing the emotions and feelings of the characters and even the author, and so on. Therefore, its proper functioning requires the activation of multiple brain areas and participation of the processes, abilities, and functions that arise from these areas (Horowitz-Kraus and Hutton, 2015), including the

biological structures of the brain regions associated with affect and empathy, and the ability to understand mental states of others or theory of mind (Wolf, 2020).

Consequently, performing prolecting and reading tasks at home can help enhance these biological bases and positively influence psycholinguistic, cognitive, and behavioral processes and skills associated with reading or specific to it, as verified by this research team in previous studies, one of which has been published (Romero-González et al., 2021). In both studies, the positive effects of the application of an active HLE program on phonological awareness, vocabulary, comprehension of oral narratives, reading recognition, and speed and reading comprehension were corroborated in a group of participants aged 6 to 8 years, from a charter school in the city of Malaga (Spain).

The variables analyzed in relation to HLE have an impact beyond that on reading performance. Different studies confirm a direct correlation of both dimensions of HLE, whether studied jointly or separately, with frequency and reading habit from the age of 8 years, and even more importantly, with motivation and enjoyment of reading (Baker, 2013; Wirth et al., 2020).

The scope and impact of these findings can be observed not only at the national but also at the international level, through studies and reports that include representative samples from different countries and regions. These studies seek to determine the reading performance of children and adolescents, as well as the factors that influence literacy in this population. Traditionally, reports such as PISA measured the performance of representative samples of adolescents, aged 14–15 years, in specific reading tasks and made comparisons between: (i) the results obtained by different countries; (ii) the average scores of all participating countries, European and the OECD countries; (iii) the results of the regions that make up the same country, in the case of Spain, the autonomous communities; and (iv) the average scores of each autonomous community, the Spanish, European, and OECD averages. However, although the purpose of the test and the comparisons are maintained today, with an increase in research on learning and reading, the number of participants (including up to 70 countries in 2018) and the variables measured have also increased. Thus, the latest report pays special attention to the influence of contextual and motivational factors on reading ability, yielding data on the reading enjoyment index, which explains 10% of the variability in the reading performance of Spanish participants. In other words, children who enjoy reading the most read better. These findings have prompted education professionals to look for ways to encourage a taste for reading and incorporate new ways of increasing motivation for literature and for reading in their reading plans.

1.2.2. Motivation as a construct

Motivation is a psychological process present in a large part of the activities and behaviors performed by human beings throughout the day in different contexts and situations. The nature of motivation and its effects on young children have led to numerous studies in recent years focused on determining the predictive validity of motivation to explain learning as measured through academic performance and success (2019; Regueiro et al., 2015; Guay and Bureau, 2018; Siegenthaler-Hierro et al., 2019; Rodríguez et al., 2020; among others). These attempts have prompted researchers from the fields of psychology, psycho-pedagogy, and education to not only accept the importance of this cognitive capacity in school results, but also in students' persistence in studies and task completion (Pintrich, 2003; Guay et al., 2010; Guay and Bureau, 2018).

Classical authors such as Pintrich and De Groot (1990) distinguish several components associated with academic motivation: goal value, perceived competence, causal attributions, and emotional reactions. The desire for achieving personal goals, as well as the beliefs and value attached to them, drives students to conduct better time management in studies and be more consistent in homework completion (Linnenbrink and Pintrich, 2002; Regueiro et al., 2015; Rodríguez et al., 2020). All this favors students' learning and academic performance, increasing their perception of competence and attributing successes to internal, stable, and controllable causes, which increases their sense of self-efficacy and task satisfaction. Specifically, according to the self-determination theory (Deci and Ryan, 1985, 2000; Ryan et al., 2008; Ryan and Deci, 2020), an increase in these components enhances the development of intrinsic motivation for academic tasks, defined as the internal tendency that leads individuals to act for the pleasure and enjoyment of the activity itself; that is, when the behavior is an end in itself and not a means to achieve another goal. Unlike extrinsic motivation, defined as an individual's interest in performing a behavior to obtain a reward or avoid punishment, intrinsic motivation is promoted by internal factors, arousing great interest in the educational community, as it plays a crucial role in the increasingly complex behaviors that cause satisfaction and last over time.

Based on the understanding that motivation is a construct linked to multiple factors and composed of several elements, Guay et al. (2010) highlighted the need to study motivation in a broad manner in relation to school (including interest in learning, establishing relationships with the peer group, etc.), as well as in association with a specific subject or element (science, reading, etc.), that is, a specific domain (Green et al., 2007). Among these domains, in the last 20 years, interest in reading and the effect of motivation on reading are prominent not only in terms of reading performance but also the quality of reading (Schiefele et al., 2012, 2016), including reading behavior and habits.

1.2.3. Motivation for reading: interaction with the home literacy environment

Siegenthaler-Hierro et al. (2019) and Ruiz et al. (2019) allude to the need to investigate the relationship between reading and motivation from an early age. In their works, belonging to the same project, they investigated the association between the learning motivation of 208 children, aged 5 to 6 years, as perceived by their teachers, and their reading ability (decoding of graphemes, lexical, syntactic and semantic processes) measured 2 years later. The results showed that the group of students with lower scores on motivation, especially on task persistence, also presented lower reading performance. This leads us to believe that increasing reading motivation will also mean fostering curiosity for the act of reading and establishing a reading habit among young students. For example, active HLE programs that would increase reading competence and autonomy, relationships and experiences with parents, positive memories of time spent reading with family, and so on, by increasing the child's motivation to carry out activities associated with the written code with his or her family.

The act of reading is a demanding behavior that involves great cognitive effort not only during the first years of learning but

throughout life. The current context in which the child and adolescent population is developing, characterized by the presence of increasingly accessible technology and its numerous forms of entertainment, can dissuade both children and adolescents from indulging in other activities, including reading. Therefore, the role of motivation and related brain structures, such as the limbic system, in reading is fundamental. Not only would it help the child choose reading over other activities but would also enhance the functioning of processes directly involved in the act of reading, such as memorization.

Specifically, among the brain structures related to motivation, the amygdala is a region that establishes connections with numerous structures in the brain. One of them is the septal area, responsible for modulating pleasant sensations and level of alertness; it is also connected with the hippocampus, the activation of which is very important during memorization. In view of this relationship and the mechanisms under which the aforementioned brain regions operate, researchers such as Almaguer-Melián and Bergado-Rosado (2002) The influence of emotions and motivation on the consolidation of memory and, therefore, on learning. A lesion in the septal area or stressful situations that alter the functioning of the amygdala can lead to changes in brain activity and in the connections that regulate the action of the hippocampus, and thereby, either enhance or impair the learning process. Thus, given the characteristics of reading and learning to read, as well as the role of motivation in this process, we believe it is essential to design programs for reading and learning that seek to improve motivational aspects of reading, such as active HLE programs (Siegenthaler-Hierro et al., 2019; Cho et al., 2021).

Nevo et al. (2020) conducted an investigation with 121 participants aged 6 to 8 years, who were beginning to learn to read. They aimed to examine the relationship between reading fluency (reading accuracy and speed), reading comprehension, and reading motivation. For this purpose, they differentiated three components of motivation: (i) reading self-concept or perceived self-competence, according to the terms proposed by Ryan and Deci (2000, 2020); (ii) value of reading, that is, having the belief that reading is useful and beneficial; and (iii) literacy aloud, linked to social interactions during story reading. The results showed a significant positive correlation between reading comprehension and each of the three components of reading motivation; however, reading fluency was correlated only with reading self-concept.

The nature of reading motivation is complex and multidimensional, and is affected by internal and environmental factors such as literacy in school and at home (Baker and Scher, 2002; Nevo et al., 2020; Nevo and Vaknin-Nusbaum, 2020; Altun et al., 2021; Cho et al., 2021). In particular, improving the perceived value of one's own skills and goals depends on the combination of several elements, including the environment in which the child develops, and the practices carried out at home. Thus, motivation may be either inhibited or enhanced by parental expectations and the importance they attach to the specific behavior, task, or domain (Baker and Scher, 2002; Ruiz et al., 2019). In other words, parents who enjoy reading and hold it in high regard will be concerned about their child's reading performance and will foster experiences that encourage reading at home and a reading routine. These practices and experiences would also include literacy aloud moments, for example, through storytelling or shared reading.

1.2.4. Interaction between home literacy environment, motivation, and reading

Parents' expectations that lead them to carry out certain activities may constitute the central axis of an active HLE, made possible by the power of affective relationships between parents and children and the motivating capacity of parents, as well as by the availability of families to dedicate time and attention to these practices (Sonnenschein and Munsterman, 2002). Adults create spaces for leisure and enjoyment with the children around literacy activities. This makes children want to repeat the activity and learn while performing it, not so much because of the activity itself but because of the agents involved in it. As time passes, their performance on literacy tasks improves, and consequently, their reading self-concept and the value they place on reading increase, and they develop an interest in it. It is noteworthy that, at an early age, the value of reading depends on the rewards received by the child in the short term, and the degree of usefulness and benefit of reading perceived by the child varies according to these rewards. However, as their reading experience increases and they approach adulthood, their assessment of the reading actor changes, anticipating or expecting medium and long-term benefits, in addition to immediate internal rewards (enjoyment of the narrative, distraction and escape from other problems, acquiring new knowledge on a topic of interest, etc.).

The child establishes a reading routine guided by extrinsic motivation, the main reinforcer being the leisure time with family performing a prolecting or reading task. Together, these points suggest that families begin the process of scaffolding reading in the child's early years by creating an HLE. This HLE evolves and transforms based on modifications in the role played by the agents that compose it and the resources they possess, adapting to the child's zone of proximal development at each time point. Meanwhile, the active HLE is maintained due to the fact that it manages to enhance the main motivational aspects involved in reading in the early years of learning to read and schooling. In particular, emotional reactions and feelings are enhanced through the social interactions and positive interpersonal relationships that are established and developed, based mainly on affection and pleasant experiences, giving rise to a feeling of belonging and connectedness inherent to building a relationship. In turn, there is an improvement in children's reading performance, and consequently, in their reading self-concept or need for competence, which benefits from structured environments with positive feedback and learning facilitators (Deci and Ryan, 2000; Ryan and Deci, 2017, 2020). In such an environment, adults begin by acting as a role model, for example, by reading aloud stories to their children. As the child's linguistic and cognitive development progresses, the activity varies such that the child takes an increasingly active role in the task by modifying the activities (reading together, reading aloud by the child to the adult, internal reading by the child, etc.), under parental guidance and supervision. Parents continue to gradually eliminate direct supervision of the task and focus on stimulating the activity indirectly—for example, through conversations about books—until the child is able to read autonomously. However, it should be noted that, in order to achieve the ultimate goal of reading independently and frequently, the causal attributions that the child establishes for his or her successes and failures during reading as well as the value of the goal achieved are essential, among other factors, thanks to the beliefs and expectations transmitted by the family throughout the child's development.

Baker et al. (2001), Bus et al. (2000), and Sonnenschein and Munsterman (2002), among others, collected measures of verbal interactions and the nature of those interactions during literacy activities such as shared reading as an indicator of affective appraisals. Baker et al. (2001) confirmed that conversations associated with the meaning of the text between parents and children—in the first years of schooling—were correlated with more positive affective appraisals, compared with conversations about the process of identifying the written code (reading decoding). Whereas, Sonnenschein and Munsterman (2002) investigated the influence of the affective quality of interactions between parents and children, aged 5 to 6 years, during reading and the type of discourse produced in these interactions on components of literacy (i.e., phonological awareness, print orientation, story comprehension, and children's motivation for reading). Their results demonstrated that students who experienced more positive reading interactions at an early age showed greater motivation for reading in the first grade (between 6 and 7 years of age).

The types of interaction between adults and children during literacy activities have also been studied by Luo and Tamis-LeMonda (2017) and Patel et al. (2021) who identified differences between interactions based on "immediate" questions (related to immediate memory and literal comprehension of the narrative) and "non-immediate" questions (associated with developing hypotheses and making inferences, comparing stories, comparing fiction with reality, etc.). They found that: (i) children show reciprocity and participate actively in conversations; (ii) children tend to respond with questions similar to those of their parents, whether "immediate" or "non-immediate," of lower or higher level of difficulty, thus imitating the type of interaction; and (iii) parents increase their interactions when they perceive greater involvement on the part of their children.

The active HLE model involves even greater interest and availability on the part of families, which are directly dependent on parents' expectations and perceived value of the task. As stated by Baker and Scher (2002), a positive attitude on the part of adults, including beliefs about the importance and pleasure of reading, influences their children's enjoyment of reading. Thus, the more knowledge adults have about the benefits of reading, the greater their concern for their children to read correctly and the greater their interest in designing a literate environment.

Wiescholek et al. (2018) explored the perceptions of a group of 281 children aged 6 years and their parents regarding passive and active HLE. Specifically, they investigated the relationship between the children's perception of HLE and their parents' educational level, enjoyment of literacy, reading frequency, and phonological awareness. The adults completed a questionnaire assessing their educational level, while the children completed a questionnaire with questions about the number of books in the home (an indicator of passive HLE), and another five questions related to the frequency of literacy activities performed in the family (active HLE). The frequency and enjoyment of reading were assessed using the German version of the Children's Interest Measure scale (Baroody and Diamond, 2012), while the standardized PB-LRS test (Barth and Gomm, 2008) was used to collect measures of phonological awareness. On analyzing the data, among other findings, the researchers observed that a passive HLE was more prevalent in households where parents had a higher level of education, and that both dimensions were associated with children's enjoyment of reading. However, only active HLE was associated with a higher reading frequency. This leads us to suppose that, in children who are advanced in their linguistic and reading development (with an adequate phonological level, who have mastered grapheme-phoneme conversion strategies and overcome their difficulties in reading recognition, etc.), the implementation of an HLE is not sufficient. It would not be enough to implement a passive HLE program to increase the taste and enjoyment of reading, or to establish a reading habit that lasts over time and in adulthood; it would be more beneficial to implement an active HLE that also seeks to improve other variables and processes of greater complexity (readers, motivational …).

Meanwhile, several researchers allude to the influence of parents' positive beliefs about their ability to assist their children in acquiring skills and learning to read on children's reading motivation and emergent literacy skills. They suggest that parents' positive beliefs about literacy are directly related to the quality of literacy activities carried out at home (Bingham, 2007; McElvany and Van Steensel, 2009; Bojczyk et al., 2016; Patel et al., 2021).

Therefore, we propose to reformulate the existing concept of an active HLE, based on the understanding that it not only improves the psycholinguistic and cognitive variables traditionally studied (phonological skills, reading fluency or comprehension), but also enhances motivational aspects associated with reading in children, including components such as self-concept or reading competence, sentimental and affective relationships, parents' expectations and motivation to improve their children's reading, and the home literacy environment.

Consequently, this study pursued the following objectives. First, it aimed to confirm families' expectations about the future influence of an active HLE program on the improvement of positive affective relationships between parents and children, reading performance (reading speed and comprehension), and children's motivation to read, before starting the intervention at the first evaluation time point. In line with this, the second objective was established, seeking to confirm teachers' expectations about the future effects of active HLE training on the abovementioned variables at the same evaluation time point, allowing us to reflect on whether the expectations of both groups coincide and on the effects of the HLE on the children.

Once the expectations of the two groups of adults had been verified, the active HLE program was started and teachers and families were evaluated at three different time points, with the aim of improving the expectations of both groups regarding the influence of the program on positive affective relationships between parents and children, reading performance (reading speed and comprehension), and children's reading motivation after 18 months of training (two academic years). However, prior to the end of the program and this last evaluation, measurements of all variables were collected twice—after 9 months of intervention and 3 months without training (due to summer vacations)—to monitor and control the study variables.

In summary, firstly, we hope to verify that both families and teachers hold positive expectations regarding the future influence of an active HLE program on improving positive affective relationships between parents and children, reading performance (reading speed and comprehension), and children's motivation to read, prior to commencing the intervention or the initial assessment. A motivational aspect highly linked to the interest, quality, and frequency of educational and reading practices carried out by adults. Therefore, if these expectations are high, we would anticipate increased interest and involvement in the HLE program – from the outset of the intervention

– on the part of teachers and family members, requiring fewer training sessions.

Secondly, we expect to enhance the expectations of both groups of adults—families and teachers—concerning the program's impact on positive affective relationships between parents and children, reading performance (reading speed and comprehension), and children's motivation to read, after 18 months of training (two academic years). Consequently, this improvement is expected to positively influence motivational aspects associated with the child's motivation to read.

2. Materials and methods

2.1. Participants

To select the participants for this study, a cluster sampling method was employed involving parents and teachers of students aged between 6 and 8 years from a private school in Malaga, Spain. Families and teachers of two groups of students who were starting formal education in the Primary Education stage were included in the study. They implemented the active HLE program in their homes and monitored its progress in the classroom over two academic years (1st and 2nd grades of Primary Education). The selected school was located in a socioeconomically and culturally middle-to-high-class area, which allowed controlling for other variables that might influence the program's implementation and outcomes, such as the families' linguistic and reading levels, educational background, etc.

It is worth mentioning that the school's management team, teaching staff, and families were interested in incorporating the active AFA model as the school's reading program. Considering the school and families' preferences, no family members or teachers within the specified age range were excluded from the study.

The adults were divided into two groups. One group consisted of 54 family members with an average age of 43 years, which included 85% of participants with a university education and 75% of individuals who were already working. The other group comprised two teachers in charge of tutoring their students, with an average age of 55 years, and 30 years of experience as teachers and classroom tutors in their current school (see Table 1).

The following inclusion criteria were established for the selection of participants. On the one hand, with respect to families:

- The child should have been in the 1st grade of primary school at the beginning of the program.
- The children must have attended the same school, a charter school in the city of Malaga.
- The child could not receive, or have received, specific reading acceleration programs.

On the other hand, for teachers, the following inclusion criteria were determined:

- Acting as a tutor for the group of students participating in the project.
- Maintain their permanence in the study, as a tutor for the same group of students, until the end of the project.

The study was approved by the Ethics Committee of the University of Malaga (145-2021-H).

TABLE 1 Groups and characteristics of the study participants.

Groups of participants	N	Average age	Percentage of participants with university studies	Percentage of participants who have joined the workforce
Family members	54	43	85%	75%
			Average years of professional experience	
Teachers	2	55	30 ages	

2.2. Instruments

Four instruments, two of which were aimed at families and the other two at teachers, were used to measure the variables in this study (that is, family and teacher expectations regarding the influence of an active HLE program—before and after its application—on positive affective relationships between parents and children, children's reading ability, and reading motivation). All instruments were designed *ad hoc* using Likert-type scales with five response options. Depending on their level of agreement, participants had to check one of the boxes from 1 to 5 (1 being "totally disagree" and 5 "totally agree").

Regarding the composition and selection of items for the scales, the collaboration of five expert judges in the field was sought. All of them had extensive research experience in the disciplines of psychology, educational psychology, and education, as well as clinical and/or teaching practice. These judges evaluated each item based on its relevance, suitability, and comprehensibility, resulting in a high level of agreement (Cohen's Kappa 0.9) among all of them. This process led to the creation of a scale with high interjudge reliability (Cohen et al., 2011; León and Montero, 2015).

(1) *Scales on expectations about the future active Home Literacy Environment program and its effects on children.* These scales were used prior to the implementation of the program. Two independent scales, one aimed at families and the other at teachers, were used to measure expectations about the influence of the future active HLE program on the improvement of affective relationships between parents and children, children's reading ability (comprehension and speed), and reading motivation. In relation to the scale aimed at family members, 5 items were selected from a total of 10 items that made up the scale; whereas, in the scale aimed at teachers, 6 items were included from the total 17 (see Appendix A).

(2) *Scales on expectations about the active Home Literacy Environment program and its effects on children.* These scales were used during and after the implementation of the intervention program. Two independent scales, one aimed at families and the other at teachers, were used to measure expectations about the influence of the active HLE program on the improvement of affective relationships between parents and children, children's reading ability (comprehension and speed),

and reading motivation. In relation to the scale aimed at family members, 5 items were selected from a total of 10 items that made up the scale, while in the scale aimed at teachers, 6 items were included from the 17 that made up the scale (see Appendix B).

2.3. Procedure

The first step in the project was to select the participants. Subsequently, the informed consent form and pertinent authorizations were signed, and field work was started (see Figure 1).

2.3.1. Evaluation phase

The variables were evaluated at four different time points, that is, at the beginning and end of two school years: (i) before the application of the program, (ii) after 9 months of intervention, (iii) after 3 months of summer vacation, during which no training was provided, and (iv) after another 9 months of application of the active HLE program.

2.3.2. Intervention phase

The intervention began with counseling for families and teachers, explaining what the program consisted of and the benefits of an active HLE. Then, they were provided with the necessary tools for the implementation of the intervention. To this end, two training sessions were held for families and two for teachers.

The main literacy task, around which the program revolved, was reading aloud by the child to the adult, four times a week for 10–15 min. The person in charge of reading with the child had to correct the reading decoding errors detected, in addition to promoting reading comprehension (activation of previous knowledge, short-term memory…) through four questions related to the text (for example, who were the characters in the story, why they could act or feel the way they did, etc.). Families were also encouraged to enhance their enjoyment of reading through comments and conversations with their children about the books read, comparison of characters, and so on.

To ensure that the reading was appropriate to the linguistic and reading level of the children and to include different themes, reading material—narrative texts—was purchased according to the level of curricular competence of the children. The teachers chose 54 books, which were exchanged every Friday. The teachers dedicated 1 h to the book exchange, ensuring that each child had a different book every week to perform the literacy activity at home. In this way, the teachers not only had the opportunity to exchange reading material but also to encourage students' interest in the program and, more importantly, in reading, through conversations with the students about the texts, their opinions and tastes, and even those of their families (see Figure 2).

To monitor the intervention, a notebook or daily log was designed to record data such as the date, title of the book, pages read, difficulties encountered, doubts, praise, and so on (see Figure 3). These notebooks were reviewed daily by the teachers and weekly by the research team. In addition, a brief summary was included with the instructions and fundamental indications for the application of the active HLE program, previously explained in the training sessions (see Figure 3).

2.4. Data design and analysis

The present study proposed the application of the quantitative method and two different designs (Cohen et al., 2011; León and Montero, 2015). The first was a quasi-experimental pre-post design with a single group, with the objective of establishing a relationship between the independent variable (active HLE program) and the dependent variables (parents' expectations about the influence of the HLE program on the improvement of positive affective relationships between parents and children, children's reading performance, and children's reading motivation). Second, a single-case ABA design was adopted to identify the relationships between the independent and dependent variables (teachers' expectations about the influence of the HLE program on the improvement of positive affective relationships between parents and children, reading performance, and reading motivation of their students).

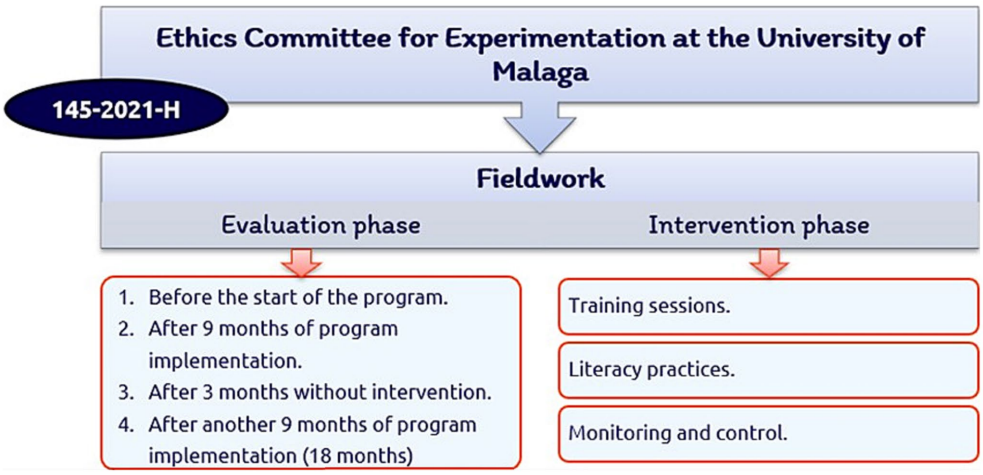

FIGURE 1
Phases of the work procedure.

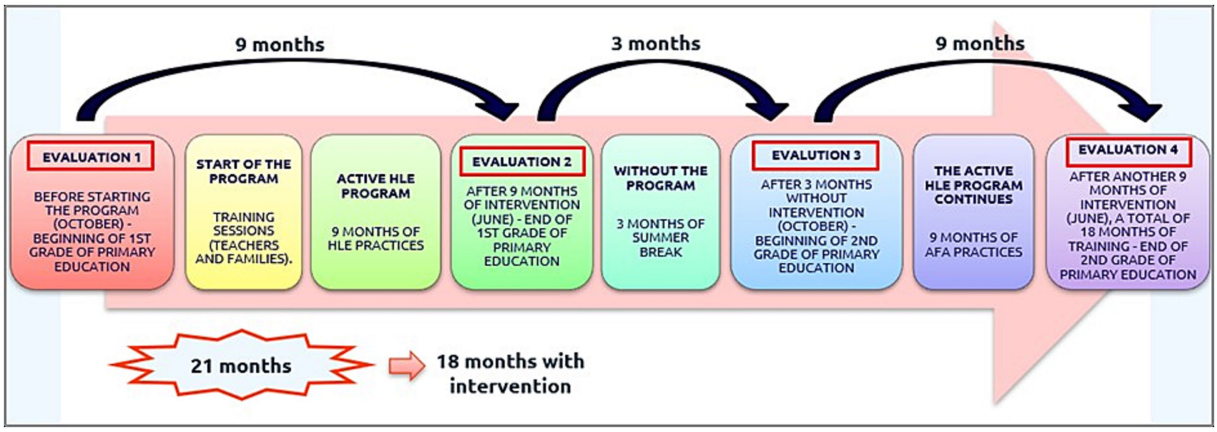

FIGURE 2
Schedule for the implementation of active HLE.

FIGURE 3
Daily reading log.

Statistical analyses were performed using Statgraphics 18 and SPSS 24 programs, beginning with an analysis of the descriptive statistics of each variable. To compare the scores obtained for all variables at the four different evaluations, a simple analysis of variance (ANOVA) with repeated measures was performed. Finally, to detect improvements in the variables, significant differences were observed in each factor.

3. Results

First, to confirm families' expectations regarding the influence of an active HLE on positive affective relationships between parents and children, children's reading performance (reading speed and comprehension), and motivation to read, a descriptive analysis of all the variables was performed at the first evaluation, prior to the implementation of the intervention program (see Table 2). The data showed that, from the beginning of the study, the families presented a positive and high evaluation of the effect of an active HLE on affective relationships between parents and children (M = 3.81), their children's reading performance (M = 8.59), and motivational aspects involved in the act of reading (M = 8.54).

It is also interesting to note that, on comparing the results of teachers with those of families, the teachers presented lower expectations about the effects of an active HLE on the reading motivation (M = 7.5) of their students; however, after the implementation of the program, the teachers' mean scores regarding the improvement of positive affective relationships between parents and children (M = 3.5) and children's reading performance (M = 8.5) were similar to the families' scores.

Second, to verify whether these expectations improved after the application of the active HLE program, descriptive analyses of all the selected variables were conducted on the following three evaluation occasions: evaluation 2, after 9 months of training; evaluation 3, after 3 months of vacation period (without intervention); and evaluation 4, after nine more months of application of the active HLE program. The

TABLE 2 Summary statistics.

		Evaluations	Average	Standard deviation	Coefficient of variation	Minimum	Maximum	Range	Standardized Skewness	Standardized Kutorsis
Positive emotional relationships		1	3.81	1.05	27.56%	1	5	4	−1.6	−0.64
		2	4.26	0.83	19.44%	3	5	2	−1.5	−2.01
		3	3.83	1.09	28.55%	1	5	4	−3	1.01
		4	3.92	0.9	23.13%	1	5	2	−2.37	1.27
Reading ability	Reading comprehension	1	4.04	0.83	18.97%	2	5	3	−4.52	2.81
		2	4.57	0.72	15.66%	2	5	3	−5.12	3.77
		3	4.31	0.69	16.12%	3	5	2	−1.55	−1.19
		4	4.59	0.59	13.05%	3	5	2	−3.57	0.69
	Reading speed	1	4.55	0.74	16.33%	2	5	3	−5.73	5.55
		2	4.72	0.59	12.62%	2	5	3	−7.81	11.97
		3	4.57	0.66	14.47%	3	5	2	−3.89	0.73
		4	4.65	0.55	22.94%	3	5	2	−3.93	1.25
Motivation and enjoyment of reading	Time dedicated to reading homework in the family	1	4.02	0.94	23.42%	2	5	3	−1.8	−0.86
		2	4.13	0.91	22.08%	2	5	3	−1.72	−1.28
		3	3.76	1	26.81	1	5	4	−1.22	−0.55
		4	4.06	0.88	21.64%	2	5	3	−0.85	−1.86
	Conversation about reading	1	4.51	0.63	14%	3	5	2	−2.95	−0.08
		2	4.63	0.59	12.79%	3	5	2	-4.12	1.43
		3	4.52	0.66	14.73%	2	5	3	−4.39	3.95
		4	4.53	0.64	14.01%	3	5	2	−3.17	0.13

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results confirm that the positive expectations regarding the influence of an active HLE on the variables remained high at all four points in time, that is, from the beginning to the end of the active HLE intervention program. However, it should be noted that the observations made by the families were slightly asymmetric to the left, that is, they presented a standardized Kurtosis or negative Skewness statistic due to the low scores of a few individuals, possibly the most critical and demanding families, whose results did not evolve or behave similarly to the rest of the participants (see Table 1). These results, which were high at all four evaluation occasions, are also presented in the data obtained from the teachers, when compared with the average values found in parents' responses to the questionnaires. Thus, the highest averages were observed in the fourth evaluation, increasing up to four points between the first and last evaluation, that is, two academic years and 18 months of training, for the reading motivation variable.

Finally, to measure the efficacy of the active HLE program for improvements in the variables, a simple repeated measures ANOVA was performed and the changes were observed at the four evaluation time points. Additionally, sphericity was tested with the Mauchly Test of Sphericity. Thus, after the first 9 months of training, significant differences (*value of* $p = 0.0273$) were detected in affective relationships between parents and children and children's reading performance. That is, families perceived improvements in both these aspects after the first period of application of the active HLE program.

These improvements were maintained until the end in terms of the children's reading performance as perceived by their parents; however, the same was not true for the remaining variables. Specifically, within the framework of reading performance, the families' perception of their children's reading speed and comprehension was included. After the descriptive and variance analyses, as there were no high correlations between the variables and there were only two indicators, a fact corroborated by an exploratory factor analysis (AFE), we decided to conduct a separate study. This allowed us to observe that the scores are high for all variables on all four occasions, but there was a phenomenon that was repeated, as reading speed had a descriptively higher average in the four measurements, obtaining significantly higher values at evaluations 2 and 3, that is, after the first academic year and 9 months of intervention ($W = 0.005$, *value of* $p = 0.000$). Whereas, significant differences in reading comprehension ($F = 3.238$, *value of* $p = 0.026$, $\eta^2 = 0.058$) were found at evaluations 2 and 4, at the end of each academic year and the end of the active HLE intervention program (after each 9-month stretch of training).

With regard to expectations about reading motivation, it should be noted that, although no significant differences were found (*value of* $p > 0.05$) throughout the study period, high scores were obtained on all four evaluation occasions. Thus, the families started out with positive expectations regarding the influence of an active HLE on their children's motivation and enjoyment of reading ($M = 8.54$; maximum score = 10), which were maintained after 9 months of training ($M = 8.76$), 3 months without any intervention ($M = 8.28$), and nine more months of application of the active HLE program ($M = 8.59$).

The reading motivation variable is composed of two items which, despite establishing significant correlations, were weak, a fact confirmed after AFE, which led to further study of the items separately. This analysis showed that the descriptive average of one of the items, which refers to the effect of time spent reading by children under parental supervision, on motivation for the activity is always slightly lower. However, the item with slightly higher scores focuses on the effect of holding conversations about reading as a family on children's reading motivation. Consequently, the data suggest that, although not significant, parents perceive that their attitude toward reading, conversations about books, and their role as a reading role model would have a slightly greater influence on their children's motivation than the amount of time spent reading.

In summary, prior to the application of the active HLE program, families and teachers had high and positive expectations of the effects of the program on affective relationships between children and parents, children's reading performance, and reading motivation. These expectations were maintained throughout the study, and, in the case of family members, there were significant changes and improvements—after the first 9-month training period—in the quality of affective relationships and reading performance of their children. At the end of the study, significant improvements were maintained in reading performance.

4. Discussion

This study, framed within a larger project, was conducted to explore the expectations of families and teachers of a group of 54 students aged 6 to 8 years, regarding the effects of HLE on positive affective relationships between parents and children, children's reading performance (reading speed and comprehension), and reading motivation, before and after the implementation of an active HLE program.

4.1. Main findings and the implications of these results

In relation to the first objective, the results showed that the parents and teachers had high expectations regarding the effects of the HLE program on all measured variables from first evaluation occasion before the implementation of the program, that is, from the beginning of the project. These high expectations, far from being a drawback, are very important and valuable, as it is desirable for all participating families to share these values. These findings are in line with those reported by authors such as Baker and Scher (2002), and Ruiz et al. (2019), who emphasized the influence of parents' positive attitudes and beliefs toward reading on their children's motivation and pleasure in reading, through the promotion of literacy practices. More importantly, these positive beliefs are also fundamental to the design of quality literacy activities (Bojczyk et al., 2016; Patel et al., 2021). Based on these, the involvement of the families in this study may have been greater when considering that the act of reading and HLE have a high influence on their children, beginning their incursion into the active HLE program due to the motivating effect of their expectations, which, taking into account the scores of the teachers in charge of tutoring the students in the Educational Center would be enhanced by the attitudes of the teachers and the initial training sessions.

The second objective was to improve and maintain the expectations of families and teachers regarding the effects of the active HLE program on positive affective relationships between parents and children, children's reading performance (reading speed and

comprehension), and reading motivation after the application of the intervention for 18 months. In contrast to the results obtained by Wiescholek et al. (2018), no significant differences were found in the students' reading motivation. Regarding this variable, it is worth noting that motivation for reading is a complex psychological construct influenced by numerous factors and aspects that vary and evolve over time and with increasing task demands. This fact, along with the results obtained, leads us to believe that designing instruments to measure motivation in young children, regarding the active HLE model and reading, is equally complex and requires a thorough evaluation of each of its components. As observed throughout the study, despite not perceiving changes in their children's motivation for reading, parents do recognize improvements in motivational aspects that contribute to their interest in reading. Two other factors in this study that could be influencing the results are: on the one hand, the effects of an active HLE on students' reading motivation were not directly assessed through the child, but data were collected on the effects of different active HLE practices on children's reading motivation as perceived by families and teachers; on the other hand, and even more important, the statistical averages extracted in this study were high from the beginning of the project until its completion, thus allowing a smaller margin for improvement. It is also interesting to note that the aspects perceived by the families that most influence reading motivation were the conversations around reading, rather than the time the child spent reading aloud supervised by the parent. In other words, adults attached slightly greater importance to their role as role models, their attitudes, and the time spent together after reading, in which they conducted dialog about the content of the reading material; the adult asked a series of questions to enhance children's reading comprehension and exchanged opinions and impressions. This suggests that this space of time dedicated to conversations about reading also coincides with one of the most important occasions for fostering affective relationships between parents and children, creating positive experiences together.

In line with this, Baker et al. (2001) showed that conversations associated with the meaning of the text between children and parents are correlated with more positive affective evaluations than conversations about reader recognition. This aspect should be taken into account when interpreting another finding of this study—the significant improvements obtained in the expectations of the effect of the active HLE program on positive affective relationships between parents and children, after 9 months of intervention. As indicated by Sonnenschein and Munsterman (2002), the affective quality of the interactions between parents and children aged 5–6 years during reading influences reading motivation when the children reach the first grade (between 6 and 7 years of age). Consequently, although the participants did not consider that the HLE and the program significantly improved their children's interest and enjoyment of reading, they maintained their high positive expectations about its influence on positive affective relationships at home, and therefore, on one of the fundamental components of both HLE and reading motivation. These interactions arising from the affective family bond would produce emotional and sentimental reactions that are fundamental for the promotion of the taste and enjoyment of reading, as well as for the implementation and maintenance of an active HLE, constituting a motivational aspect to be taken into account in this study, which should be investigated independently and in relation to the reading motivation variable.

Finally, significant improvements in students' reading performance, as perceived by families, were also observed after the implementation of the full active HLE program (lasting two academic years). According to the data obtained by other researchers such as Niklas et al. (2020) and Niklas and Schneider (2014, 2017); among others, as well as those found in two studies that make up our research project, one of which has been published (Romero-González et al., 2021). Specifically, families detected a significant improvement in reading speed at evaluations 2 and 3 (after 9 months of training and 3 months of vacation without intervention), a phase of learning in which children were automating the process of reading recognition, as well as in reading comprehension at evaluations 3 and 4 (at the beginning and end of the second academic year, after the application of the entire program), when fluency errors had been reduced, children had advanced in their general psycholinguistic development (phonological awareness, vocabulary, oral comprehension, etc.), and could use more cognitive effort in text comprehension. Based on existing literature, although it is not part of the variables analyzed in this study, we believe that the effects of an active HLE on children's reading ability as perceived by families should lead to benefits in their learning and, above all, in their interest in learning, particularly learning to read (Baker and Scher, 2002; Wirth et al., 2020). This would be explained by the fact that students would show an increase in their level of perceived competence during the task, acquiring and developing confidence in the resolution of reading activities and improving their reading self-concept, another motivational components of great relevance for interest in reading (Nevo et al., 2020; Nevo and Vaknin-Nusbaum, 2020).

In summary, the adults began the active HLE program with high expectations about its future effects on the different variables, which were maintained after its implementation. This is important, because it allows the application of the HLE program in better conditions, facilitating its implementation as there is no need to implement specific improvement aspects of expectations. In addition, it can be affirmed, thanks to the training families improved their expectations about the influence of the active HLE on fundamental motivational components for reading, such as positive affective relationships at home and children's reading performance, on different evaluation occasions. The improvements observed in the parents' perception of children's reading ability lasted until the end of the 18-month active HLE program; taking into account the results of previous studies, this indicates an increase in perceived reading self-competence, and therefore, in the child's reading self-concept, which is fundamental for the child's taste and enjoyment of reading.

4.2. Limitations and future lines of research

Some limitations were encountered during the research, which should be noted. The first was the impossibility of including a control group for ethical reasons, as the families and the teaching staff of the educational center requested that all the children in the class receive the training. It was not possible to include a group of participants, that is, families and teachers, with children who did not participate in the active HLE program, with the same characteristics and from the same context as those who completed the 18-month intervention.

Second, to control for variables such as cultural and linguistic differences, the reading level of the families, their accessibility and

availability for work reasons, and so on, we chose to conduct the active HLE program with children from a middle and upper middle class charter school in the city of Malaga, and their respective families and teachers. However, in the future it would be interesting to carry out applied research with larger and more heterogeneous samples of participants, and examine socioeconomic and cultural variables, including linguistic and reading levels. This would allow generalizing the results to other contexts, different adults, and children with diverse personal and family characteristics, often in more disadvantaged settings and less enriched environments.

5. Conclusion

Research on HLE formally began at the end of the 20th century, defining this term as the quantity and quality of resources and skills that families possess to design environments that facilitate reading and learning to read for young children. HLE highlights the role of the family as a model and reinforcer during children's learning in general, and reading, in particular.

Studies on HLE have increased in the past few years, mostly focusing on the influence of HLE—passive and/or active—on the language and reading ability of children aged approximately 4 to 6 years (Sénéchal and Young, 2012; Silinskas et al., 2012; Niklas and Schneider, 2014, 2017; Boerma et al., 2017; Dong et al., 2020; Korucu et al., 2020; Niklas et al., 2020; Sénéchal, 2020; among others). However, due to the complexity of these studies and the numerous variables that need to be controlled, applied research conducted with older children—aged 6 to 8 years—focusing on the active dimension of HLE is less frequent. This includes research on the attitudes and role model behavior of families, as well as the types and characteristics of reading and reading practices and activities carried out at home.

In this study, framed within a larger project, we pursued and managed to deepen all these aspects, and further, analyzed the effects of an active HLE on variables other those traditionally investigated; we included variables that are involved in reading and the acquisition of a reading routine, such as motivational aspects and the influence of affective bonds between parents and children during literacy. To this end, following previous studies (motivation, attitude in activities…) and taking into account the multifactorial character of HLE, a possible cause of the continuous emergence of new classifications, dimensions, and types of literacy practices, we suggest a novel classification of literacy practices (Burgess, 2002, 2011; Sénéchal and LeFevre, 2002, 2014.). We provide a redefinition of the concept of active AFL, which was the basis of the active HLE program designed in this study.

Children become involved in reading activities with their families motivated by the leisure time shared with adults with whom they share a strong affective bond, and not so much by the task itself. These approaches to reading allow children to train their reading ability and enjoy it, which raises their level of perceived competence and increases their achievement motivation, leading to internal, stable, and controllable attributions for their reading successes, resulting in an improvement in motivation and reading frequency and in autonomy at older ages. Most importantly, just as this type of environment is possible thanks to the positive affective relationships established between parents and children, the latter are nurtured and benefit from it (generating moments that allow parents and children to continue getting to know each other, have common views and tastes, etc.). As a consequence, these types of relationships remain in the memory linked to a positive valuation of the time and moment lived, as well as of the activity around which these spaces of enjoyment revolve; an active HLE provides a context that favors the creation of opportunities to establish and strengthen these affective bonds.

According to the first and second objectives of the study, the obtained results confirm that both families and teachers' expectations regarding the future influence of the active HLE model on affective relationships between parents and children, the reading ability of young children, and their motivation to read, are high from the beginning before the intervention program's implementation. As for the third objective, it is verified that these family expectations remain throughout the entire study, from the start of the intervention program until its completion. Moreover, among the various variables included in this study, families consider that the variables that have benefited the most from the active HLE intervention are affective relationships—specifically, the conversations held after reading tasks—and reading performance. Both components are fundamental for reading motivation and are therefore essential aspects for the development of the active HLE model.

Regarding the fourth and final objective, it is worth noting that the high expectations also persist among teachers, who highlight changes in children's behavior during recess. The children started including discussions and opinions about books, comparisons, evaluations, and recommendations to their peers during playground conversations.

These data, together with previous findings, induce us to reflect on the role of the teacher, because it should not be forgotten that teachers' perform constant and weekly supervision of the active HLE program. Therefore, although not directly measured in this study, their high expectations and involvement in the project suggest that their role could be more relevant than expected. Teachers have several functions beyond training their students, including providing positive reinforcement and collaborating in the design of a facilitative context for learning, directly influencing the children's motivation (Ryan and Deci, 2020). Moreover, through tutoring, they train and advise students' families, transmitting knowledge and the importance and benefits of literacy practices, as well as providing feedback and support to the families. The tutoring program also offers feedback and reinforces the families' successes. In short, we believe that this could not only impact the young children's motivation, but also that of the adults in charge of implementing and guiding the training, and could emerge as a key component in active HLE.

These findings indicate new lines of research. Just as an active HLE should be adapted to the child's psycholinguistic and reading development and level, modifying the type of task as the child advances in age and maturity, it could be interesting to design active HLE programs in which the central task revolves around such conversations about reading. In populations similar to our participants' children and students, from the age of eight onwards, most children are able to read autonomously and with less supervision. Without requiring training for the improvement of phonological skills or reading decoding, it may be more interesting to promote deep reading and the motivational aspects associated with it. Thus, in the scaffolding that is built through an active HLE, parents must withdraw

and transform their guidance to adapt to the new zones of proximal development, focusing their efforts on increasing children's motivation for deep reading, with the ultimate goal that they read autonomously and enjoy it.

Finally, although there is a need for further research on the subject and for applied research to shed light on its implications in populations with different characteristics, we believe that this study provides new data that could be useful to the scientific and educational community. On the one hand, the expectations of parents and teachers in this study corroborate the benefits of active HLE on the improvement of psycholinguistic, cognitive, and reading processes and skills in young children, which have been directly evaluated in previous studies and showed similar results (Romero-González et al., 2021). On the other hand, the possible relevance of motivational and affective aspects is confirmed, not only for the acquisition of a habit and taste for reading, but also for the development and success of an active HLE.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Comité Ético De Experimentación De La Universidad De Málaga (CEUMA). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

MR-G: Writing – original draft, Writing – review & editing. RL-C: Writing – original draft, Writing – review & editing. SG-T: Writing – original draft. GR-I: Writing – original draft. RJ-R: Writing – original draft. JR-P: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1261662/full#supplementary-material

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The impostor phenomenon among doctoral students: a scoping review

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Emerging evidence suggests that the Impostor Phenomenon (IP) among doctoral students is a serious problem worldwide academic. Although previous studies demonstrate that IP can endanger doctoral students' academic advancement and psychological well-being, limited studies systematically and comprehensively explore the IP among those population. Thus, the fundamental goal of this study is to conduct a scoping review of IP among doctoral students so as to clarify the reality of their situation. Systematic searches were conducted using 5 databases: Springer, Google Scholar, Web of Science, PubMed, and JSTOR for empirical studies published from 1978 to 2023. Two reviewers independently carried out the literature search, study selection, data extraction and assessment of study; disagreements were resolved by a third reviewer. Thirty empirical studies covering four specific domains were include in current research, including the characteristics of IP among doctoral students, factors contributing to IP among doctoral students, correlation of IP with doctoral students' mental illness, and measurement of IP. The findings of this study may provide insight to improving the comprehension of IP among doctoral students and establishing the groundwork for future research in this field.

KEYWORDS

the impostor phenomenon, doctoral students, academic development, psychological well-being, scoping review

1. Introduction

Recent studies have revealed that graduate students worldwide are increasingly affected by psychological problems and their associated manifestations are a source of concern. For example, a study by the American Psychiatric Association (2017) found that 92% of graduate students felt anxious during their first year. Graduate students are at least six times more likely than the general population to suffer from depression and anxiety, with 41% of graduate students suffering from moderate to severe anxiety and 6% of the general population having such experience (Evans et al., 2018). These populations are also more likely to commit suicide. Based on a poll of 3,352 UK Ph.D. students, 33 and 35% of them met the criteria for "risk of suicide" (Hazell, 2022). This result indicates that postgraduate students' mental health status is not promising and should be addressed carefully. Simultaneously, doctorate students are plagued by the prevalence of mental health crises, with dropout rates ranging from 30 to 50% (Stubb et al., 2012). Research from French Ph.D. students found comparable results, with 40% reporting that excessive stress was a significant factor in their decision to drop out (Van de Velde et al., 2019). In addition to focusing on aforementioned problems, recently, serious concerns have been raised about the Impostor Phenomenon (IP) in the academic field, such as increasing doubts in Ph.D. students regarding their self-identity roles and doctoral-level studies (Bothello et al., 2019).

Clance and Imes put forward the definition of the IP in 1978. They used it to designate an internal experience of intellectual phoniness which appears to be particularly prevalent and intense among a select sample of high achieving women. Despite outstanding academic and professional accomplishments, women who experience the impostor phenomenon persist in believing that they are really not bright and have fooled anyone who thinks otherwise (Clance and Imes, 1978), and maintain low expectations for their own performance, as well as for other women. They have undoubtedly been instilled with family-entrenched notions and self-consolidated preconceptions of societal gender roles (Kolligian and Sternberg, 1991). A preliminary study by Clance and Imes suggested that the occurrence of Impostor Phenomenon (IP) is less frequent in men and more widespread among high-achieving women (Clance and Imes, 1978). Indeed, subsequent studies demonstrated that IP occurs in both men and women. And compared with women, men occasionally had higher levels of IP (Topping and Kimmel, 1985). Overall, the academic community is divided on whether there are substantial gender disparities concerning IP.

The subsequent development of this phenomenon has garnered widespread attention from scholars, who believe that it encompasses a broader range of groups and involves more complex characteristics. Our study draws on the research of Nori and Vanttaja (2022), and it suggests that IP refers to a mindset in which a person considers themselves less proficient than they actually are. While the people around them might find the person skilled and competent, they themselves think that they only managed to give an impression of their prowess. Roughly speaking, impostor phenomenon is a condition suffered by people who have external markers of success, such as high grades and professional accolades, who nevertheless believe themselves to be inadequate (Hawley, 2019). Overall, IP includes three typical characteristics: fear of success, fear of failure, and low self-esteem (Neureiter and Traut-Mattausch, 2016). First, individuals with IP believe that their achievements are attributable to chance rather than hard work or their competence or intelligence. Previous achievements are nothing more than a corroboration of their intellectual deception (Harley, 2019). Consequently, they fear success since it implies sustaining the same high level of achievement in the future. Second, they are terrified of failure, which for them entails total self-denial. This causes individuals to put themselves under high pressure and anxiety, worrying that any deviation may increase the risk of failure (Chandra et al., 2019). In fact, individuals with IP fall short of expectations for their own (Clance and Imes, 1978), and are unable to mitigate all possibly uncontrolled hazards with their personal strength. Third, they may display low self-esteem and tend to focus on their negative traits, leading them to isolate themselves from others due to the belief that they are not flawless (Patzak et al., 2017).

The impostor phenomenon is common among doctoral students, as evidenced by various research. For example, 50.6% of Ph.D. students in ECOOM Ghent University believed they suffer from IP (Van de Velde et al., 2019). This statistic closely matches the findings of an experiment of 130 Romanian psychology graduate students. In Maftei et al. (2021) research, they used the Clance Impostor Phenomenon Scale (Clance, 1985) to measure IP. The 20 items contained in the scale measure each answer on a 5-point Likert scale, with 1 = not at all true, and 5 = very true. Therefore, the higher the score, the higher the chance of experiencing associated symptoms of the impostor phenomenon. When adding the scores for each answer, a score lower than or equal to 40 means that the individual has several characteristics of IP; a score between 41 and 60 suggests moderate experiences of IP, while a score between 61 and 80 suggests that the individual frequently feels the associated symptoms of the impostor phenomenon; finally, a score higher than 80 suggests intense experiences of IP. Their results indicated that 56.15% of the participants experienced high and intensity IP. More specifically, they presented high levels of psychological distress and procrastination. Similarly, in an analysis, 73% of 1,450 medical students from three Canadian institutions had moderate or severe IP symptoms (Neufeld et al., 2023). Through quantitative investigations, all of the aforementioned studies confirmed the prevalence of IP among the doctoral student population. Moreover, several in-depth qualitative studies have been conducted on this issue. For example, several studies showed that the majority of postgraduate students have imposter feelings (Cisco, 2020). Craddock et al. (2011) used a planned and standardized sample including six American doctoral students of various ages and backgrounds. Semi-structured interviews were centered on the respondents' academic achievement, fears, and struggles. When the researchers presented the concept "IP" to the participants, they quickly identified it and exhibited an interest in sharing their experiences with IP. Overall, both quantitative and qualitative research have the comparable findings that IP exists among Ph.D. students and is not an intended consequence but has spread throughout the doctoral student population.

While highly educated individuals are often recognized for their academic achievements, society often overlooks the emotional and physical pain that they may experience. This imposter feeling had a serious impact on doctoral students' daily life and academic performance and threatened their psychological health. Recently, there has been a growing research focus on IP. For example, some scholars have studied IP in groups, such as corporate workers, university staff members, and adolescents. Review articles have also been published on the prevalence, prediction, and treatment of IP (Bravata et al., 2019), measurement scales for IP (Mak et al., 2019), and IP in the resident population (Gottlieb et al., 2019). The objective of our study is to map the impostor phenomenon among doctoral students, aiming to understand the research progress in this field. Specifically, we aim to uncover the characteristics and quantitative trends of the impostor phenomenon among doctoral students. Additionally, we seek to explore the underlying causes of this phenomenon and gain a visual understanding of its connection with psychological issues faced by doctoral students. Moreover, we plan to compile and summarize existing measurement tools for assessing impostor phenomenon among doctoral students, with the intention of facilitating targeted evaluations in the future. Finally, we will summarize the gaps in existing studies to provide valuable insights for future research endeavors.

2. Methods

Scoping reviews, a type of knowledge synthesis, are now seen as a valid approach (Daudt et al., 2013). A key strength of the scoping study is that it can provide a rigorous and transparent method for mapping areas of research. In a relatively short space of time (compared with full systematic review), reviewers are in a position to

illustrate the field of interest in terms of the volume, nature and characteristics of the primary research. This analysis in turn makes it possible to identify the gaps in the evidence base, as well as summarizing and disseminating research findings (Arksey and O'Malley, 2005), which is apt for our study. Given that Arksey and O'Malley have built a more classical five-step research methodology, we outlined a framework in this section based on their approach. The steps were as follows: (1) identifying the research question, (2) identifying relevant studies, (3) selecting the studies, (4) extracting and charting the data, and (5) summarizing the results (Arksey and O'Malley, 2005). We reported the study according to PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Review), which was proposed by Tricco and his colleagues. The PRISMA-ScR is a checklist that consists of 7 sections and 27 items. It provides guidance for every aspect of scoping research, such as defining research questions, formulating search strategies for literature retrieval, the process of literature screening, methods of data extraction, and assessing the quality of included studies (Tricco et al., 2018). When conducting our research, we followed the guidance of PRISMA-ScR to plan, conduct, and report our scoping study. By adhering to the guidance of PRISMA-ScR, the quality and transparency of the research can be ensured.

2.1. Identifying the research question

In order to conduct a thorough examination of this topic, we took into account the broader context of the impostor phenomenon, including its underlying theories, conceptions, and measurement approaches. This foundational understanding provided a basis for investigating the presence of IP specifically among doctoral students. Furthermore, to ensure a comprehensive understanding, we also discussed the associations between academic performance and mental health, with a particular focus on how IP may mediate or moderate these relationships. As such, in the first step of this study, our research questions were placed into a broader domain. In general, the following five aspects were addressed: (1) What are the latest research developments in the impostor phenomenon? (2) What are the characteristics of impostor phenomenon among doctoral students? (3) Why do doctoral students experience the Impostor Phenomenon? (4) Are there any potential connections between mental health status and impostor phenomenon among doctoral students? (5) What scales are currently available to measure the impostor phenomenon?

2.2. Identifying relevant studies

Since scoping reviews require access to as comprehensive a literature as possible (Arksey and O'Malley, 2005), we identified several widely used electronic databases in academic research to ensure a comprehensive and up-to-date review of the existing literature, including: Springer, Google Scholar, Web of Science, PubMed, and JSTOR. We selected a combination of relevant keywords such as: "impostor phenomenon," "psychological health," with "doctoral students" to capture all relevant studies related to IP among doctoral students. We restricted our searches to English as it is the primary language of scholarly publication and dissemination. In addition to our initial search, we searched the reference lists of existing reviews for additional publications that may have been overlooked. We employed the following steps to search the reference lists: (1) extract the reference lists from each obtained article; (2) review the extracted reference lists and identify potentially relevant studies based on their titles and authors; (3) search in electronic databases and determine the availability and accessibility of the full texts of the identified studies; (4) assess the relevance and suitability of the studies found in the reference lists; and (5) repeat the above steps iteratively, going back and forth between the extracted reference lists and the database searches.

2.3. Study selection

Before commencing the search, we developed inclusion and exclusion criteria prior to initiating our search. For a publication to be eligible for inclusion, it must meet the following four conditions: (1) focus on IP among doctoral students; (2) be written in English; (3) direct access to the full text; and (4) constitute a complete, peer-reviewed journal study. Any studies that fail to meet the above criteria were excluded from this review. At the same time, we did not impose any constraints on the year of publication to ensure a comprehensive and broad-ranging search approach, as a result, the oldest study was published in 1978 and the most recent study was published in 2023. The initial electronic database search yielded 578 articles that fulfilled the search criteria. After a thorough evaluation of titles and abstracts, publications, there were 161 articles left for further examination. To eliminate any potential duplication, we compiled a comprehensive catalog of these articles, including authors, titles, and publication years. After that, we then conducted a more detailed and in-depth analysis of the literature and assessed the full-text articles' relevance based on their topic, research design, and findings. By employing this method, we were able to locate 21 articles that specifically addressed the subject of doctoral impostor phenomenon. Furthermore, we meticulously examined the reference lists within these articles and unearthed an additional 9 articles that related to impostor phenomenon among doctoral students. In the end, 30 articles met our inclusion criteria (as shown in Figure 1).

2.4. Data extraction

During the first stage, we collected essential information from each study, including the author, year of publication, country, sample size, discipline, study purpose, measure and results. To facilitate a systematic synthesis of the literature, we divided the above information into four main groups: (1) general overview (featuring author, publication date and country), (2) target group (including discipline and sample size), (3) study design (including study purpose, measure), and (4) results. In the second stage, we used descriptive and tabular formats to document our findings. Please refer to Table 1 for more detailed information.

3. Results

Over the past 10 years or so, the issue of impostor phenomenon among doctoral students has become increasingly

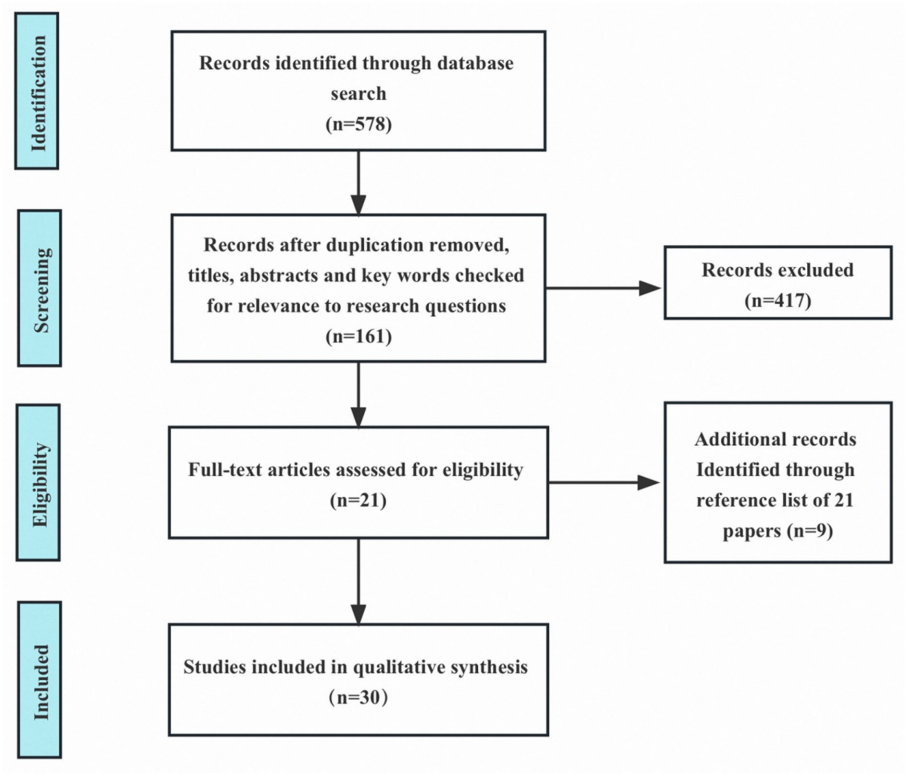

FIGURE 1
PRISMA flow diagram of the study selection process.

prominent in academic research, as reflected by the fact that two-thirds of the 30 papers reviewed were published between 2010 and 2023. Over half studies conducted in the United States and the remaining studies were conducted in the United Kingdom, Australia, Canada, Finland, Israel, Romania, and Russia. Additionally, a wide range of disciplines (i.e., management, clinical psychology, business, psychology, STEM, and medicine) studied this topic. Collectively, these studies provide valuable insights into the prevalence, causes, and consequences of IP among doctoral students across different contexts and fields of study.

3.1. Characteristics of the impostor phenomenon among doctoral students

First, empirical studies suggest that the pursuit of higher education does not necessarily foster a strong sense of self-efficacy among doctoral students. Self-efficacy refers to how doctoral students subjectively perceive and understand themselves as researchers and scholars, comprising their confidence and research capabilities. As the doctoral experience is widely recognized as both challenging and exhilarating, with the development of a high sense of self-efficacy playing a pivotal role in ensuring a successful doctoral pursuit. Despite entering programs with a variety of background experiences, motivations, ranges of academic and social situations, and capacities for research and scholarly productivity (Nettles and Millett, 2006), some doctoral students may not always feel confident in their research abilities or motivated to pursue higher academic aspirations. In particular, many doctoral students cannot view themselves as talented and competent students, after successfully completing baccalaureate and master's degrees (Craddock et al., 2011). Throughout their doctoral studies, these students experience a pervasive sense of intellectual inadequacy, often believing that they lack the necessary skills for academic research. Students with IP focus on the recognition of others and external feedback instead of measuring their ability by what they have actually achieved. They may maintain a sense of relative value as long as the admiration of others exists. However, when positive feedback is not received, their good sense of self will then plummet (Langford and Clance, 1993).

Second, doctoral students with IP have a more negative attributional style. Specifically, the impostor phenomenon describes the self-attribution of success to luck and interpersonal skills rather than to intelligence and ability (Sightler and Wilson, 2001). Evidence suggests this presence of impostor characteristics among a group of 90 graduate students in clinical psychology programs. The survey revealed that those who experienced IP tended to attribute failure outcomes internally and globally. They also had an external locus of control in situations with successful outcomes and an internal locus of control for failure outcomes. This is because they cannot internalize success due to their inherent ability. When they are unsuccessful, they are likely to ascribe the reasons to factors such as effort (Niles, 1994). Simply put, participants tended to attribute their successes to external factors and blame themselves for their failures. According to attribution theory suggests that, attributions are a function of

TABLE 1 Summary of reviewed studies.

Elements		Number
Decade	1990's	4
	2000's	4
	2010's	13
	2020's	9
Country	America	19
	England	3
	Canada	2
	Russia	1
	Indian	1
	Brazil	1
	Israel	1
	Romania	1
	Finland	1
Discipline	Medicine	6
	Psychology	4
	STEM	3
	Clinical Psychology	2
	Others (eg:Arts, Business, Music, Management, English, Literacy)	7
Assessment tool	The Clance Impostor Phenomenon Scale (CIPS)	10
	The Hebrew version of the CIPS (HCIPS)	1
	The Doctoral Impostor Syndrome Scale (DIS)	1
	The Perceived Fraudulence Scale (PFS)	1
	The Zelen-O"Reilly Scale	1
	The Brief Symptom Inventory (BSI)	1
Study type	Survey	24
	Narrative review	2
	Qualitative	4

expectations. When a successful outcome is perceived as unexpected, this outcome is likely due to attribution to temporary external causes, such as luck or effort (Deaux, 1976). Thus, it appears that the way doctoral students attribute success and failure, as well as low expectations of success, is also, to some extent, a psychological projection of insecurity about self-competence.

Third, doctoral students with IP can fall into an abyss of fear. On the one hand, doctoral students face a variety of assessed such as publications, grants, qualifying examination, and their dissertations. Pursuing a Ph.D. degree is a long and challenging journey, requiring individuals to overcome several barriers. There are four general tasks of transition and initial socialization into graduate student life and the future career common to most doctoral students: gain intellectual competence, learn about the realities of life as a graduate student, learn about the profession for which one is preparing, integrate oneself into the department (Golde and Dore, 2001). Completing these challenges means being continuously evaluated by others and requiring a lot of time and effort. Doctoral students with IP often feel anxious and fearful of facing the dilemma of failing the challenge when their abilities and intelligence may be judged implicitly or explicitly. Indeed, these feelings are not caused by an external competitive environment or measures of success (e.g., publication or awards), but rather stem from a deep-seated personal denial of self that one is not effectively fulfilling the responsibilities that come with the role (e.g., as a doctoral student or academic researcher) (Nori and Vanttaja, 2022). On the other hand, others may have not yet discovered the deceptive behaviors of these doctoral students, causing them to live in constant fear of being exposed for the illusions they have created academically and intellectually. This fear is deeply unsettling and can push them into a painful cycle of impostorism (Gediman, 1985).

Fourth, doctoral students with IP may perform poorly academically and thus gradually drift off the academic track. When faced with a new task, individuals with IP usually doubt their ability to cope with the challenge and become overly concerned with their social image, which can lead to inefficient completion of the task (Maftei et al., 2021). For instance, regarding presentations and communication, doctoral students were consistently afraid of saying something foolish and being criticized by the audience. Similarly, they also worried that the articles they submitted for publication or those already published would be rejected by reviewers or readers (Chakraverty, 2020). Moreover, as they realize that their academic career may not be successful, they gradually lose their academic aspiration and adopt behaviors that are contrary to university expectations. A study by the Centre for Excellence in Teaching and Learning at the University of Waterloo (2016) found that graduate students with IP tend to have less contact with other students, struggle to effectively perform their duties as teaching assistants, and are less involved in practical activities, which can hinder their competence (Meurer and Costa, 2020). These characteristics can be used as indicators of impostor among doctoral students.

3.2. Factors contributing to IP among doctoral students

First, most doctoral students who have experienced IP indicate a lack of adequate academic preparation, specifically the ability of read, write, and academic think (Cisco, 2020). Overall, the doctoral stage of study requires individuals to be able to cope with unknown challenges and ultimately complete their studies (Kiley, 2009; Trafford and Leshem, 2009). One of the primary challenges that doctoral students face when entering graduate school is professional socialization. The process of transition from a learner to a researcher is akin to a rite of passage, requiring a liminal period of uncertainty, confusion, or doubt to achieve a change in identity (Van Gennep, 2019). In fact, many students may not understand the competencies requires for doctoral studies, how the educational process at the doctoral level works, or what it takes to successfully complete their studies (Golde and Dore, 2001)."Drifting" into doctoral education can exacerbate feelings of unease, incompetence, and low self-esteem (Nori and Vanttaja, 2022). In addition, doctoral students generally face multiple dilemmas such as difficult coursework, an increasingly competitive academic environment, and low levels of social support, which contribute to a challenging and stressful doctoral phase (McCauley

and Hinojosa, 2020). When consciously struggling to meet the demands of their studies, they may consider themselves impostors.

Second, the impostorism of doctoral students is closely linked to their perceptions of role identity. Role identity serves as a frame of reference for assessing thoughts and actions and is the primary source for individuals to interpret and process life events and take further action plans (Vignoles et al., 2006). Max Weber regarded the academic profession at that time as a "calling" (Weber, 1994), highlighting the sacred status of academic work and its value implications. Currently, many Ph.D. students enter the academic world with enthusiasm but cannot break free from the continuous evaluation, monitoring of results, and glorification of excellence, some doctoral students might begin to demand too much from themselves and feel like an impostor who is not good enough for doctoral studies (Nori and Vanttaja, 2022).

Third, as far as the current educational environment is concerned, a culture of genius seems to permeate all stages of learning. The most direct effect of the cultural view of genius is to motivate individuals to try to hide. Individuals often alter their self-presentation to make themselves appear to have natural, primitive, and extraordinary intelligence. For the group of doctoral students, who have reached the top of the educational pyramid, external illusions about the intellectual talent of doctoral students induce them to fall into a strange circle. On the one hand, it is typical of them to feel they do not deserve to be in higher education and constantly need to prove themselves (O'Donnell and Tobbell, 2007). Thus, they will challenge themselves to difficult tasks and strive to achieve high standards of personal achievement. On the other hand, their confidence in their ability may be tested by unfamiliar academic practices making them feel vulnerable and marginalized (Housee and Richards, 2011). Out of low self-esteem, fear, and self-protection, they will try to avoid tasks that are beyond their ability to handle (Leary et al., 2000). This is in large part because they want to validate external illusions about their intellectual gifts are correct and use them to boost their self-esteem (Schubert and Bowker, 2017). However, it is undeniable that success at the doctoral level is not determined by a single factor, intelligence, but by a combination of multiple factors, which involves motivation and mental toughness at the individual level; school climate and faculty support at the organizational level; and institutional culture at the societal level. Ph.D. students with IP, by focusing too much on the role of intelligence in the learning phase, may attribute their failures to a lack of ability when they faced frustrations in their research, further exacerbating the sense of impostorism.

Fourth, IP is a habit-related phenomenon that can date back to early stages in the life course, i.e., deeply influenced by the family (Clance and Imes, 1978). IP feelings seem to be predicted by parenting patterns, suggesting family environments emphasizing grade-related achievement are associated with higher occurrences of IP (King and Cooley, 1995). Traditionally, in various studies on the influence of family background on children's educational opportunities and outcomes, students from low-income families are generally considered to be in a disadvantaged position. However, studies have found that experiences of IP were evident, regardless of the home background (Nori and Vanttaja, 2022), though be differences in the degree of IP. For example, doctoral students from the working class or low-income families typically face more barriers such as financial pressures and cognitive limitations, in large part because they are the first generation of college students in their families. Ph.D. students from the middle- or upper-class families, on the other hand, are under tremendous pressure to succeed from their families, which leads them to feel insecure about their abilities and fear that they will not be able to surpass the success of the previous generation. In a word, both factors contributed to the experience of IP among doctoral students. Certainly, first-generation Ph.D. students tend to experience IP more frequently and to a greater extent (Terenzini et al., 1996). Thus, it is evident that the emergency of IP among doctoral students is influenced by deeper and more complex reasons. It cannot be solely attributed to individual imagination or perception but requires more comprehensive and scientific verification.

3.3. Correlation of IP with doctoral students' mental illness

Previous studies have shown that IP is significantly associated with psychological problems among doctoral students. On the one hand, Ph.D. students with IP are accompanied by a variety of psychological problems including anxiety, fear, and depression (Craddock et al., 2011; Lane, 2015). These psychological problems can, in turn, lead to behavioral tendencies such as academic burnout, procrastination, or perfectionism. Poor academic performance and academic psychological problems can further contribute to the development of IP in doctoral students, generating a cycle. Specifically, discrepancies between reflected evaluations and one's ideal self-image (what one would like to be) can lead to depression. Likewise, discrepancies between reflected evaluations and ones perceived standards can spawn anxiety and distressing emotions (Higgins, 1989). Due to impostors' relentless pursuit of success and their difficulty accepting affirmation when they achieve and falling short when they fail, they are often under increasing stress and highly vulnerable to psychological problems. These psychological crises are often implicit and can subconsciously weaken an individual's ability to function at the highest level, resulting in a gradual decline in academic performance and satisfaction (Hirschficld, 1982; Zorn, 2005; Whitman and Shanine, 2012; Pervez et al., 2020). On the other hand, IP can also act as a mediator, moderating the relationship between perfectionism or procrastination and anxiety. For example, a survey of 169 Russian college students indicated that imposter Phenomenon fully mediated the link between perfectionism and anxiety, whereas it served as a partial mediator between perfectionism and depression (Wang et al., 2019). Additionally, IP can effectively mediate the relationship between procrastination and anxiety (Maftei et al., 2021). Although some studies have generally highlighted the negative effects of IP on individuals' psychological and behavioral performance and ignored its beneficial side, the above findings reveal that we are supposed to view IP rationally and take advantage of its positive effects.

3.4. Scales measuring IP

Overall, the Harvey Impostor Phenomenon Scale (HIPS) and the Clance Impostor Phenomenon Scale (CIPS) are two widely used measures for imposter feelings. Specifically, HIPS was constructed by Harvey in 1981 that aims to evaluate the individuals' perception and

cognition regarding IP. It consists of 14 items and scored on a scale ranging from 1 (not at all true) to 7 (completely true). Such measure was valided among 74 students and the internal consistency coefficient was 0.85 (Harvey, 1981). Subsequently, Clance developed the Clance Impostor Phenomenon Scale, and identified a three-factor model including self-doubts about ones' own intelligence and abilities (Fake), tendency to attribute success to chance/luck (Luck), and the inability to admit a good performance (Discount) (Clance, 1985). It consists of 20 items and scored on a scale ranging from 1 (not at all) to 5 (fully). After examining the clinical and non-clinical samples, the scale was found to have a Cronbach coefficient between 0.84 and 0.96 (Clance, 1985). In summary, both these two scales have a stable factor structure and are practical tools for measuring IP among clinical or no-clinical sample, and confirmed by previous studies (Edwards et al., 1987; Chrisman et al., 1995). In comparison, CIPS is capable of independently identifying impostors and non-impostors in both clinical and non-clinical samples. Therefore, CIPS is more sensitive and reliable, and is considered as the "gold standard" for measuring IP (Holmes et al., 1993).

In terms of specific applications of the scale, the CIPS has been used to assess the impostor phenomenon in various population, including female Hebrew students (Yaffet, 2020), Romanian psychology students (Maftei et al., 2021), and others. For the measurement of IP among doctoral students, Nori and Vanttaja developed the Doctoral Impostor Syndrome (DIS) scale, according to a survey in 2015 that included 1,694 Finnish doctoral students. As the original questionnaire covered a broad range of topics and consisted of 70 items, Nori et al. simplied the questionnaire and selected 10 items in relation with IP of doctoral students in the DIS scale, such as their family background, social network, professional socialization, and personal abilities (Nori and Vanttaja, 2022). In summary, the DIS scale provides a more accurately and scientifically grounded assessment of IP among Finnish doctoral students. Given the lack of measurement scales tailored to doctors students' IP, researchers can draw on the methodology employed by Nori to develop other scales that explore doctors students IP, thereby further enriching the fields' findings.

4. Discussion

Since the concept of impostor phenomenon was introduced, attention to it has increased dramatically in the past decade, both in academic research articles and in the popular media (Feenstra et al., 2020). In early studies, psychologists and social scientists primarily focused on individual traits and behaviors, exploring the impact of IP on an individual's mental health and career development. For example, much of the research on IP focused on the early stages of an individual's career, such as medical interns, and has explored the dilemmas they encounter in their professional development. Studies on similar groups suggests that IP is not unique to a particular culture but may be a product of professional characteristics, namely, IP plays an important role in successful career development. As time went on, researchers began to shift their focus toward the social, cultural, and institutional dimensions of IP and actively explored methods to address it. These studies have not only revealed the prevalence of IP but also provided important insights into its negative impact on individuals and groups. There is no doubt that the research conducted over the past few decades has deepened our understanding of IP and equipped us with frameworks and strategies to recognize, comprehend, and address this psychological phenomenon.

In recent years, IP among doctoral students has gradually become a research hotspot in academia. This is due to the profound changes in the global higher education environment, the pervasive crisis of uncertainty worldwide, and the continuous conflicts and challenges individuals face. For doctoral students, the most prominent issue is academic career development. In the past, academic profession was regarded as a "Linear Pipeline" for post-degree career development, while entering a non-academic profession was seen as a "Leakage of the Pipeline" (Fuhrmann et al., 2011). Nowadays, tenure opportunities are becoming less and less available, the academic career market is saturated, and new modes of selection and recruitment have been introduced (Benz et al., 2020). There is data indicating that in 11 countries, about 10% of doctoral graduates found jobs that were not related to their specialization or only required a lower degree (Auriol, 2007). Graduates have realized that a Ph.D. degree is no longer a passport to a lifelong job. They need to acquire transferable and flexible skills that can in turn adequately condition them to be prepared for the changing academic market (Delanty, 2001). Doctoral students thus oscillate between the development of a professional identity (which is critical to career success) and that of a professional scholar (which is critical to academic success), moving between different roles and expectations and trying to form both identities (Austin and McDaniels, 2006). In summary, with the changing academic career landscape and increasing competition, the psychological pressures on doctoral students have intensified, which exacerbate doctoral student's perception that they do not have the ability to reach the requirements of academic career, and finally leading to a growing number of cases of IP among doctoral students.

The research reviewed and synthesized nearly 40 years of research, theories, and frameworks on the impostor phenomenon. After conducting a systematic and comprehensive review, we have found that previous research on IP among doctoral students has explored various key areas. We examined common experiences, emotions of self-doubt, and cognitive patterns among doctoral students, explored various dimensions of mental health, including stress, anxiety, depression, and other psychological indicators relevant to the doctoral student population. In addition, we summarized existing literature and research findings to determine whether individuals who experience the impostor phenomenon are more prone to mental health issues or vice versa. Last, we focused on identifying and examining existing scales used to assess the impostor phenomenon and evaluated various scales specifically designed to measure IP among doctoral students. The research findings provide updated insights into the impostor phenomenon. And one of the contributions of our study is to summarize the characteristics of doctoral students experiencing IP, including low self-efficacy, a tendency toward negative attributions, heightened anxiety, and lower academic performance. In conclusion, within the existing research, IP is indeed described as a combination of various concepts, representing a comprehensive description. We tend to view it as a distinct psychological pattern in which individuals doubt their achievements, believe their abilities do not match their accomplishments, and live in fear of

eventually being exposed. The studies also highlight the impact of the impostor phenomenon on the mental health of doctoral students and explore the potential relationship between mental health status and IP. Additionally, the research results provide an overview of scales that can be used to specifically measure IP among doctoral students, offering convenience for future research. Overall, the research findings contribute to a deeper understanding of the impostor phenomenon and its effects on the well-being of doctoral students.

The former studies on IP among doctoral students have indeed made significant contributions. However, there are certain gaps that require addressing. For instance, research on interventions still needs to be enriched. Existing studies point out how to curb IP among doctoral students, for example, by considering that the more confident doctoral students are in their abilities, the more likely they are to succeed in their academic research. Therefore, supervisors can help doctoral students correctly perceive their abilities when they express imposter emotion (Coryell et al., 2013). If individuals with IP attribute positive outcomes to luck, their misattributions and perceptions of achievement can be changed by identifying stable, positive personality traits associated with their success (Wang et al., 2019). It should be noted that the emergency of IP among doctoral students is not only about individual academic literacy but also directly linked to the mismatch between the purpose of doctoral education, the student's vision, and their actual situation both in and out of academia. Accordingly, when suggesting countermeasures, we should not only stop at a single surface level, but also place it in a more macro context for comprehensive consideration and further suggest targeted recommendations. For example, how to prepare Ph.D. students for multiple career paths, and how to enhance the adaptability of Ph.D. students from academic to non-academic tracks are all questions that deserve careful consideration in future research (see Table 2).

Moreover, the existing research on IP among doctoral students offers many exciting possibilities for further investigation. Chance's study highlighted that IP, especially the internal experience of intellectual phoniness, is prevalent and intense among high achieving women (Clance and Imes, 1978). Indeed, previous studies have suggested two types of IP: "True" impostors characterized by the negative self-views associated with the construct definition, and more "strategic" impostors who seem to be less encumbered by self-doubt. It is assumed that "strategic impostors" are characterized by a form of deliberate self-presentation (Leonhardt et al., 2017). Therefore, it is necessary to treat IP among doctoral students with more caution. In the current educational environment, Ph.D. students undergo a heavy competitive selection process to gain admission, which serves as evidence of their ability to complete their studies. Thus, they are in a very different situation from genuine impostors who lack ability and intellectual talent. The case in point is researchers can explore the hypothesis that IP is driven not only by suspicion but also by fear (Lee et al., 2020). By creating novel scales and distinguishing various types of impostors, researchers can examine how fear and suspicion contribute to the development of IP among doctoral students. Additionally, it is crucial to consider the impact of cultural and social backgrounds on doctoral education systems and how they shape doctoral students' experiences with the Impostor Phenomenon. Conducting comparative or country-specific research can help identify differences in these experiences and challenges across districts and geographical locations, contributing to the advancement of global higher education. By continuing to explore new avenues of research, we can better understand the impostor phenomenon among doctoral students.

5. Limitations

There are some limitations to this study. First, it is important to note that this study exclusively focused on English-language publications, potentially overlooking the extensive utilization of other languages such as Spanish, French, and Russian in academic publishing and dissemination. Consequently, there is a possibility of incomplete incorporation of research findings. Second, the scoping review aimed to provide a broad overview of the existing evidence base related to a particular topic, without considering the quality of the literature. However, not assessing the quality of the literature may lead to a lack of accuracy in the conclusions drawn from them. Furthermore, the conclusions drawn from these studies may not be verified due to the lack of actual inquiry. Therefore, it is important for future reviews to consider the quality of the literature when conducting a scoping review, to ensure that all relevant studies are included and that the conclusions drawn from these studies are accurate and reliable.

6. Conclusion

This review explored four key aspects of IP in doctoral students, including manifestation characteristics, reasons for its emergence, correlation with psychological problems, and scales for evaluation. In conclusion, current research indicates that this population may be particularly susceptible to experiencing feelings of intellectual fraudulence and self-doubt. Doctoral students with IP often struggle with low self-efficacy and suffer from negative attributions and fears, which can hinder their academic performance and derail their academic paths. Moreover, factors such as inadequate academic preparation and support, and the influence of the genius culture can all contribute to the emergence of IP among doctoral students and may have negative impacts on academic progress and mental health. Research has shown that symptoms of anxiety, depression, and burnout are common among this population, and may be related to feelings of imposture as well as other factors. Evidence also suggests that poor mental health can have negative impacts on academic success, and that interventions aimed at improving mental health may also lead to improvements in academic outcomes. Although there are two commonly used scales, HIPS and CIPS, that can measure the impostor phenomenon (IP), the DIS scale developed by Nori is considered more appropriate in assessing IP among doctoral candidates specifically. It is important to improve doctoral students' comprehension of IP to address this issue and promote their success in academia. By conducting further research and collaborating with stakeholders, we can work together to create a more equitable and inclusive learning environment that empowers doctoral students to achieve their academic and professional goals. Overall, it is critical that we continue to prioritize the well-being and development of doctoral students in our efforts to improve the impostor phenomenon.

TABLE 2 Key characteristics of reviewed studies.

Author (Year)	Country	Sample size	Discipline	Study purpose	Measure	Main findings
Niles (1994)	America	*N* = 90	Clinical Psychology	If graduate students in clinical psychology programs differ from Ph.D. graduates and experienced clinicians.	Professional Attributional Style Questionnaire; the Zelen-O″Reilly Scale.	Impostors scored significantly higher on measures of external locus of control than non-impostors
Chrisman et al. (1995)	America	*N* = 269	Psychology	Compare the PFS with the CIPS.	PFS; CIPS.	Both CIPS and PFS had similar internal consistency reliability. CIPS is a more useful instrument for clinical and research purposes.
Ewing et al. (1996)	America	*N* = 269	NA	Examine whether IP exists among African American graduate and professional students.	Online questionnaire.	There was no correlation between racial identity attitudes and IP.
Henning et al. (1998)	America	*N* = 477	Medicine	Examine the severity of perfectionism and the IP in health profession students, and assess the relationship between these personality traits and students' psychological adjustment.	The Brief Symptom Inventory (BSI); The Multidimensional Perfectionism Scale; CIPS.	Strong associations were found between psychological distress, perfectionism and impostor feelings and these character traits were stronger predictors of psychological adjustment than most of the demographic variables associated previously with distress in health professional students.
Golde and Dore (2001)	America	*N* = 4,114	Arts and science	Provide a snapshot of the experiences of doctoral students in the arts and sciences.	The Survey on Doctoral Education and Career Preparation.	Many students did not understand what doctoral study entails, how the process works, or how to navigate it effectively.
White (2001)	America	*N* = 158	Clinical Psychology	Explore the nature of perceived fraudulence from a perspective informed by self-psychological theory.	Online questionnaire.	One dimension of self-cohesion (goal instability), as well as shame, are significant predictors of perceived fraudulence in this sample.
Castro et al. (2004)	America	*N* = 213	Psychology	Examine individuals who were parentified as children are more likely to report impostor feelings in adulthood.	The Parentification Questionnaire; CIPS.	The impostor phenomenon can be explained, in part, as a significant long-term effect of childhood parentification.
Gibson-Beverly and Schwartz (2008)	America	*N* = 170	NA	Examine the utility of attachment and entitlement as predictors of the impostor phenomenon in female graduate students.	CIPS; Entitlement Attitudes Scale (EAS); Experiences in Close Relationships Scales–Revised (ECR-R).	Individuals with high levels of self-reliance/self-assurance entitlement are able to associate positive feedback with stable internal attributes.
Cope-Watson and Betts (2010)	Canada	*N* = 2	NA	Connect the theoretical frameworks around IP to our experiences as women graduate students in a doctoral program.	Autoethnography.	The tensions created between an externally imposed perception of academic ability and an internally imposed perception of self-deficit can contribute to feelings of inadequacy.
Craddock et al. (2011)	America	*N* = 6	NA	Explore IP feelings.	Interview.	IP feelings were a normal part of graduate study.
Knights and Clarke (2014)	England	NA	NA	Provide a brief examination of the literature on identity, insecurity and academic selves, particularly those in business schools.	Semi-structured interview.	Academic settings in higher education can trigger impostor phenomenon.

(Continued)

TABLE 2 (Continued)

Author (Year)	Country	Sample size	Discipline	Study purpose	Measure	Main findings
Lane (2015)	America	*N* = 29	Business, Music, Engineering, Psychology, Counseling	Qualitatively explored IP.	Survey; interview.	Most offered specific examples of experiences consistent with the IP.
Aubeeluck et al. (2016)	England	NA	Medicine	Debate an issue.	Article review.	70% of the participants had frequent to intense experiences of IP.
Neureiter et al. (2016)	America	*N* = 212	Psychology	How IP functions in career development.	Questionnaire.	IP was relevant to career development in different ways at different career stages.
Schubert and Bowker (2017)	Canada	*N* = 304	Psychology	Examined how the Impostor Phenomenon relates to multiple dimensions of self-esteem.	CIPS, the Rosenberg Self-Esteem Scale.	People with low self-esteem were especially vulnerable to impostor feelings.
Villwock et al. (2016)	America	*N* = 2,612	Medicine	Describe levels of burnout and IP in medical students, and recognize demographic differences in those experiencing burnout and IS.	Survey.	Almost a quarter of male medical students and nearly half of female students experience IS and IS was found to be significantly associated with burnout indices.
Bothello et al. (2019)	England	NA	Management	One where the induction rituals both formal and informal are in many ways misaligned with the multi-dimensional roles of our profession.	NA	These students are noticeably more self- assured and motivated than their peers and less likely, we find, to suffer from feelings of imposterhood.
Chakraverty (2020)	America	*N* = 120	STEM	Explore different themes related to impostor phenomenon, as experienced by graduate students and postdocs in science, technology, engineering and mathematics (STEM) fields.	Open-ended survey.	Those experienced the impostor phenomenon in graduate school have attributed it to one's good luck and ability to pretend as well as other's kindness and poor judgment of skills.
Cohen and McConnell (2019)	America	*N* = 1,476	Arts, Sciences, Business, Library science	Examine the relationship between perceived characteristics of graduate school program environments and students' impostor feelings.	The 2013 Graduate Student Stress and Coping (GSSC) survey.	Students' perceptions of lower-quality mentorship, increased competition, and increased isolation are associated with more frequent impostor fears.
Gottlieb et al. (2019)	America	*N* = 18	Medicine	Analyze the existing literature on IS among practicing physicians and physicians in training.	Article review.	Gender, low self-esteem, and culture were associated with higher rates of IS.
Wang et al. (2019)	Russia	*N* = 169	Management, Economics, Business Informatics, Law, Program Engineering	Understand factors that put individuals with this particular profile at risk is important.	Mediated and moderated the link between perfectionism and psychological distress were examined.	IP fully mediated the link between perfectionism and anxiety, whereas it served as a partial mediator.
Chakraverty (2020)	Indian	*N* = 90	STEM	Explored various facets of impostor phenomenon in STEM.	Interview.	Progress and public recognition, comparing oneself with others, developing skills: public speaking and scientific writing, application of new knowledge, and asking for help triggered IP.

(Continued)

TABLE 2 (Continued)

Author (Year)	Country	Sample size	Discipline	Study purpose	Measure	Main findings
Cisco (2020)	America	*N* = 42	Art, English, Literacy, Math, Music, Science	In what ways are postgraduate students experience impostor phenomenon?	CIPS; interview.	The majority of the participants experienced IP and felt academically unprepared.
Lee et al. (2020)	America	*N* = 959	STEM, Medicine	How IP relates to self-evaluation.	CIPS.	Different types of IP included more strategic self-presentations of ability, and the defining feature of IP might be fear rather than self-doubt.
Meurer and Costa (2020)	Brazil	*N* = 181	Business	Analyze the relationship between IP and the academic behavior of postgraduate students in business.	Meurer and Costa Scale of Academic Behaviors Stricto *Sensu* (MCSABSS).	56.15% experienced high and intense impostor syndrome and presented high levels of distress.
Pervez et al. (2020)	America	*N* = 113	Management	Examine the prevalence of depression and anxiety Symptoms in management doctoral students.	Online questionnaire.	Management doctoral students experienced depression and anxiety symptoms at significantly higher rates.
Yaffet (2020)	Israel	*N* = 248	NA	Investigate the psychometric properties of the Hebrew form of the CIPS (HCIPS).	HCIPS, CIPS.	HCIPS was a sound instrument for assessing impostor feelings among female Hebrew-speaking students.
Maftei et al. (2021)	Romania	*N* = 130	Psychology	Explore the prevalence of the impostor syndrome and its associated factors.	CIPS.	56.15% experienced high and intense impostor syndrome and presented high levels of distress.
Nori and Vanttaja (2022)	Finland	*N* = 1,694	NA	Focus on the prevalence of IP among Finnish Ph.D. students.	DIS.	Impostor feelings occurred most commonly. The DIS formed an internally congruent gage.
Neufeld et al. (2023)	Canada	*N* = 1,450	Medicine	Explore the prevalence of IP among the students.	CIPS.	Students who are more self-determined (both in general and in medical school), and whose basic psychological needs are more supported in their medical program, will experience less frequent and severe IP symptoms.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

YW made significant contributions to the conception and design of this work, as well as interpreting the data, revising important intellectual content, and writing the manuscript. Meanwhile, WL oversaw the study's design, participated in data collection and analysis, and contributed to revision of the manuscript. All authors were involved in the manuscript's final version, which they approved.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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How to effectively overcome fixation: a systematic review of fixation and defixation studies on the basis of fixation source and problem type

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As a cognitive state that impedes idea generation, fixation has been well studied across various domains in relation to the cultivation of creativity. With the aim of contributing to the development of an effective approach to overcoming fixation in order to enhance creativity, a systematic review is conducted of 53 experimental studies concerning the source of fixation and the problem type, which are two critical factors influencing the effectiveness of defixation approaches. Based on the results, it is indicated that an enhancement of the search beyond the frame, constructed by either information that is externally provided or memory that is internally activated by information about the problem, is essential in overcoming fixation. Further, the elimination of fixation leads to an increase in solution rates of closed-ended problems. However, in open-ended problem solving, defixation does not necessarily lead to an improvement in the performance of problem solving, and an advancement can still be achieved by enhancing the search within the constructed frame even when there is no search beyond the frame. Accordingly, an examination of both beyond-frame searches and within-frame searches is essential for an effective defixation approach to enhance creativity in open-ended problem solving.

KEYWORDS

fixation, creativity, overcoming fixation, fixation source, problem type

1. Introduction

Creativity is considered to be a critical factor in the advancement of civilization (Hennessey and Amabile, 2010). Specifically, the term *creative society* has been coined to describe constantly changing modern society, and it is viewed as an expansion of the traditional perspective of the information and knowledge society (Reimeris, 2016). When confronting an unpredictable future in a rapidly changing world, cultivating individuals who are capable of facing these challenges becomes vital, and nurturing creativity is the first step to achieving this goal (Taddei, 2009). Accordingly, creativity is taken to be one of the most important issues in education around the world (Shaheen, 2010), and specialized pedagogy, which takes improving creativity as one of its main purpose, is well established. For instance, in response to escalating global competitiveness and rapid technological advancements, an increased emphasis on science and mathematics became imperative. This led to the inception of STEM education, an acronym representing Science, Technology, Engineering, and Mathematics, which has gained significant popularity since the year 2000 (Breiner et al., 2012). In STEM education, one of the key objectives is to enhance students' capabilities in solving complex real-world problems (Rifandi and Rahmi, 2019). Later, with the recognition of the growing need for creativity in education, the arts were integrated into STEM, giving rise to STEAM (Land, 2013; Henriksen, 2014). In this expanded framework, the cultivation

of creativity is expected as a learning outcome (Perignat and Katz-Buonincontro, 2019), and empirical studies further revealed the beneficial influence of STEAM on nurturing creativity (e.g., Conradty et al., 2020; Ozkan and Umdu Topsakal, 2021). In the light of this notion, numerous studies have been committed to developing effective approaches for enhancing creativity (e.g., Torrance, 1972) and to examining the factors that influence creativity, such as motivation (e.g., Collins and Amabile, 1999) and metacognition (e.g., Davidson and Sternberg, 1998). Among these factors, various studies reported that one phenomenon, fixation, significantly impedes creativity.

As early as 1,620, in his book *Novum organum,* Francis Bacon, who established the scientific research method of inductive reasoning, described four idols of the mind that mislead individuals' reasoning and interfere with scientific exploration. Specifically, Bacon (1902) stated that people tend to collect information which is supportive of the idea that they have adopted and overlook contrary information. Later, the tendency of being influenced by information that has been obtained was reported across various domains (e.g., confirmation bias, Wason, 1960; naive concept, Borun et al., 1993) and it was firstly empirically verified in the domain of Gestalt psychology. Specifically, in the study of solving insight problems, a type of non-routine problem that involves insight and one of the cognitive processes contained in creative problem solving (Hélie and Sun, 2010), individuals were found to be constrained by their prior knowledge of using tools and were not able to solve problems that required them to generate novel usage of tools (Maier, 1931; Duncker, 1945). Meanwhile, Luchins (1942) also reported that participants kept using recently learned arithmetic solutions even when such a solution was no longer applicable to solving a new problem. Later, Jansson and Smith (1991) revealed the tendency to keep copying obstacle features of given examples in solving design problems. Though these findings are termed differently, such as the Einstellung effect (Luchins, 1942), mental set (Wiley, 1998), functional fixedness (Duncker, 1945) and design fixation (Jansson and Smith, 1991), as they share a nature which illustrates the tendency of being fixated by certain information in problem solving, a unified name, fixation, is adopted in this paper to refer this phenomenon.

In problem solving, studies on fixation are well established. For instance, studies have been conducted to investigate what would fixate individuals (e.g., Wiley, 1998; Smith et al., 2017) and clarify the mechanism of how fixation influences problem solving (e.g., Ward et al., 2002; Bilalić et al., 2008). Importantly, as fixation is reported as an obstacle that suppresses the performance of solving problems which involve creative processes (e.g., Jansson and Smith, 1991; Wiley, 1998), and reducing fixation indicates an enhancement of creativity (e.g., Lu et al., 2017; Beda and Smith, 2022), the discussion of fixation and defixation is taken to be an important topic in the study of creativity (e.g., Loesche and Ionescu, 2020). Moreover, as individuals are usually unaware of being fixated (e.g., Bilalić et al., 2008), fixation is difficult to diminish. Accordingly, numerous researchers have focused on developing effective approaches to overcoming fixation (e.g., McCaffrey, 2012; Okada and Ishibashi, 2017; Sio et al., 2017). On the basis of these studies, reviews concerning various aspects have been performed from different perspectives. For instance, regarding fixation found in a specific domain, Sio et al. (2015) clarified the influence of a specific variable in terms of the fixation (Sio et al., 2015), and Alipour et al. (2018) identified the variables that induce fixation, and established a framework to illustrate the relationships of these factors. Further, in the context of specific cognitive processes, Beda and Smith (2022) investigated the mechanism of fixation induction and effective defixation approaches. In addition, based on a methodological perspective, Vasconcelos and Crilly (2016) provided an overview of experimental design and settings to suggest possible reasons for the mixed results obtained across different studies. Moreover, Sio and Ormerod (2009) conducted a statistical meta-analytical review of certain defixation approaches, providing empirical evidence to confirm their effectiveness. However, these reviews only focused on a certain defixation approach, a specific cognitive process or fixation found in restricted domains, and none of these studies systematically reviewed fixation or defixation from a holistic viewpoint. Critically, although the effect of the defixation approach is claimed to be different according to the source of fixation (Wiley, 1998) and the problem type (Sio and Ormerod, 2009), no review on fixation in problem solving has been conducted giving consideration to the source of fixation and the type of problem. Accordingly, in this study, on the basis of the axis of source of fixation and problem type, after reviewing the mechanisms of fixation induction that have been investigated in empirical studies, research that experimentally examined how fixation could be overcome is discussed with the aim of contributing to the development of an effective defixation approach for enhancing creativity.

2. Two axes: source of fixation and problem type

The first axis is the source of fixation. Based on previous studies, two sources of fixation are suggested in the present review. One is developed from external stimuli proposed in Vasconcelos and Crilly's (2016) review of variables manipulated in empirical studies of design fixation. In their review, external stimuli were suggested to be example solutions in design idea generation. In a more general setting, introducing external stimuli, such as the misleading cues given in studies involving Remote Associate Test (RAT) problems (e.g., Koppel and Storm, 2014; Sio et al., 2017) and solutions newly learned from the information provided (e.g., Bilalić et al., 2008; Blech et al., 2020), to induce fixation is a common approach to investigating the influence of fixation. Moreover, even though there is no external information, the performance of problem solving is still impeded by fixation that is induced internally. For instance, past experience of using certain tools is found to impair the generation of novel usage (Duncker, 1945). In this case, prior knowledge of tools, which is activated by problems that involve tool functions, becomes the fixation. Further, in studies which reported that experts were bounded by their expertise in certain domain (e.g., Wiley, 1998), domain knowledge that is activated by domain-related information in a given problem is another example of fixation induced by an internal source. In terms of memory activation, it suggested that fixation is induced by the manner in which activated knowledge is utilized (Agogué et al., 2014). Specifically, they claimed that generating a solution based solely on the knowledge that is spontaneously activated by the source without any further alteration is considered to be fixated. Building on this perspective, our current review proposes that the sources of fixation can be categorized into two types. The first type, which we term *misleading information*, refers to fixation that is triggered by memory related to externally provided information, such as examples. The second type, termed *problem information-related memory*, relates to fixation originating from the long-term memory associated with the problem itself, such as prior knowledge.

The present review also distinguishes problems as being closed-ended or open-ended. Traditionally, problems are differentiated as being well-defined and ill-defined according to the condition of the initial state, the operator, and the goal of the problem (e.g., Reitman, 1964; Newell, 1993).

The problem type is critical in cognitive studies, since different cognitive processes are expected in solving different types of problem (Schraw et al., 1995). However, it is argued that this classification of problems is obscure (Simon, 1973). Therefore, instead of this traditional differentiation, studies adopt an alternative classification by distinguishing problems as being closed-ended and open-ended based only on the goal status. Specifically, in terms of goal status, the number of solutions for closed-ended problems is limited, while the number of solutions for open-ended problems can be unlimited. Additionally, the two types of problems are also differentiated by who defines the goal: the goal of a closed-ended problem is set by the problem giver, whereas the goal of an open-ended problem is set by the problem solver. In terms of the search in problem space, problem solvers can only solve closed-ended problems if they conduct their search within the frame which contains the correct solution. In contrast, there is a personal standard for identifying the correct solution in solving open-ended problems; therefore, problem solvers can address open-ended problems by searching within any frame. Importantly, goal status affects the effectiveness of specific defixation approaches (Sio and Ormerod, 2009). Therefore, considering the type of problem in such a categorization is essential for fixation studies. As such, in addition to the source of fixation, the present review also establishes an axis of problem type to clarify whether a problem's goal status—closed or open—influences how fixation is induced and eliminated.

3. Method

3.1. Inclusion criteria

A systematic review of studies on fixation was conducted to examine the mechanism of fixation induction and effective defixation based on the two axes of fixation source and problem type with the aim of contributing to creativity improvement. The following criteria were proposed to select the papers for the present review. First, the study was required to be an empirical one that adopted experiment as the main research approach, as the statistical analysis of experiments provides results that can be generalized. Second, a standardized experiment was generally required. However, as studies have reported that setting a control condition, i.e., the condition without intervention, is challenging for practical reasons (e.g., Viswanathan et al., 2014), the studies included in the current review were required to have a baseline condition, along with Randomized Condition Treatment, to ensure both the validity and reliability of the experiments. Third, although fixation has been well-studied historically across various domains, such as philosophy and sociology, as the current review focuses on the mechanism of fixation induction and fixation mitigation, studies that discussed fixation/defixation within the domain of cognitive science and psychology, particularly those involving problem solving, were selected. Finally, to ensure the quality of the selected papers, they were required to be peer-reviewed articles written in English.

3.2. Approach to search

Literature was collected by the following steps. Firstly, a search of Google Scholar, ScienceDirect, JSTOR, PsycINFO and ERIC was conducted. In the study of fixation, distinct terms are coined for this phenomenon across different domains. For instance, Maier (1931) described the constraint of prior knowledge in using tools as functional fixedness, while Wiley (1998) termed the constraint of prior knowledge in solving RAT problems as mental set. However, the unified terminology adopted in the current study, i.e., fixation, is often employed in general settings and refers to distinctive concepts across various domains. Accordingly, the keywords for the literature search were selected according to previous studies on fixation rather than using the single term *fixation*. Specifically, the keywords: *functional fixedness, mental set, mental ruts, Einstellung effect*, and *design fixation* were used in the search for article titles in the search in Google Scholar and for titles and abstracts in the search in the rest of the databases. Next, to include studies involve this phenomenon in a more comprehensive scope, a backward search (i.e., examining the citations in the selected literature) and a forward search (i.e., examining the citations of the selected literature) were conducted as a further step in the literature search. Further, though studies claimed that fixation might bring advancement (e.g., Youmans and Arciszewski, 2014), as this review focused on the positive effect of overcoming fixation, studies which discussed the advancement of fixation in problem solving were excluded. Finally, studies that discussed similar research questions and attained similar results with similar explanations were carefully examined and basically selected by the date of publication, as later studies were conducted on the basis of older studies.

4. Results

Following these three steps, 53 articles meeting the seven selection criteria are systematically reviewed in present study. Based on the two axes of fixation source and problem type, the reviewed studies are categorized in Table 1 and the critical information in these articles is sorted in Tables 2, 3. Further, as the main purpose of this review is to identify a preferable defixation approach, a perspective for characterizing the expected cognitive process of effective defixation for individuals is constructed in Figure 1. As depicted in the figure, closed-ended and open-ended problems are categorized into two distinct sections based on their different mechanisms for achieving the expected effects on the solution in problem solving. Specifically, fixation in closed-ended problems can be mitigated by conducting a beyond-frame search, resulting in enhanced solution rates. Similarly, conducting a beyond-frame search is also essential for mitigating fixation and consequently enhancing creativity in open-ended problem solving. However, in solving open-ended problems, even when fixation is not mitigated, creativity can still be improved through within-frame searches. To achieve successful defixation, approaches that facilitate beyond-frame searches are effective. Additionally, while there are approaches that can indirectly promote beyond-frame searches, their efficacy depends on the source of fixation. For instance, approaches which provide opportunities for reflection prove effective in mitigating

TABLE 1 Categorization of reviewed studies on the basis of two axes.

	Closed-ended problems	Open-ended problems
Misleading information	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13	29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45
Problem information-related memory	14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28	22, 37, 46, 47, 48, 49, 50, 51, 52, 53

The numbers in the matrix are the No's of reviewed studies shown in Tables 2, 3.

fixation when the fixation is either induced by misleading information or problem information-related memory. Moreover, approaches designed to allow a decay of misleading information are also effective in reducing fixation.

Based on this perspective, first it is discussed how fixation is induced by misleading information and problem information-related memory in closed-ended problems. Next, approaches that are effective in overcoming the fixation induced by these two sources are reviewed. Then the mechanism of fixation induction and the defixation approaches investigated in the studies involving open-ended problems are examined. Finally, limitations of this review are indicated and future studies are suggested.

TABLE 2 Fixation/defixation studies involving closed-ended problems.

No.	Reference	Type of task	Fixation				Defixation		
			Source		Effect on problem solving	Proposed main mechanism	Approach	Effect on problem solving	Proposed main mechanism
1	Luchins (1942)	Arithmetic problem	Misleading information	Newly learned arithmetic solution	Makes individual repeatedly use this learned solution and makes it difficult to find another solution when the learned one is not applicable	This effect is not a fundamental feature of human behavior, but the result of intelligent assumptions with consideration of characteristics of the whole situation	N/A	N/A	N/A
2	Dunbar (1993)	Scientific discovery		Newly learned concepts	Individuals keep using goals that are developed on the basis of the newly learned concepts to deal with inconsistent experimental data	N/A	N/A	N/A	N/A
3	Munoz-Rubke et al. (2018)	Insight problem		Newly learned knowledge of tool function	Impedes individual's novel usage of tools in simple problems regardless of learning modality	Recently learned inaccurate experience biases the search process for novel solutions	Failure experience of physical interaction	Functional fixedness disappears after initial failure in physical implementation	Information accessed is changed by current task goal and modified by experience
4	Sheridan and Reingold (2013)	Chess		Suboptimal familiar solution	Biases expert and novice chess players to focus on the area related to a suboptimal familiar solution and impedes problem solving performance	Activated familiar solution directs individual's attention towards information related to the familiar solution and suppresses the discovery of other solutions	Blunder solution	Increases solution rates by making all experts and the majority of novices gradually disengage their attention from the blunders of the familiar solution and avoid choosing them	Blunder solution provides feedback indicating that the familiar solution is not optimal

(Continued)

TABLE 2 (Continued)

No.	Reference	Type of task	Fixation				Defixation		
			Source		Effect on problem solving	Proposed main mechanism	Approach	Effect on problem solving	Proposed main mechanism
							expertise	experts who discover the optimal solution gradually disengage attention from the distracting solution	N/A
5	Bilalić et al. (2008)	Chess		Suboptimal familiar solution	Makes expert chess players subconsciously focus on the relevant area on board and suppresses recognition of the optimal solution	Experts' schema is activated when the situation is recognized as applicable; this schema directs attention to gathering compatible information and drives attention away from irrelevant information, suppressing the discovery of other solutions	N/A	N/A	N/A
6	Blech et al. (2020)	Arithmetic problem		Newly learned arithmetic solution	Makes individuals repeatedly use this learned solution and makes it difficult to find another solution when the learned one is not applicable	The activated memory of inappropriate information drives individuals to pay attention to perceiving elements that are related to the activated inappropriate elements	N/A	N/A	N/A
7	Neroni and Crilly (2021)	Arithmetic problem		Newly learned solution	Makes it difficult for individuals to find an optimal solution when the learned one is suboptimal	N/A	Experience of demonstrating vulnerability	Decreases fixation	Defixation is achieved by the enhancement in the recognition and being alert to fixation, the memory of the experience of being fixated, and the new information provided by feedback
							Instructions on	No effect	N/A

(Continued)

TABLE 2 (Continued)

No.	Reference	Type of task	Fixation				Defixation		
			Source		Effect on problem solving	Proposed main mechanism	Approach	Effect on problem solving	Proposed main mechanism
8	Vallée-Tourangeau et al. (2011)	Arithmetic problem		Newly learned solution	Makes it difficult for individuals to find an optimal solution when the learned one is suboptimal	N/A	Solving problem through physical manipulation of real objects	Increases solution rates and decreases usage of newly learned solution	The rich and dynamic perception from the interaction with real objects draws individuals' attention to problem features which contribute to adopting other solutions
9	Storm and Angello (2010)	RAT problem		Misleading cues	The strong association between misleading cues and RAT problem impedes individuals' solution rates	N/A	Retrieval induced forgetting (RIF)	The more RIF exhibited, the more problems solved by those who are misled by cues	Inhibition underlies RIF and inhibition in the accessibility of inappropriate solutions helps individuals to defixate
10	Koppel and Storm (2014)	RAT problem		Misleading cues	The strong association between misleading cues and RAT problem impedes individuals' solution rates	N/A	Retrieval induced forgetting (RIF) + incubation	The effect of RIF in improving solution rates is reduced by incubation; low-RIF individuals solve more problems with incubation whereas high-RIF individuals solve more problems without incubation	Incubation effect can be partially explained by forgetting hypothesis
11	Kohn and Smith (2009)	RAT problem		Misleading cues	The strong association between misleading cues and RAT problem impedes individual's solution rates	N/A	Incubation with the unsolved problem completely put aside	Increases solution rates of individuals who are misled by cues	Individuals work subconsciously during incubation
							Incubation with the presentation of unsolved problem	No effect	

(Continued)

TABLE 2 (Continued)

No.	Reference	Type of task	Fixation				Defixation		
			Source		Effect on problem solving	Proposed main mechanism	Approach	Effect on problem solving	Proposed main mechanism
12	Smith and Blankenship (1989)	Rebus problem		Misleading cues	The strong association between misleading cues and the rebus problem impedes individuals' solution rates	N/A	Incubation	Increases solutions rates and decreases the recall of misleading cues	Forgetting inappropriate information helps individuals to defixate
13	Sio et al. (2017)	RAT		Misleading cues	Strong association between misleading cues and RAT problem impedes individuals' solution rates	N/A	Alternating incubation	Increase in solution rates	Alternating between tasks prevents the repetition of recently retrieved items which strengthen fixation and provides time for decay of these retrievals
							Alternating incubation + incubation	Further increases solution rates when massed working with shorter incubation and distributed working provided with longer incubation	Break provides opportunity for problem-related activation to spread through semantic network and enhances the activation of remote associative items
14	Maier (1931)	Insight problem	Problem information	Prior knowledge of tool's function	Impedes individuals from generating new way of using known tools	N/A	N/A	N/A	N/A
15	Duncker (1945)	Insight problem		Prior knowledge of tool's function	Impedes individuals from generating new way of using known tools	N/A	N/A	N/A	N/A
16	Chesney et al. (2013)	Math problem		Prior knowledge of arithmetic strategy	Makes individuals spontaneously use typical arithmetic strategies that were acquired in past education practice and are suboptimal	The activated typical strategy from prior knowledge suppresses the activation of optimal strategy and forms a problem representation that only contains the typical strategy	N/A	N/A	N/A

(Continued)

TABLE 2 (Continued)

No.	Reference	Type of task	Fixation				Defixation		
			Source		Effect on problem solving	Proposed main mechanism	Approach	Effect on problem solving	Proposed main mechanism
17	Wiley (1998)	RAT problem		Domain knowledge related to the task	Biases individuals with higher domain knowledge resulting in lower solution rates and longer response times	Domain knowledge defines and narrows the search space	Instruction	No effect on high domain knowledge individuals, and fixates low domain knowledge individuals to increase solution rates	N/A
							incubation	only effective for fixation induced by external misleading cues found in low domain knowledge individuals to increase solution rates	N/A
18	Knoblich et al. (2001)	Insight problem		Prior knowledge of Roman numerals, arithmetic operations, and equals sign	Makes individuals unable to perceive the problem in a new way and constructs inappropriate problem representation, and this representation produces impasses	Initially constructed inappropriate representation biases individuals' attention	Constraint relaxation and chunk decomposition	Individuals who relax inappropriate constraints and decompose unhelpful chunks successfully solve the problem	Relaxing constraints and decomposing chunks helps individuals to achieve representational change
19	Tseng et al. (2014)	Insight problem		Prior knowledge of Roman numerals, arithmetic operations, and equals sign	Makes individuals unable to perceive the problem in a new way	Initially constructed inappropriate representation biases individuals' attention	Providing hints	Increase in solution rates	Directing attention away from the region that fixates i ndividuals to the region that is key for problem solving enhances representational changes

(Continued)

TABLE 2 (Continued)

No.	Reference	Type of task	Fixation				Defixation		
			Source		Effect on problem solving	Proposed main mechanism	Approach	Effect on problem solving	Proposed main mechanism
20	Moss et al. (2011)	RAT problem		Prior knowledge related to the task	Produces impasses	The item that is activated is repeatedly retrieved due to its recency and becomes the fixation in individuals' generate-and-test search through memory	Providing hints	Incidental hints are most effective in increased solution rates when provided at the point of reaching an impasse rather than before or delayed	Reaching an impasse makes individuals recognize the need for a new search; repeated retrieval of activated items in generate-and-test searches decreases the likelihood of using hints
21	Segal (2004)	Insight problem		Prior knowledge of shape	Makes individuals unable to perceive the problem in a new way	N/A	Incubation	Increase in solution rates but no difference in effects of incubation with different interval lengths	Incubation only serves as a diversion of the attention from the influence of the failed solution and this diversion enables individuals to apply new assumptions
22	Lu et al. (2017)	RAT problem + insight problem		Prior knowledge	Impedes individuals' problem solving performance	N/A	Alternating incubation	Switching tasks before reaching an impasse improves solution rates	Individual is not sensitive to recognizing impasses, instructing individuals to switch task before reaching an impasse reduces fixation
23	Beeftink et al. (2008)	Insight problem		Prior knowledge related to the task	Makes individuals unable to perceive the problem in a new way	N/A	Alternating incubation	Switching tasks before reaching an impasse increases solution rates more than being instructed to switch after reaching an impasse	Self-initiated switching allows individuals to choose their ending and starting of a task
24	Kiyokawa and Nagayama (2007)	Insight problem		Prior knowledge related to the task	Makes individuals unable to perceive the problem in a new way	N/A	Reflective writing	Increases solution rates	N/A

(Continued)

TABLE 2 (Continued)

No.	Reference	Type of task	Fixation				Defixation		
			Source		Effect on problem solving	Proposed main mechanism	Approach	Effect on problem solving	Proposed main mechanism
25	Knoblich et al. (1999)	Insight problem		Prior knowledge of Roman numerals, arithmetic operations, and equals sign	Makes individuals unable to perceive the problem in a new way	Prior knowledge constructs inappropriate representation of problem	Constraint relaxation and chunk decomposition	Individuals who relax inappropriate constraints and decompose unhelpful chunks successfully solve the problem	Relaxing constraints and decomposing chunks are individuals' responses to persistent failure and they help individuals to achieve representational change
26	Weller et al. (2011)	Insight problem		Prior knowledge of Roman numerals, arithmetic operations, and equals sign	Makes individuals unable to perceive the problem in a new way	N/A	Physical interaction	Increases solution rates and is more effective for more difficult problems	Providing opportunity to perceive problem in another way by directing attention to unrecognized aspects of the problem to enhance representational change
27	McCaffrey (2012)	Insight problem		Prior knowledge of tool's function	Makes individuals unable to generate novel use of tools	N/A	Generic-parts technique (chunk decomposition with function free descriptions for each part)	Increases solution rates, listing more target features, and listing key obscure features more often	N/A
28	Patrick and Ahmed (2014)	Insight problem		Prior knowledge related to the task	Makes individuals unable to perceive the problem in a new way	Prior knowledge constructs inappropriate representation of the problem	Training to enhance representational change	Increases solution rates	N/A

4.1. Fixation in closed-ended problems

4.1.1. Mechanism of the fixation induced by misleading information in closed-ended problems

Fixation induced by misleading information was firstly described by Maier (1930) and experimentally verified and named the Einstellung effect in Luchins' experiment with the water jar task (1942). In Luchins' study, participants were required to pour a certain amount of water using three water jars with different volumes. When participants learned a specific way of pouring water from practice problems, they kept using this method in solving new problems even when this method was suboptimal or inapplicable. This phenomenon was found not only in method information about pouring water when solving water jar problems, which is arithmetic problem solving. Individuals are biased by information given in solving different problems, such as in scientific discovery (Dunbar, 1993). Further, the information provided misled problem solvers regardless of the modality of the information. Munoz-Rubke et al. (2018) reported that the conformity to given information was observed regardless of whether the information was presented in text, video, or audio formats. Additionally, Sheridan and Reingold (2013)

TABLE 3 Fixation/defixation studies involving open-ended problems.

No.42	Reference	Type of task	Fixation				Defixation		
			Source		Effect on problem solving	Proposed main mechanism	Approach	Effect on problem solving	Proposed main mechanism
29	Jansson and Smith (1991)	Design	Misleading information	Example presented in line-drawing	Makes individuals copy features from example and impedes creativity	N/A	Instruction	No effect	N/A
30	Smith et al. (1993)	Creative idea generation		Example presented in line-drawing	Makes individuals copy the features of example	N/A	Inserting delay between example presentation and idea generation	No effect	N/A
							Instruction	No effect	N/A
31	Perttula and Liikkanen (2006)	Design		Example presented in picture with the instruction not to copy	Makes individuals generate fewer categories of ideas	Sampling probability effect	N/A	N/A	N/A
32	Viswanathan and Linsey (2013a,b)	Design		Example presented in line-drawing	Makes individuals copy features from example	N/A	Instruction with the explanation of flawed features	No effect	N/A
33	Viswanathan et al. (2014)	Design		Example presented as physical object	Makes individuals copy features from the example	N/A	Instruction	No effect	No explanation of why features are negative and sunk-cost effect
							Externalizing ideas	Decreases copying of negative features of example	Instant feedback makes individuals reflect and be aware of negative features
34	Chrysikou and Weisberg (2005)	Design		Example presented in line-drawing	Makes individuals copy features from example	N/A	Instruction	Decreases copying of the features of example	N/A
35	Ezzat et al. (2020)	Design		Example presented with the instruction not to copy by mentioning specific example	Makes individuals generate more fixated idea and decreases the originality of generated idea	Specific example in instruction makes individuals follow the path of least resistance	Instruction not to copy by mentioning example at a category level	Decreases the number of fixated ideas and increases the originality of generated ideas	High level of abstraction of the example forces individuals to reason beyond fixation

(Continued)

TABLE 3 (Continued)

No.42	Reference	Type of task	Fixation				Defixation		
			Source		Effect on problem solving	Proposed main mechanism	Approach	Effect on problem solving	Proposed main mechanism
36	Cardoso and Badke-Schaub (2011)	Design		Example presented in line-drawing and photo	Makes individuals copy features from example, decreases the ease of use and photo example decreases originality, whereas both of them increase manufacture	Pictorial examples are easily accessible and individuals tend to follow a solution which is already available	N/A	N/A	N/A
37	Agogué et al. (2014)	Design		Example that is identified to restrain the search range	Makes individuals generate fewer ideas with less originality	The knowledge spontaneously activated by example limits the search range due to its accessibility	Example that is identified to expand the search range	Increases the originality of generated ideas	Provides alternative solution in C-space (the space which involves the development of conceptualization in idea generation)
38	Atilola and Linsey (2015)	Design		Example presented in CAD, photo and sketch	Makes individuals copy features from examples but CAD and photo examples enhance feasibility	CAD and photo examples present the working principle well	N/A	N/A	N/A
39	Wilson et al. (2010)	Design		Superficially dissimilar example presented in line-drawing and text	Increases novelty, and induces higher variety than similar example	Leaving design space open to foster variation by transferring less attributes from example	N/A	N/A	N/A
				Superficially similar example presented in line-drawing and text	Increases novelty but decreases variety	N/A	N/A	N/A	N/A

(Continued)

TABLE 3 (Continued)

No.42	Reference	Type of task	Fixation				Defixation		
			Source		Effect on problem solving	Proposed main mechanism	Approach	Effect on problem solving	Proposed main mechanism
40	Cardoso and Badke-Schaub (2009a)	Design		Example presented in line-drawing	Makes individuals copy the features from example	Pictorial examples are easily accessible	N/A	N/A	N/A
				Example presented in text	Does not induce fixation	Examples with more abstractness and lower accessibility for generating design solutions, thereby leave room for more interpretations and active avoidance of copying			
41	Cardoso and Badke-Schaub (2009b)	Design		Example presented in line-drawing with incubation	Makes individuals copy the features from examples but increases the number of generated ideas	Pictorial examples are easily accessible	N/A	N/A	N/A
				Example presented in text with incubation	Makes individuals copy the features from the example	N/A			
42	Atilola et al. (2016)	Design		Example presented in line-drawing	Makes individuals copy the features from the example	N/A	N/A	N/A	N/A
				Example presented in text	Decreases copying from examples compared with line-drawing example and improves the quality of generated ideas	The text written in a function tree presenting the functions that need to be met without introducing the specific features of example			
				Example presented in line-drawing and text	Makes individuals copy the features from the example	N/A			

(Continued)

TABLE 3 (Continued)

No.42	Reference	Type of task	Fixation				Defixation		
			Source		Effect on problem solving	Proposed main mechanism	Approach	Effect on problem solving	Proposed main mechanism
43	Cheng et al. (2014)	Design		Example presented with incomplete information	Increases originality and positive self-evaluation	Incomplete information changes the format of the example; thereby influences how the information is processed and breaks away from the path of least resistance	N/A	N/A	N/A
44	Tsenn et al. (2014)	Design		Examples presented in CAD, photo and sketch with incubation	Decreases copying features from example, technical feasibility and contextual relativeness, but increases novelty	N/A	N/A	N/A	N/A
45	Kohn and Smith (2011)	General idea generation		Others' ideas	Makes individuals generate fewer ideas with less variety and narrower range of categories	N/A	Incubation	Makes individuals generate more ideas in more varied categories	Forgetting hypothesis
37	Agogué et al. (2014)	Design	Problem information	Prior knowledge related to task	Makes individuals tend to generate ideas in similar categories	The knowledge spontaneously activated by problem information limits the search range due to its accessibility	N/A	N/A	N/A
46	Ward (1994)	creative idea generation		Prior knowledge of animals on earth	Makes individuals' imaginative thoughts be bounded by prior knowledge	Items retrieved from the basic level exemplars are used as the base for generating novel ideas	N/A	N/A	N/A
47	Ward et al. (2002)	General idea generation		Prior knowledge related to task	Constrains individuals' imaginative idea generation	The retrievability of items predicts the activation of specific memory	N/A	N/A	N/A

(Continued)

TABLE 3 (Continued)

No.42	Reference	Type of task	Fixation				Defixation		
			Source		Effect on problem solving	Proposed main mechanism	Approach	Effect on problem solving	Proposed main mechanism
48	Moreno et al. (2016)	Design		Prior knowledge related to task	Makes individuals generate repetitive ideas	N/A	WordTree	Decreases fixation, increases novelty	Enables divergent mindset by designer-driven semantic re-representation
							SCAMPER	No effect in defixation but increases novelty more significantly than WordTree	Enables divergent mindset by proposing active questions to guide individuals, but the rework on developed ideas promotes fixation
49	Smith et al. (2017)	General idea generation		Prior knowledge related to task	Makes individuals generate fewer ideas with less novelty	N/A	Alternating incubation	Enhances the number of generated ideas for flexible categories and the stable, flexible mixed category, and both the number and novelty of generated ideas for flexible categories	Incubation effect is achieved by restructuring
22	Lu et al. (2017)	AUT		Prior knowledge related to task	Makes individuals generate ideas with less flexibility and novelty	N/A	Alternating incubation	Switching task before reaching impasses enhances flexibility, novelty and decreases fixation	Individual is not sensitive to recognizing impasse, and instructing individuals to switch task before reaching impasse reduces fixation
50	Madjar et al. (2019)	General idea generation		Prior knowledge related to task	Impedes creativity	N/A	Alternating incubation	Switching to in-domain task at a later time enhances creativity more	Sufficient immersion in the main task before incubation contributes to the enhancement of creativity

(Continued)

TABLE 3 (Continued)

No.42	Reference	Type of task	Fixation				Defixation		
			Source		Effect on problem solving	Proposed main mechanism	Approach	Effect on problem solving	Proposed main mechanism
51	Wang et al. (2022)	Drawing		Prior knowledge related to task	Makes individuals draw in the same way for specific themes	N/A	Providing an environment that blocks access to prior knowledge with instruction and reflection enhancing session	Increases creativity and enhances the awareness of fixation and the construction of subjective perspective	The inaccessibility of prior knowledge effectively inhibits memory retrieval, and the instruction and reflection prompts critical reflection
52	Bonnardel and Marmèche (2004)	Design		Prior knowledge related to task	Makes individuals only evoke intradomain sources	N/A	Example + expertise	Enhances the evocation of interdomain sources	N/A
53	Okada and Ishibashi (2017)	Drawing		Prior knowledge of realism	Makes individuals draw with realism	N/A	Imitating and appreciating the artwork in unfamiliar style	Increases creativity and enhances the construction of subjective perspective	The interaction with unfamiliar artwork helps individuals to achieve representational change, thereby to construct new perspectives and new patterns of drawing

demonstrated that the influence of the information provided affected not only novice problem solvers but also experts. Importantly, Bilalić et al. (2008) found that individuals were not conscious of such conformity and subjectively believed that they were exploring different solutions.

To clarify how individuals are fixated by information given, in other words, to examine the mechanism of the fixation induced by misleading information, Blech et al. (2020) replicated Luchins' experiment with the requirement of asking participants to think aloud during problem solving. Based on similar results and protocol data, this revealed that memory which was activated by the information given biased individuals to perceive elements that were related to this inappropriate information. Further, attention paid to inappropriate information activated memories related to the perceived elements. That is, fixation was induced in a cycle of misleading information activating related memory and the activated memory driving attention towards information that was related to the memory that had been activated. This interaction of memory, perception and attention was also revealed in chess problem solving from data about eye movements (Bilalić et al., 2008; Sheridan and Reingold, 2013). Additionally, this also showed that searching for an optimal solution was inhibited by a suboptimal solution rather than being completely blocked.

4.1.2. Mechanism of fixation induced by problem information-related memory in closed-ended problems

In Maier's (1931) experiment of solving problems by using tools in a novel way, it was found that participants were bounded by their prior knowledge of using pliers to cut or hold and failed to use the pliers as a pendulum to solve the problem. Later, similar results were reported in Duncker's (1945) candle task. In the task, participants were required to use a box which contained thumbtacks as a candle holder, and to tack it to a wall to solve the problem. As this is related to the phenomenon of being fixated in generating novel usage of tools, it is called functional fixedness. However, the phenomenon of being fixated by prior knowledge relating to a specific problem is not exclusive to tool function, rather it is reported in solving various problems, such as mathematics problems (e.g., Chesney et al., 2013), RAT problems (e.g., Wiley, 1998), and insight problems (e.g., Knoblich et al., 2001). Based on these studies, the memory activated by information related to a given problem is considered to be the fixation that inhibits problem-solving performance.

To clarify the mechanism, studies tracked the eye movement of participants who were solving a matchstick problem. The matchstick problem is a classical insight problem that is represented in an arithmetical form and solved by perceiving Roman numerals,

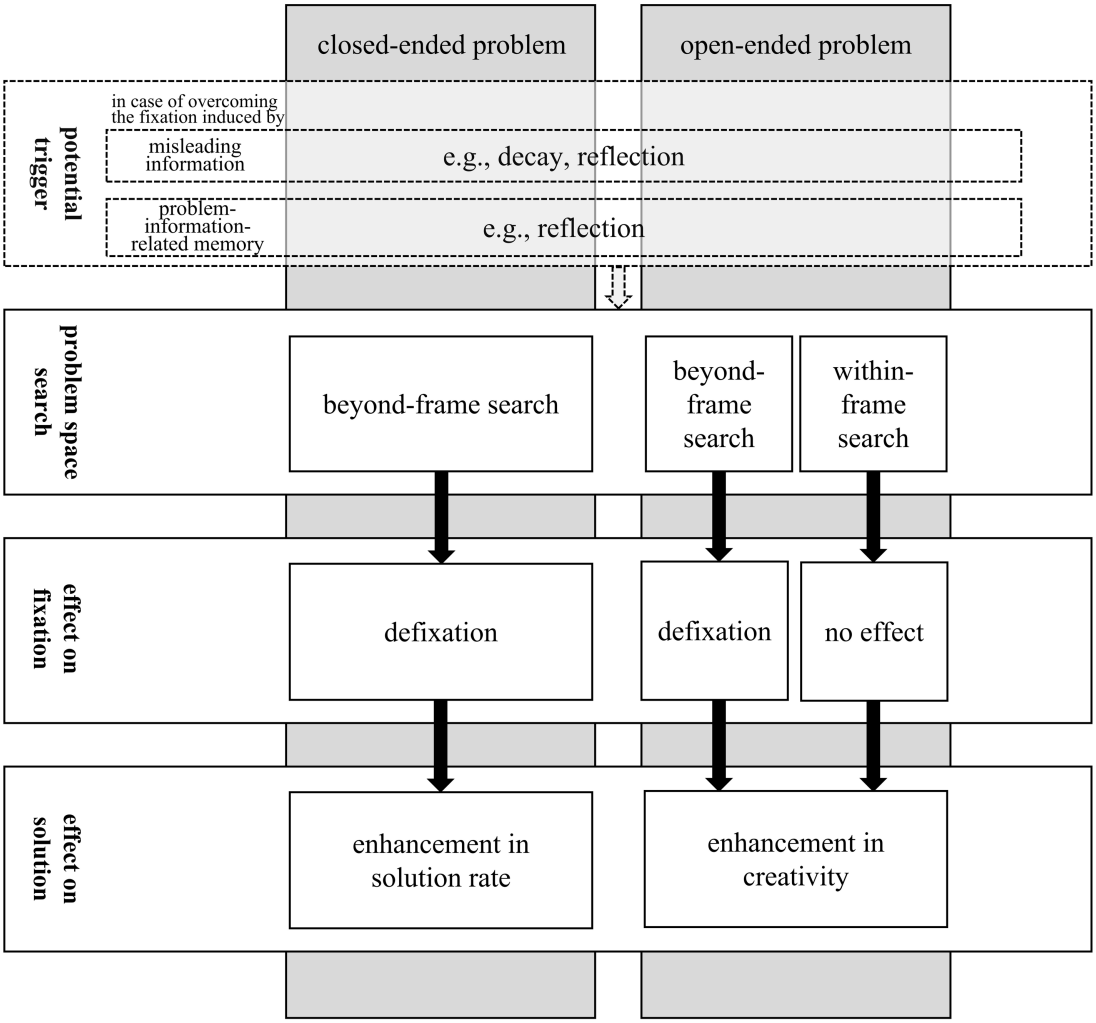

FIGURE 1
Perspective for characterizing the expected cognitive process of effective defixation for individuals.

arithmetic operations, and equals signs that are made up by matchsticks as separate matchsticks and moving these matchsticks to form new mathematical notations. According to the results, it was found that the arithmetical representation of the problem activated arithmetic related prior knowledge. Further, this activated prior knowledge constructed an inappropriate problem representation and caused impasses (Knoblich et al., 2001; Tseng et al., 2014). In the study of solving mathematical problems, similar results were reported by revealing that information about tasks activated the schema of a suboptimal approach, which was acquired from previous educational practice, in addition, the activated prior knowledge suppressed the activation of the schema of optimal solutions (Chesney et al., 2013). Further, in a study involving RAT problems, the protocol data indicated that individuals tended to conduct a generate-and-test search through memory after the initial failure (Moss et al., 2011). Based on the ACT-R model of memory, Moss et al. (2011) proposed that the fixation could be considered to be the construction of the baseline activation developed by recently retrieved items. Further, this baseline activation became the most retrievable due to its recency in generate-and-test searches. According to these findings, it could be concluded that information about the problem activates related memory. Later, if the activated memory is inappropriate, the problem cannot be solved, but this memory is repeatedly retrieved in the process of generate-and-test for problem solving due its retrievability. Finally, this repeated activation of inappropriate memory becomes the fixation that impedes problem solving.

Based on data which indicated the process of problem solving, studies identified the mechanism of fixation induction in closed-ended problems. Specifically, when misleading information is given, the memory of this information is activated when solving problems and the activated memory biases individuals to pay attention and perceive the information that is related to this retrieved memory. Fixation is induced in this interaction between memory activation, perception and attention. In contrast, when there is no misleading information, the information about the task activates the task-related memory depending on its retrievability and if this activated memory is inappropriate, it becomes a fixation due to the recency induced in the repeated retrieval in the generate-and-test search. Further, regardless of whether there is misleading information or not, the activated memory inhibits the activation of other possible solutions.

This inhibitory effect is similar to the interference effect that is claimed in response competition theory (Smith, 1995). Specifically, response competition theory suggests that the likelihood of retrieving a target response diminishes as the strength of competing responses increases, and this strength is determined by the number of competing responses and the association between the stimulus and these competing responses. In accordance with this theory, Smith (1995) believed that the retrieval of an inappropriate solution blocks the retrieval of the target solution, thereby fixation is induced by the block, which is strengthened by the retrieval of an inappropriate approach or inappropriate information.

4.1.3. Defixation approach for fixation induced by misleading information in closed-ended problems

To relax the fixation induced by misleading information, as a direct approach, studies examined the effects of instructing individuals not to utilize the given information. However, little effect is brought about by a mere warning (e.g., Neroni and Crilly, 2021). Moreover, such instruction is even argued to be another fixation (Blech et al., 2020), such as in a study which reported that the instruction of not to think about a white bear functioned as an accelerator of associative thinking about white bears (Wegner, 1989), which hinders problem solving. For this ineffectiveness, an individual's belief of not being susceptible to the negative effect of fixation themselves is proposed as a possible explanation (Neroni and Crilly, 2021). Specifically, Neroni and Crilly (2021) posited that individuals may not perceive themselves to be susceptible to fixation, even if when warned about this potentiality, they acknowledge that such a risk is applicable to people in general. Based on this view, researchers attempted to create a condition where individuals could receive feedback on how they were influenced by fixation, which was information that could not be obtained by being warned to defixate. For instance, a study revealed that providing instruction about fixation on the basis of having experienced failure in solving the water jar problem, rather than just giving instructions to avoid using the information provided, was effective in reducing the negative effect of misleading information and enhancing problem solving performance (Neroni and Crilly, 2021). Importantly, the reflection enhanced by failure-experience-based instruction increased the awareness of fixation and encouraged individuals to modify their behavior in solving problems. This was suggested to be one of the possible explanations for the effectiveness of this intervention. Similarly, providing the opportunity to interact with the physical environment by allowing participants to utilize actual water jars to solve the water jar problem could be seen as an approach which diminishes fixation by providing feedback through the interactive experience with dynamic environmental information (Vallée-Tourangeau et al., 2011). Further, the defixation effect was also indicated by the intervention of offering a second chance after the first failure in solving problems by the physical manipulation of real objects (Munoz-Rubke et al., 2018). Providing a blunder solution is a less straightforward approach to providing feedback for individuals to reflect and realize that the solutions they have tested are not optimal (Sheridan and Reingold, 2013). Based on the results of these studies, providing feedback to enhance reflection is indicated as an effective approach to defixation.

As the fixation discussed in this section is induced by misleading information, inhibiting access to the source of fixation to diminish the negative influence of inappropriate information is considered to be viable. This has been verified, for instance in studies that utilized Retrieval-Induced Forgetting (RIF) (Anderson et al., 1994), a memory phenomenon which indicates a tendency for the retrieval of a target item to suppress the accessibility of a competitive item. On the basis of results showing that the more RIF exhibited, the more RAT problems were solved, forgetting was proposed as a mechanism for the defixation effect (Storm and Angello, 2010; Koppel and Storm, 2014). Actually, forgetting is proposed as a critical mechanism for eliminating fixation (Beda and Smith, 2022). Specifically, forgetting is considered to be one of the possible cognitive processes that could explain how incubation mitigates the influence of fixation.

Incubation, which was originally proposed as one of the four stages of creative process (Wallas, 1926), is shown to be effective in relaxing the fixation induced by misleading information in various studies (e.g., Smith and Blankenship, 1989; Kohn and Smith, 2009; Sio et al., 2017). For the mechanism of the incubation effect, however, studies showed inconsistent results. Two main hypotheses are proposed: one claims that individuals still consciously work on problems even when they are away from problem solving. In contrast, another hypothesis suggests that individuals work subconsciously during a break. Based on results that showed that the incubation was effective when an unsolved problem was put aside and ineffective when the unsolved problem was presented during incubation, Kohn and Smith (2009) confirmed the unconscious hypothesis and rejected the conscious work hypothesis. Further, according to the results of a meta-analytic review of incubation studies, it was not only concluded that little supportive evidence was shown for the conscious work hypothesis, but also pointed out that more studies should be conducted to clarify the specific cognitive processes that account for unconscious hypothesis, as there were three proposals for explaining how incubation work: forgetting, spreading activation, and restructuring (Sio and Ormerod, 2009). The forgetting hypothesis, which is proposed by Smith and Blankenship (1989), claims that incubation is effective by inhibiting the access to the source of fixation and so enhances the possibility of obtaining the correct answer. This hypothesis is strongly supported by their study, which demonstrated that incubation not only improved the solution rates but also decreased the performance of recalling misleading cues. Nevertheless, significant results were not shown in the examination of whether the degree of incubation was affected by modifying the length of the incubation interval. Though there are more studies showing supportive evidence for the forgetting hypothesis (e.g., Wiley, 1998; Koppel and Storm, 2014), there is insufficient evidence indicating that the longer incubation interval, the more the performance of problem solving is enhanced. This is a critical objection for rejecting the forgetting hypothesis. In a study which verified the cognitive process of incubation by investigating how problem solving was influenced by switching between tasks, which is seen as a kind of incubation that provides the same type of experimental task as the incubation task (Smith et al., 2017), Sio et al. (2017) claimed that the spreading activation hypothesis (Yaniv and Meyer, 1987), which suggests that overlooked solution-relevant items are activated during incubation, was the mechanism of incubation, rather than forgetting. Specifically, a study conducted by Sio et al. (2017) reported that the efficacy of incubation in improving the solution rate of distributed work and massed work varied by the length of incubation interval. According to the activation-based processes of memory, a high activation of

misleading cues would cause quick decay. Therefore, this result was considered to support acceptance of the spreading activation hypothesis and rejection of the forgetting hypothesis, which assumes that longer incubation would always be more effective regardless of the work condition. However, data of a lexical decision task, which was designed to examine the effect of spreading activation, did not show any further supporting evidence.

From a holistic view, though these studies seemed to show evidence for claiming a different mechanism for incubation, they all demonstrate that fixation induced by misleading cues is eliminated by achieving a decay of its influence. Further, the decay of the influence from a fixated item would enhance the activation of a competitive solution and the performance of problem solving might be improved by this enhancement, since the fixated item is shown to suppress the retrieval of other competitive solutions. Moreover, fixation induced by misleading information could also be effectively diminished by approaches which commit to enhancing reflection by providing information for receiving feedback.

4.1.4. Defixation approach to fixation induced by problem information-related memory in closed-ended problems

In Wiley's (1998) study, which investigated the fixation induced by domain knowledge in solving RAT problems, two proposals were made by examining the effectiveness of two defixation approaches. First, it claimed that such fixation was not a subjective utilization of knowledge by showing the ineffectiveness of instructions to avoid the use of knowledge. Importantly, Wiley (1998) noted that the efficacy of a defixation approach may vary depending on the source of fixation. This conclusion was drawn from results showing that incubation was effective in mitigating fixation induced by misleading information, but not that induced by the domain knowledge activated by problem information. As incubation is a commonly employed defixation approach, subsequent studies have been conducted to further examine its effects and underlying mechanisms in overcoming fixation induced by problem information. For instance, Segal (2004) employed an insight problem, which involves fixation induced by an individual's prior knowledge of a given problem, to verify the mechanism of incubation at the point of reaching an impasse reported by participants. Specifically, the returning-act hypothesis, which suggests that a break does not lead to any cognitive process but only works as a diversion that allows individuals to restructure incorrect attempts, was proposed as the mechanism. The results which indicated that the effectiveness of incubation was independent of the interval length of incubation, and a no-cognitive-load-demanding task, which functioned as a weak diversion, indicated a weaker incubation effect, were claimed to be consistent with the prediction of this hypothesis. Considering the importance of an impasse, which was emphasized in Segal's (2004) experiment by claiming that individuals would spontaneously divert their attention from a given problem when they reached an impasse, this hypothesis is similar to the third main proposal of the cognitive process of incubation, the opportunistic assimilation hypothesis. Specifically, this hypothesis assumes that an individual becomes sensitive to the surroundings after reaching an impasse, and the restructuring or re-encoding of the unsolved problem, which contributes to successful problem solving, is enhanced by encountering environmental hints during incubation (Seifert et al., 1995). According to this hypothesis, the incubation effect reported in Segal's (2004) study could also be seen as the result of the problem restructuring which is prompted by perceiving environmental hints during a break after initial failure. Moreover, a stronger incubation effect found in an incubation task which demanded more cognitive load might be due to an encounter with richer information in the environment. Though further studies on examining whether the incubation is effective by diverting an individual's attention or by providing new information for an individual to encounter, there are two critical issues shared by these two hypotheses. Firstly, both of the hypotheses suggest that defixation is achieved by the restructuring of the initial idea. In other words, a break in the frame constructed by a failed solution of the search in the problem space is essential for overcoming fixation. In the light of this notion, the ineffectiveness of incubation in Wiley's (1998) study could be also explained as an insufficiency in the incubation task in enhancing a search beyond the frame constructed by the activated domain knowledge, whereas such an incubation task is sufficient for breaking the frame constructed by misleading information by achieving a decay. Secondly, both of the hypotheses emphasize the importance of reaching an impasse. Actually, an impasse is a critical topic in studies of insight problems, with many defixation studies conducted with consideration of an impasse. An impasse is a mental state that individuals reach when they cannot make any further progress in their problem solving process (Ohlsson, 1992). An impasse can be not only a feeling reported by the individual (e.g., Segal, 2004), but can also be observed in various ways, such as through behavior (e.g., Ohlsson, 1992), protocol (e.g., Fleck and Weisberg, 2004) and eye movement (e.g., Tseng et al., 2014). An impasse is considered to be vital, and it is described as one of the fundamental stages in an insight sequence for solving insight problems (Ohlsson, 2011). Insight is thought to be a consequence of an impasse from the perspective of productive thinking in Gestalt psychology (Haavold and Sriraman, 2022). Further, being fixated is argued to be a cognitive state that is prior to an impasse (Beeftink et al., 2008). In the investigation of an effective defixation approach, given that reaching an impasse is not an essential condition for solving insight problems (Fleck and Weisberg, 2004; Tseng et al., 2014) and a longer impasse might produce more fixation (Lu et al., 2017), studies were conducted to examine the defixation effect of reducing impasses. For instance, instructing individuals to switch task before reaching an impasse is found to contribute to enhancing solution rates (Lu et al., 2017). Further, Beeftink et al. (2008) revealed that individuals who switched tasks at their own discretion solved more problems. It was reported that those switching before reaching an impasse solved more problems than those instructed to switch after reaching an impasse. However, reducing impasses does not necessarily ensure higher solution rates than, for instance, sequentially engaging in tasks (Beeftink et al., 2008). Importantly, reaching the status of an impasse is also crucial in defixation, since it is considered to be a factor which triggers a new search (Seifert et al., 1995; Segal, 2004; Moss et al., 2011). Moreover, it relates to a failure experience which encourages individuals to reflect (Fleck and Weisberg, 2004). Reflection, which is a well-studied topic in research of education, is not only shown to be effective in defixation (e.g., Neroni and Crilly, 2021), but also significantly related to creative thinking (Akpur, 2020), and a higher level of reflection involves double-loop learning (Greenwood, 1998), which is a transformative learning that involves the modification of habituated action (Argyris, 1994). Therefore, studies also examined the defixation effect of providing intervention with consideration of the point at which an

impasse is reached. For instance, a study on the timing of implementing defixation interventions revealed that providing incidental hints aimed at enhancing representational change (i.e., a form of cognitive restructuring) was most effective in improving solution rates when offered at the point of an impasse (Moss et al., 2011). Further, studies were also conducted to examine the effectiveness of encouraging individuals to reach the status of an impasse to trigger cognitive dissonance that prompts reflection, such as the investigation of a failure experience (Neroni and Crilly, 2021), physical interaction (Vallée-Tourangeau et al., 2011) and blunder solution (Sheridan and Reingold, 2013) in eliminating fixation induced by misleading information. To overcome fixation induced by problem information-related memory, Kiyokawa and Nagayama (2007) confirmed that inserting a reflection session about failure experience by asking participants to write down the failed solutions that were attempted while solving insight problems effectively increased the solution rates.

In the meanwhile, defixating by restructuring is not limited to incubation. There is more supportive evidence showing the effectiveness of restructuring in defixation. Based on the theory proposed by Kaplan and Simon (1990), representational change, which is a restructuring of problem representation, is shown to be an effective defixation approach for solving the classical insight problem, the matchstick problem (Knoblich et al., 1999). Specifically, the decomposition of the chunks that are developed from patterning familiar items or events, and the relaxation of constraints, which is defined as the prior knowledge not adaptable to solving the given problem, are proposed as two processes for achieving representational change. In studies that replicated this experiment, this proposal was confirmed by eye movement data (Knoblich et al., 2001; Tseng et al., 2014). In addition, according to results which revealed that providing hints for averting attention to a key area, which was the area involved in fixation and needed to be restructured to achieve successful problem solving, enhanced solution rates. Averting attention away from the fixated area was argued to be another critical process for overcoming fixation (Tseng et al., 2014). Similar to the intervention of averting attention to defixate, though chunk decomposition and constraint relaxation are specified as an individual's response to repeated failures during trial-and-error in problem solving (Knoblich et al., 1999, 2001), studies were also conducted to examine whether these processes could be promoted. For instance, similar to what has been examined in the study of overcoming fixation induced by misleading information, Weller et al. (2011) presented the matchstick problem in a three-dimensional format which an individual could physically manipulate. As it found that the solution rates of individuals who had an interactive experience were significantly higher than of the group with the problem presented on a piece of paper, the physical interaction was reported to be effective in facilitating chunk decomposition by providing the opportunity to perceive the elements of a given problem in a different way, and to enhance constraint relaxation by new representations that were constructed by the action of manipulation. In addition, according to the discussion about eliminating the fixation induced by misleading information, feedback received from the interaction with the environment could also be seen as a potential trigger for enhancing these two cognitive processes. Further, McCaffrey (2012) developed the generic-parts technique by integrating the enhancement of personal interpretation to chunk decomposition to increase the solution rate for insight problems. Patrick and Ahmed (2014) confirmed that representational change could be enhanced by training that consisted of three stages: being provided information about fixation, practicing with support, and practicing without support.

Various approaches have been developed for relieving fixation induced in closed-ended problems. Considering the source of fixation, there are approaches effective for overcoming fixation by the same mechanism regardless of its source, such as approaches which encourage individuals to reflect. Critically, the present review also indicates that the mechanism of a specific effective defixation approach varies according to the source of fixation. For instance, incubation is found to be effective for diminishing fixation induced by misleading information through the decay of the influence of information that misleads problem solving. However, as the influence of fixation cannot decay when it is induced by problem information-related memory, which involves the activation of long-term memory, this approach is reported to relax such fixation by enhancing the restructuring of the frame that is constructed by failed attempts. As a correct solution is not contained within the frame constructed by previously failed solutions, the enhancement of a search beyond the existing frame is essential for successful defixation. Specifically, interventions contribute to restructuring in a direct approach to prompt a beyond-frame search, and intervention which allows the influence of misleading information to decay and individuals to reflect is considered to be an approach which offers an opportunity to trigger the enhancement of a beyond-frame search.

4.2. Fixation in open-ended problems

4.2.1. Mechanism of fixation induced by misleading information in open-ended problems

The first empirical study that confirmed fixation induced by misleading information in open-ended problems was conducted by Jansson and Smith (1991). In their experiment asking participants to solve design problems with the presentation of example solutions, it was found that participants copied features, even including flawed ones, from the examples provided, and such copying impeded creativity. This finding was also reported in other domains, such as creative idea generation (Smith et al., 1993).

Subsequent to the study conducted by Jansson and Smith (1991), further investigations were conducted into how designers were fixated by a given example were conducted, and theoretical frameworks were proposed to explain this phenomenon. For instance, in a meta-analytic review by Sio et al. (2015), attention allocation was identified as the mechanism of fixation induction. Specifically, it suggested that examples direct designers' attention to specific domains, thereby narrowing the range of their search in problem space. Concurrently, Viswanathan et al. (2014) offered two possible explanations for the mechanism of such fixation. The first, grounded in the network models of memory, claimed that once an initial concept is activated by a given example, related concepts become more likely to be retrieved unconsciously. The second explanation considered the speciality of the domain of design and proposed that the adverse effects of examples might arise from the strategies that designers employ, as they often generate ideas based on their first concept or familiar examples.

Alongside these theoretical discussions, empirical investigations have also been conducted to elucidate the mechanism. For instance, by considering that designers often rely on existing design solutions, Perttula and Liikkanen (2006) performed an experimental study that challenged the notion that design fixation is due to subconscious conformity to given examples. Instead, they introduced the concept of the sampling probability effect as an alternative explanation for such fixation. This effect suggests that certain solutions are easier to access cognitively, and exposure to these solutions can preoccupy the solution space, thereby reducing the diversity of ideas generated.

Additionally, Agogué et al. (2014) proposed that the way of using spontaneously activated knowledge may induce fixation in design problems. Further, the notion of sunk cost has been widely discussed as another explanatory theory (e.g., Viswanathan et al., 2014; Sio et al., 2015; Hu et al., 2020). Moreover, theoretical modeling of design fixation has been established by Nguyen and Zeng (2017), contributing to a rich body of literature on fixation induced by misleading information in open-ended problems. However, existing studies have either offered theoretical discussion without empirical data or limited their discussions to specific domains, such as design, where misleading information is predominantly presented as example solutions. Importantly, the problem type was usually not taken into account in these discussions. As different types of problems involve different cognitive processes (Schraw et al., 1995), rather than simply applying the knowledge from the previous studies which only involved closed-ended problems or did not consider the problem type, it is legitimate to suggest that it is necessary to examine how fixation is induced by misleading information in open-ended problems based on empirical data that reveals the cognitive process.

4.2.2. Mechanism of fixation induced by problem information-related memory in open-ended problems

Besides examining the influence from example solutions, studies on design fixation also indicated that fixation was not only induced by given examples but could also be induced by internal elements, such as designers' experience (e.g., Crilly, 2015). The phenomenon of being fixated by experience or prior knowledge in solving open-ended problems was reported across different domains. For instance, in the domain of design, a study reported that both novices and experts generated ideas within similar categories in solving design problems (Bonnardel and Marmèche, 2004). Further, in general idea generation, studies revealed that individuals were bounded by their prior knowledge of creatures on earth in generating imaginative ideas of extraterrestrials (Ward, 1994). To clarify the mechanism of such a restraining effect of prior knowledge, Ward et al. (2002) conducted a study to investigate how the generation of new ideas was impeded by prior knowledge by asking participants to list items from different categories, such as animals and fruits. According to the results, firstly, the fixation induced by prior knowledge was confirmed by showing that the ideas generated by the majority of participants were based on specific category knowledge. Further, rather than other measures, such as typicality, familiarity, frequency of occurrence or rating of ideas, it was identified that the retrievability or coming-to-mindedness, which was the measure of how readily an item would be activated when a problem was presented, was the main predictor of how likely an item would be adopted in idea generation in an imaginative task. This is not only consistent with what is proposed in the path-of-least-resistance model (Ward, 1994), which assumes that the items retrieved from basic level exemplars are used as the base for generating novel ideas, but also similar to what is claimed by Wiley (1998), who suggested that the generation of prior knowledge-bound ideas was not a subjective choice in solving closed-ended problems. However, as there is no certain answer for open-ended problems. It is still a mystery why individuals kept generating ideas in such a way even when they were told to be creative. Though Ward et al. (2002) proposed several explanations, such as inappropriate monitoring, as there was no data collected for examining the process of creative idea generation, further studies are necessary.

4.2.3. Defixation approach for fixation induced by misleading information in open-ended problems

The same as studies involving closed-ended problems, the effect of explicit instructions not to copy flawed features of an example was examined in Jansson and Smith's (1991) study. Participants kept copying unwanted features even when they were told not to. Similarly, in studies examining the effect of warning participants about the problematic features, again instruction was ineffective regardless of whether the warnings were (Viswanathan and Linsey, 2013a,b) or were not (Viswanathan et al., 2014) accompanied by an explanation of why these features were negative. However, in a replication of the experiment conducted by Jansson and Smith (1991), results indicated that instruction did relax the fixation (Chrysikou and Weisberg, 2005). Chrysikou and Weisberg (2005) explained that these contradictory results for the same defixation approach might due to a difference in experimental conditions, since the earlier study was conducted in a group and the replicated study was conducted individually. With consideration of the source of fixation, another possible explanation for this result might be the participants, since the individuals engaged in the study which reported that instruction contributed to defixation were psychology students, while the participants in the study which found instruction was ineffective were either senior engineering students, professional design engineers, or freshmen on an engineering course. In other words, the participants' knowledge-base relating to the given problem was different. Similar to the fixation investigated in Wiley's (1998) experiment, though misleading information was provided, the source that induced fixation was domain knowledge, since the task was designed to be biased by domain knowledge. In solving design problems, an example design solution provided for students majoring in design-related courses might activate prior knowledge of design. Based on previous discussion, it might be considered that instruction is sufficient to prompt an individual to conduct a search beyond the frame constructed by example, whereas it is insufficient to enhance the search beyond the frame constructed by example and prior knowledge. A study which showed that presenting an example that involved domain knowledge of mechanical engineering only fixated individuals who were majoring in the related domain of solving mechanical engineering design problems (Purcell and Gero, 1996) provides a supporting evidence to indicate the necessity of considering the source of fixation in overcoming its negative effect. Consequently, further study might be necessary to validate the effectiveness of such instruction on overcoming fixation induced by misleading information in solving open-ended problems with consideration of the source of fixation.

However, as Agogué et al. (2014) suggested that the direct use of spontaneously activated knowledge can induce fixation in idea

generation, mentioning examples in warning instructions may paradoxically act as a trigger that activates related knowledge, thereby offering individuals the opportunity to utilize this activated knowledge directly. To address this complexity, rather than merely warning individuals to avoid using examples, Ezzat et al. (2020) investigated the impact of instructional approaches that considered the manner in which examples were presented. Specifically, they reported that warning instructions mentioning examples at a higher level of abstraction not only mitigated fixation, but also enhanced the originality of the generated ideas. Such instructions are considered to serve dual functions: as warnings for avoidance and as tools for abstraction. Actually, numerous studies had been conducted to examine the effect of how examples are presented on mitigating the fixation induced by misleading information in open-ended problems.

Along with the experiment conducted by Jansson and Smith (1991), the majority of studies on design fixation focused on the influence of example. As design is usually thought to be based on the adaptation of previous products (Eckert et al., 2005), practically example is an unavoidable issue in generating design solutions. Therefore, how to present examples in a way that would induce less fixation is a predominant topic in the study of design fixation. Importantly, producing less fixation is usually described as successful defixation in studies of design fixation (e.g., Cardoso and Badke-Schaub, 2009a). In this sense, it is legitimate to consider that examining the approach to decreasing fixation induced by provided example solutions contributes to the development of a defixation approach for design fixation. Accordingly, though information from research on the effect of example is summarized in the category of Fixation in Table 3, examinations of how to present examples in a less fixated way are discussed in the present review through representative studies of the approach to relaxing fixation induced by misleading information by modifying the source of fixation. Moreover, it should also be noted that the discussion in this section only focuses on the influence of example in terms of defixation rather than obtaining a comprehensive review of example effect.

As most previous studies adopted examples presented in line drawings (e.g., Jansson and Smith, 1991; Chrysikou and Weisberg, 2005; Viswanathan and Linsey, 2013a,b), studies attempted to adjust the amount of information that the example delivered to defixate, such as presenting examples in photos, computer-aided designs (CAD) or sketches, and predicted that the degree of fixation would depend on the richness of the information that examples conveyed. Though results rejected this prediction by showing that there was no significant difference found in fixation by presenting examples with different amounts of information (Cardoso and Badke-Schaub, 2011; Atilola and Linsey, 2015), examples presented in CAD and photos enhanced the quality of solutions generated by demonstrating working principles more clearly (Atilola and Linsey, 2015), and photos and line drawing examples improved the manufacturability (Cardoso and Badke-Schaub, 2011). To explain the ineffectiveness for defixation in these studies, in terms of analogical reasoning, as a possible reason, it was proposed that the distance between source (i.e., the example) and target (i.e., the generated solution) was too close (Cardoso and Badke-Schaub, 2011). Therefore, the defixation effect of distant examples was examined. For instance, compared with human-engineered examples, presenting biological examples, which were superficially dissimilar to the target, significantly improved the novelty and variety of design solutions (Wilson et al., 2010). As the product of a design solution is usually presented in a visual form, pictorial examples could be considered to be close sources, and textual examples as distant sources in terms of modality. In the light of this notion, study confirmed the effect of presenting examples written in words in defixation by reporting that textual examples reduced fixation by reducing the accessibility of the source and providing information in a more abstract way that allowed more personal interpretation compared with pictorial examples (Cardoso and Badke-Schaub, 2009a). However, in the replication of the study conducted by Cardoso and Badke-Schaub (2009a), a contradictory result was reported, revealing that there was no difference in the level of the fixation induced by examples presented in pictures and text (Cardoso and Badke-Schaub, 2009b). To clarify the defixation effect of presenting textual examples, studies utilized well-structured techniques developed on the basis of written information. For instance, Atilola et al. (2016) demonstrated that presenting examples in a function tree (Figure 2), which is an approach that conveys textual information about design solutions without specifying particular features, successfully mitigated fixation. This was evidenced by a decrease in the number of copied features from examples, while the quantity of ideas generated remained constant. Moreover, this approach also enhanced the quality of the ideas generated. These findings align with a study which showed that instructions to avoid using examples were effective and originality was enhanced when examples were mentioned at a more abstract level. Notably, Ezzat et al. (2020) suggested that the abstraction of examples forced participants to extend their search beyond the fixation frame, thereby mitigating fixation. This is consistent with Agogué et al. (2014), who confirmed the efficacy of expansive examples (examples which were identified to widen the range of the search in solving specific design problems) in the mitigation of fixation and the enhancement of idea originality. As such, an approach which can prompt a beyond-frame search is shown to be beneficial for defixating and enhancing other aspects which are expected in a solution, such as originality. However, Atilola et al. (2016) also reported that the defixation effect and the enhancement of other aspects dissipated when a sketch of an example was added, and this was not as effective in enhancing novelty and variety compared with sketch examples alone (Atilola et al., 2016). Given these considerations, presenting examples in a function tree can be understood as an abstraction technique that facilitates beyond-frame searching. Moreover, when sketches displaying specific features accompany such textual examples, the ineffectiveness of providing examples in a function tree and sketch in defixation could be considered to be a result of the integration of the narrowing effect brought about by visual examples and the expanding effect brought about by textual examples in the search range. This integrated effect was not sufficient in enhancing a beyond-frame search. However, as the results indicated that novelty and variety were not affected, the enhancement in beyond-frame searches seems not to be related to the improvement in these two aspects. This result is similar to studies which revealed that adjusting the richness of the information that examples conveyed enhanced either the quality or the manufacturability of generated ideas even though it did not defixate (Cardoso and Badke-Schaub, 2011; Atilola and Linsey, 2015). In terms of search range, even though beyond-frame searches could not be prompted as it was shown that there was no defixation effect, there might be an enhancement within the frame that was constructed by example and this enhancement in within-frame searches also might

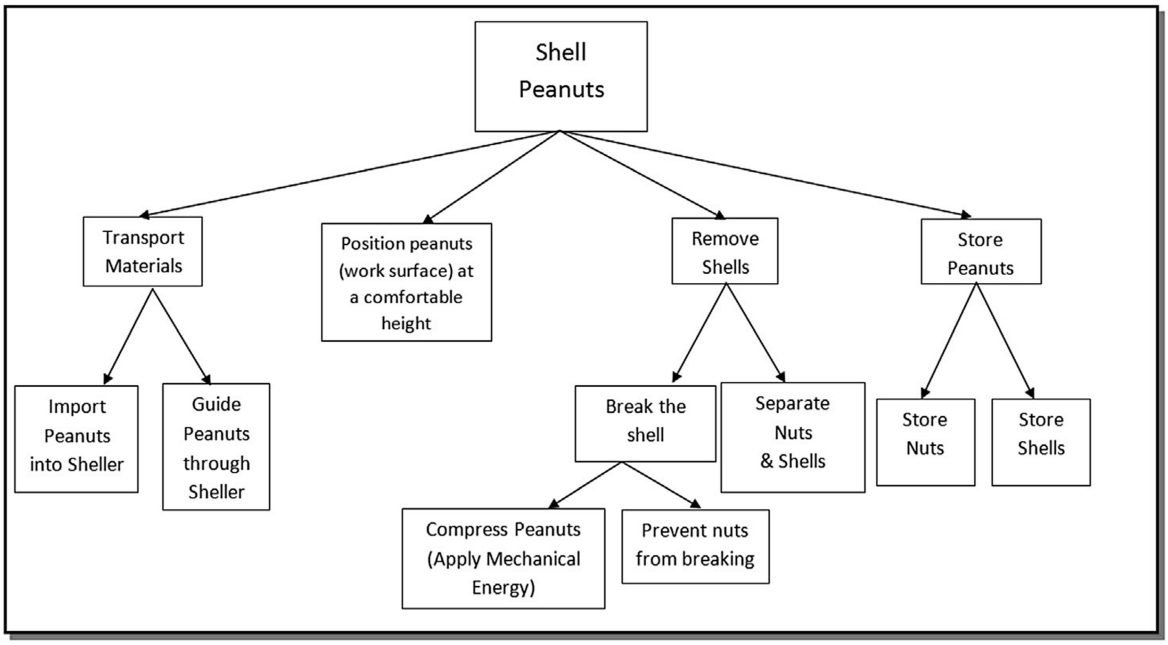

FIGURE 2
Example of design solution of peanut sheller presented in function tree. Reprinted from Design Studies, 42, Atilola, O., Tomko, M., & Linsey, J. S., The effects of representation on idea generation and design fixation: A study comparing sketches and function trees, p. 122, Copyright (2016), with permission from Elsevier.

bring about an advancement, such as improving the idea quality and manufacturability. Accordingly, though beyond-frame searches might eliminate fixation as well as bringing advancement in other aspects, the advancement in other aspects might not only depend on the enhancement in beyond-frame searches, but also be related to the enhancement in within-frame searches. Therefore, the ineffectiveness in improving novelty and variety of presenting examples in a function tree might be due to its insufficiency in enhancing within-frame searches.

Based on this discussion, defixation and advancement in other aspects seem not to share exactly the same mechanism. However, studies do not always take this into account. For instance, one study showed that presenting partial photo examples reduced fixation compared with full photos. The part presented was selected to contain rich information. Rather than the richness of the example, partial information affected the way of information processing and then broke the path of least resistance. This was proposed as the mechanism in providing incomplete information in defixation (Cheng et al., 2014). However, this result is arguable since the effectiveness of incomplete examples for defixation was indicated by showing an improvement in originality rather than measuring how fixation was influenced. In other words, such measurement was not able to distinguish whether this increase in originality was due to a search beyond or within the frame constructed by the given information. In traditional discussion of fixation, fixation is usually considered to be an inhibitory factor in problem solving. Therefore, successful defixation is commonly treated as an enhancement in problem solving performance. Specifically, in solving problems with specific answers (i.e., closed-ended problems), as relaxation of fixation leads individuals to successfully solve the problem, it is rational to claim that measuring the solution rates is sufficient to reflect how fixation is influenced by the intervention. Nevertheless, results of studies involving open-ended problems indicated that such a relationship might not always be true (e.g., Cardoso and Badke-Schaub, 2011; Tsenn et al., 2014; Atilola and Linsey, 2015; Moreno et al., 2016). Importantly, the solution to an open-ended problem is not limited to a specific answer, and the expected solution to an open-ended problem varies according to the aim of the particular study. This means that successful defixation might not necessarily direct an individual to generate an expected solution. Therefore, neither claiming the effect of defixation by measuring items related to aspects which are expected in a solution, such as variety, novelty, or originality without considering items related to fixation (e.g., Wilson et al., 2010; Cheng et al., 2014; Smith et al., 2017), nor by only measuring fixation without a discussion of expected aspects to show further effects (e.g., Viswanathan et al., 2014) is sufficient. Instead, the inclusion of measurements of both fixation and advancement in items that are expected in specific studies, such as creativity related items, is essential for examining the effects of a defixation approach.

Besides modifying the source of fixation (i.e., the example), other approaches are also examined, such as incubation. Specifically, in a study which investigated the effect of a two-day incubation, results revealed that incubation did contribute to overcoming the influence of an example solution by showing a decrease in the number of features copied from the example and an increase in variety of ideas generated on the second day. However, based on results which reported that participants still repeated many ideas from the first day after the incubation, it claimed that neither the forgetting hypothesis nor the set-breaking hypothesis, which suggests that the incubation period provides a chance to depart from initial ideas, could explain these results (Tsenn et al., 2014). Considering the source of fixation, an example solution was misleading information provided by an experimenter. The decay in the influence of the information given could occur during the two-day break, and this decay allowed a search

beyond the frame constructed by the trigger example given, as the study reported a decrease in features copied and an increase in variety. Meanwhile, the ideas generated on the first day might also have involved problem information-related memory, such as prior knowledge related to the given problem. Therefore, the decay effect of incubation might not be applicable in decreasing repetition of the first-day ideas. Further, in a study which failed to show the incubation effect in diminishing the fixation induced by a given example, an inappropriate incubation task and the presentation of examples during the incubation period were proposed as an explanation (Cardoso and Badke-Schaub, 2009b). This is consistent with a study which suggested the forgetting theory, showing that incubation was ineffective when problems kept being presented during incubation (Kohn and Smith, 2009). In a more general setting, Kohn and Smith (2011) confirmed the incubation effect by revealing that the categories and number of ideas generated were enhanced after taking a break, and the forgetting hypothesis was proposed as the mechanism of the incubation effect in overcoming fixation induced by ideas of others. Nevertheless, as fixation was not measured in this study, it is difficult to identify whether an increase in categories and numbers of ideas was due to a search that broke the frame constructed by others' ideas or a search that was expanded within this frame.

Similar to that examined in studies involving closed-ended problems, the effect of providing feedback is also examined in open-ended problems. As the answer in open-ended problems is uncertain, instead of providing information as feedback to explicitly show whether the attempted solution is correct or wrong, offering extra information by externalizing the generated ideas through building and testing physical models was examined for defixation (Viswanathan et al., 2014). Results confirmed that instant feedback that was received from the process of building and testing successfully inhibited the negative effect of examples by helping individuals to realize the flawed features of a given solution. Unfortunately, it is still unknown whether building physical models contributes to other aspects, such as creativity, as there was no extra measurement. Specifically, though providing feedback was effective in defixation by helping individuals to reflect and then to realize the fixated concept in solving closed-ended problems (Neroni and Crilly, 2021), as there is no certain answer for open-ended problems, realization of fixation does not necessarily lead an individual to break the frame constructed by fixated concepts, a further step, such as the construction of a new perspective, is essential (Okada and Ishibashi, 2017; Wang et al., 2022). Therefore, further studies including both a discussion of fixation and other aspects that are related to the aim of study are necessary.

4.2.4. Defixation approach for fixation induced by problem information-related memory in open-ended problems

As the majority of the studies of design fixation focused on example (i.e., the fixation induced by misleading information), few studies investigated how to overcome fixation induced by problem information-related memory. Among these studies, Moreno et al. (2016) utilized service design problems, which is design that does not involve any physical commodity, to examine the effects of two defixation techniques developed on the basis of analogy. The results indicated that the WordTree, which is a technique involving representational change and expansion of search space, reduced fixation and increased the novelty of ideas generated. In contrast, SCAMPER, which is a technique that instructs individuals to Substitute, Combine, Adapt, Modify, Put to other uses, Eliminate and Reverse to direct an analogical search, showed the highest level of novelty even though there was no effect on defixation. Based on previous discussion on the search range, the defixation and improvement in novelty achieved by WordTree could be considered to be a result of the enhancement of beyond-frame searches, as this technique commits to prompting representational change. In contrast, as SCAMPER allows the repetition of procedures of the search followed by instruction, the fixation was considered to be strengthened in these repetitions. In terms of search range, though SCAMPER was also suggested to involve the expansion of search, this technique might be sufficient to expand the search within a certain frame rather than the search beyond the frame.

In a more general setting, similar to the mechanism of effective defixation shown in these techniques, restructuring is also indicated to be a mechanism of incubation effect in overcoming the fixation induced by problem information-related memory in open-ended problems. Specifically, based on results which revealed that switching task was only effective in enhancing the novelty of generating the idea from a flexible category rather than a stable category, it clarified that incubation was effective by restructuring rather than decaying (Smith et al., 2017). Although it was not reported how fixation was influenced in this study, in a study which verified the timing of switching task, this mechanism was confirmed by showing the same results with the measurement of fixation. Specifically, results indicated that switching tasks before reaching an impasse was found to contribute not only to reducing fixation, but also to enhancing flexibility and novelty of the ideas generated (Lu et al., 2017). Further, in a study which revealed that the later the participants switched to a main task-related incubation task at their own discretion, the better they performed in creativity tasks. Opportunistic assimilation theory, which suggests a restructuring of existing attempts by encountering new information with the emphasis on the status of reaching an impasse, was proposed as the mechanism of the incubation effect (Madjar et al., 2019). According to the discussion of impasses in closed-ended problems, it is suggested to examine the defixation effect of encouraging individuals to reach an impasse, since an impasse relates to critical cognitive processes related to defixation, such as reflection. However, this is especially difficult in solving open-ended problems. Though an impasse is usually used as an indicator of the status of being fixated in solving closed-ended problems, as it is measurable, it might not be reported or even observed in solving open-ended problems. Specifically, because there is no certain answer in open-ended problems, instead of failing to solve the problem and feeling stuck because of not being able to find the correct answer, an open-ended problem may still be solved by submitting an answer with poor performance, such as a solution with low creativity. In the light of this notion, a study which allowed individuals to externalize ideas to reflect and realize fixation by testing ideas which copied flawed features of an example solution (Viswanathan et al., 2014) is an instance of overcoming the fixation induced by misleading information by prompting the status of an impasse. For the relaxation of the fixation induced by problem information-related memory, creating an environment that is designed to force individuals to reach

an impasse by inhibiting the accessibility to the source of fixation is effective in defixating and increasing creativity in drawing, which is a kind of open-ended problem solving (Wang et al., 2022). In this study, for example, participants were required to color a given picture while wearing red-tinted sunglasses. The red sunglasses functioned as a filter, impeding participants' visual perception and consequently inhibiting their ability to access prior knowledge of color when attempting to color the given picture. In such an environment, the study found that participants began to engage in reflection on color, leading to a decrease in the retrieval of prior knowledge of color. Further, when an instruction on the concept of fixation along with a reflective session was provided after the coloring task, defixation was achieved through critical reflection, and a subsequent enhancement in drawing creativity was observed.

Actually, reflection is claimed to be an approach that expert designers usually take to overcome fixation (Crilly, 2015). Though fixation is a universal phenomenon that challenges everyone, including experts (e.g., Bonnardel and Marmèche, 2004), studies also revealed that experts behaved differently from novices. For instance, in a study involving chess problems, though both expert and novice players were reported to be constrained by fixation induced by misleading information, experts could gradually disengage their attention from the solution which fixated them (Sheridan and Reingold, 2013). In solving open-ended problems, for instance, Bonnardel and Marmèche (2004) investigated the influence of expertise level on the effect of examples in design problem-solving. Specifically, they found that though both novices and experts were constrained by problem information, when examples were presented, experts demonstrated not only greater sensitivity to these examples but also engaged in beyond-frame searches, irrespective of whether the examples belonged to the same conceptual domain as the target or not. In the light of this notion, studies attempted to apply approaches that are used by experts to novices for defixation. For instance, interaction is proposed as an effective approach by experts. Though study showed that individuals are fixated by ideas generated by others in general idea generation during brainstorming (Kohn and Smith, 2011), rather than simply acquiring ideas from others, Okada and Ishibashi (2017) examined the effect of an in-depth interaction with the external world, which is an approach taken by artists in their conceptualization of artwork (Takagi et al., 2013), on mitigating the constraint of realism, which is the fixation induced by problem information-related memory in novices' drawing. Specifically, it confirmed that defixation and enhancement in creativity could be achieved either by prolonged appreciation or imitation of artwork in an unfamiliar style rather than artwork in styles already familiar to the participants. In terms of the search range, artwork in unfamiliar styles provided art novices with an opportunity to expand their range of search beyond the frame constructed by their prior knowledge in drawing. In support of this perspective, Okada and Ishibashi (2017) also identified achievement in representational change (i.e., beyond-frame search), as the mechanism underlying this defixation effect. Further, considering the status of impasse, similar to creating an environment that inhibits the accessibility of prior knowledge (Wang et al., 2022), interacting with artworks of an unfamiliar style, which is a style that is difficult to match to stored knowledge, could also be viewed as a way of directing individuals to reach an impasse to trigger cognitive dissonance for reflection. However, the intervention provided in these studies is more likely to be described as offering an opportunity to encounter or perceive the external world. None of them involved a reciprocal interaction as there was no feedback. Therefore, further studies on interaction with a focus on active feedback might contribute to developing an effective defixation approach to overcoming fixation induced by problem information-related memory.

Defixation in open-ended problems involves multiple aspects. Similar to what has been discussed in the section on closed-ended problems, the enhancement of a search beyond the frame constructed either by misleading information or problem information-related memory is essential for an effective defixation approach. Specifically, defixation can be achieved not only by approaches which are designed to directly expand the search range, but also by approaches which aim to develop triggers for expanding the search range. When the frame is constructed from misleading information, approaches which allow the influence of the information given to decay, encourage individuals to reflect, and directly contribute to expanding the search range, are shown to be effective. Approaches that prompt reflection and enhance the expansion of the search range, are also effective in enhancing a search beyond the frame constructed by problem information-related memory. However, as there is no certain answer to open-ended problems, more issues are considered. In closed-ended problem solving, defixation leads to an improvement in solution rates, which is the expected result. Similarly, when successful elimination of fixation in open-ended problems is accompanied by an improvement in aspects that are expected in the solution of the problems in different studies, such as creativity, the enhancement of a beyond-frame search is sufficient to achieve effective defixation. However, defixation and advancement in other aspects do not share exactly the same mechanism. Successful defixation (i.e., enhancement of beyond-frame searches) does not necessarily cause an improvement in other aspects. In other words, defixation cannot guarantee the production of expected solutions. Even though no beyond-frame search is enhanced, an advancement in other aspects could still be achieved as long as there is an expansion within the existing frame. This conclusion is supported by a study conducted by Boudier et al. (2023), which suggested that experts in the evaluation of design ideas either contribute to the development of a design solution within the frame constructed by the initial idea, or to the engagement in defixation by initiating alternative solutions beyond the existing frame. Accordingly, to ensure the effectiveness of the defixation approach to open-ended problems, an examination of the influence on both fixation and the measures that are related to the aim of the specific study is necessary to identify whether there is an enhancement in beyond-frame searches or within-frame searches.

5. Discussion

With the intention of contributing to the development of an effective defixation approach for enhancing creativity, we have reviewed empirical studies examining how fixation is induced and how fixation is eliminated on the basis of the axis of the source of fixation and problem type.

The review indicates that the mechanism of fixation induction is influenced by the source of fixation, and the way of overcoming fixation varies according to both the source of fixation and the problem type (Figure 1). Specifically, in the process of solving

problems, when misleading information is given, such as newly learned solutions and cues which impede problem solving performance, fixation is induced by the interaction of the memory related to misleading information, the perception and the attention to information that is related to activated memory of misleading information. In contrast, when there is no misleading information, fixation might still be induced by long-term memory which is activated by information about the problem due to its retrievability and recency. To overcome fixation induced in the process of problem solving, the key is to enhance a search which can break the frame constructed either by misleading information or problem information-related memory. Specifically, when fixation is induced by misleading information, approaches which allow the influence of misleading information to decay, encourage individuals to reflect, or directly contribute to expanding the search range are effective in enhancing beyond-frame searches. When fixation is induced by problem information-related memory, approaches prompting reflection and expansion of search range are effective. However, in contrast to closed-ended problem solving, in solving open-ended problems, successful defixation does not necessarily lead to an improvement in aspects that are expected in solutions in certain studies, such as creativity, and an improvement in other aspects can still be achieved by the enhancement of the search within the existing frame. Therefore, examining how fixation as well as how the expected aspects are influenced is essential for developing an effective defixation approach for open-ended problem.

This proposal is especially critical for fostering creativity. Firstly, defixation is shown to be effective in increasing the solution rates of solving closed-ended problems. When a closed-ended problem involves creativity, such as the RAT problem, it is reasonable to claim that enhancing a beyond-frame search, which is sufficient for defixation, is viable for prompting creativity. In contrast, though a beyond-frame search is effective in overcoming fixation in solving open-ended problems, defixation does not necessarily achieve an advancement in creativity, and creativity might still be enhanced if there is an enhancement in within-frame searches. Accordingly, instead of claiming the effect on creativity by showing the elimination of fixation, clarifying the effects on both of fixation and creativity is necessary for ensuring the effectiveness of defixation approach in prompting creativity in solving open-ended problem.

To develop an effective approach to overcoming fixation, besides the future research suggested in previous discussions, some more issues should be considered due to the limitations of the present review.

Firstly, as shown in Table 1, most studies focused on closed-ended problems and fixation induced by misleading information in open-ended problems. However, dealing with fixation induced by problem information-related memory in open-ended problems is a critical issue in education. Specifically, though knowledge acquired in previous educational practice is the foundation for learning new knowledge, it might also be a fixation that restrains performance in solving problems which require an atypical perspective (Chesney et al., 2013). Therefore, how to effectively utilize the prior knowledge, which is memory activated by information about a problem, without the fixation effect is an important issue in education. Further, this becomes particularly crucial for cultivating individuals who are capable of dealing with unpredictable problems with ambiguous answers in a changing future. Accordingly, it is suggested that more studies should be conducted on internally induced fixation in open-ended problems.

Further, though the present review has examined studies involving fixation induced by misleading information and problem information-related memory, there is fixation involving both of these two sources. For instance, in a study conducted by Viswanathan and Linsey (2013a,b), the influence of the timing of using different materials to test ideas was examined, and it was reported that whether or not the type and use of materials influenced the level of fixation. This study has often been cited as research which revealed the mechanism of fixation induction as a sunk-cost effect. However, considering the source of fixation, the fixation investigated in this study involves both of the two sources: knowledge of different materials, which might be considered to be misleading information that was provided by the experimenter, and memory activated by problem information. Further, the mixed source of fixation is also mentioned in this review (e.g., Tsenn et al., 2014). As the effect of defixation is influenced by the source of fixation, studies on mixed sources of fixation are indispensable for developing an effective approach for defixation.

Moreover, personal difference is another well-studied factor that is found not only to influence the effect of the defixation approach but also affect the level of fixation. For instance, an individual's visuospatial skills significantly affect the effectiveness of defixating by physical interaction in solutions (Vallée-Tourangeau et al., 2011). Further, an individual's preference for complexity and symmetry predict the ability to overcome fixation (Kharkhurin and Yagolkovskiy, 2019), while preference for cognitive simplicity and structure predict the level of fixation (Schultz and Searleman, 1998). To develop an effective approach to defixation, a discussion of personal factors which influence the level of fixation and the effectiveness of defixation might be helpful.

Finally, a study which reported that individuals were fixated by the ideas of others during brainstorming (Kohn and Smith, 2011) has been discussed in the present review. However, another study also revealed that working in pairs contributed to overcoming fixation (Okada and Simon, 1997). The reason for these contradictory results is that the discussion about the influence of the ideas of others was conducted at a level that considered individuals, rather than pairs, as the cognitive system. In terms of defixation, experts proposed interaction as an effective approach (Crilly, 2015). However, the studies on interaction that have been discussed in the present review are more likely to be considered to provide opportunities for individuals to encounter new information (e.g., Vallée-Tourangeau et al., 2011; Okada and Ishibashi, 2017). To obtain an understanding of the effect of reciprocal interaction in defixation, further discussion which takes pairs or groups as the cognitive system is necessary.

Although further discussions should be conducted to obtain a more comprehensive view, the present review offers a systematic understanding of empirical studies of fixation and defixation by establishing the axis of fixation source and problem type. Particularly, in terms of overcoming fixation to enhance creativity, the present review not only indicates the significance of the two axes, but also reveals critical issues that should be considered in developing an effective defixation approach.

Author contributions

SW and TO contributed to the conception of the study. SW conducted the review and wrote the first draft of the manuscript. TO and KT provided suggestions for the modification of the draft. All the

authors contributed to manuscript revision, and read and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Conceptual Utility Model for the Management of Stress and Psychological Wellbeing, CMMSPW™ in a university environment: theoretical basis, structure and functionality

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This article describes and introduces the *Conceptual Utility Model for the Management of Stress and Psychological Wellbeing*, *CMMSPW*™ Its purpose is to assess, evaluate and treat stress and psychological wellbeing. First, the *theoretical assumptions* of the model are presented. This model is an application of the 3P Model, Theory of Internal vs. External Behavioral Regulation and the Model of Competency for the Management of Stress and Psychological Wellbeing. Second, the *conceptual structure of the model* is presented. This model allows the structural and functional determination of the variables and predictive, mediating and final factors for stress and psychological wellbeing. Third, the *functional structure* is presented. For predictive factors, the *internal and external self-regulation* theoretical model allows us to assess levels of internal and external regulation of the individual and their context, as well as other personal and contextual factors involved in self-regulation. For mediating factors, the *model of competence* for the management of stress and wellbeing allows us to analyze conceptual (concept and principles), mediating (skills and metaskills) and attitudinal (attitudes, values and habits) variables. Finally, in relation to factors that condition outcomes, we can determine *levels of response to stress and psychological wellbeing*. Finally, *limitations* and *conclusions* are presented. The model also allows us to determine predictive relationships between those three types of variables and is functionally transferable to other contexts, including contexts proper to the psychology of education, clinical practice and healthcare, and psychosocial, organizational and technological contexts.

KEYWORDS

conceptual utility model, stress and psychological wellbeing, 3P model, self-regulation vs. external regulation behavior theory, competence model

1 Introduction

The creation in an area of study of new conceptual models—with the potential to explain and predict—based on scientific evidence is the proper endeavor of science (in general) and of the Psychological Sciences (in particular). To that end, existing conceptual models are melded with newly created models so as to allow us to better understand and expand on the variability of

dependent variables explained by such models. That is the subject of this paper, in relation to research into stress and psychological wellbeing in different contexts.

The *objective* of this study is two-fold: (1) At a *conceptual level*, to present and justify the partial models on which the general conceptual model or heuristic put forward is based, to assist the reader and those using the model to better understand it. (2) In addition, on an *applied level*, the objective includes establishing the utility of the model in interventional assessment processes having to do with stress and wellbeing among university students.

2 Justification

The inform research presented has a double justification, both theoretical and applied:

1. At a *theoretical level*, in current psychological science, there is a recognized need to advance towards broader and more integrative conceptual theoretical models, which lead to more efficient explanation and prediction of the role of the numerous variables involved in behavioral variability. That is, a mature level of psychological knowledge enables progress from discrete and specific models, specific to each area of knowledge, towards broader, molar models of an interdisciplinary scope (Mastrokoukou and Crawford-Lee, 2023).
   Traditionally, explanatory conceptual models in Psychology have been developed in the context of a specific discipline. For example, in analyzing the problem of *stress and well-being* at university, most of the existing models and evidence take a marked neuropsychological, clinical, health-related view (Gu and Mao, 2023; Wong and Yuen, 2023), and do not include the psychoeducational view, connected to the context of teaching-learning processes and other contextual variables. This positioning constitutes a microanalysis or molecular-clinical focus of analysis, ignoring the contextual-molar or interactive level (de la Fuente et al., 2019). However, in many cases they have not been extrapolated to other contexts due to the theoretical and empirical difficulty of validation in different contexts. In practice, that has made it much harder to generalize psychological theories, given that the majority of models have been restricted to the specific *theoretical domain* or *knowledge area* in which they arose. For that reason, it has generally been difficult to test explanatory mechanisms for specific problems in other academic or professional fields. There are a number of exceptions in relation to general models and theories of motivation and personality. In this case, the present conceptual model takes an *omnibus-model* view, and can be used in the spheres of educational psychology, clinical and health psychology, and organizational psychology (de la Fuente and Martínez-Vicente, 2023b,c).
2. At the *applied level,* the contribution of new, evidence-based conceptual utility models represents a professional innovation of the first order. New tools or heuristics for analysis, evaluation and applied professional decision-making become possible. In the field of innovation, there are differences between a patent and a utility model. Patents protect the invention of something that is completely new (such as vaccines against COVID-19), while utility models incorporate a useful improvement of something that already existed. The patent and the utility model are titles granted by the State and give their holder the right to temporarily prevent others from manufacturing, selling or commercially using the protected invention in a given country. Term of ownership is twenty years from the filing date in the case of patents and ten years for utility models. Once the duration has elapsed, the invention is in the public domain and anyone can use it freely (Ministry of Industry, Energy and Commerce, 2024).

3 Theoretical basis

3.1 Foundational models that precede the new conceptual utility model

3.1.1 Reasons for a new model

The proposed utility model aims to address an unresolved need in previous stress models, which have the following characteristics:

1. They take the conceptual view of stress as a maladaptive response, and give priority to a biological approach (Gulewitsch et al., 2013; Godoy et al., 2018) to the detriment of psycho-social factors of stress. If we wish to adopt a more balanced bio-psycho-social paradigm (WHO, 2001), models must be developed that adequately integrate psychological and contextual factors, due to their functional, predisposing value in explaining stress.
2. They assume that stress is an essentially individual problem, derived from the subject's personality. For this reason, they focus on molecular explanatory mechanisms or the subjects themselves (Pozos-Radillo et al., 2014, 2015; Amanvermez et al., 2020), to the detriment of contextual factors, specific to the educational context. They do not adopt an interactive view, which is key to a better understanding of the phenomenon of academic stress.
3. They take into consideration predictive variables in the subject as determinants of the level of stress (Restrepo et al., 2023), but do not sufficiently incorporate mediating variables, namely, the subject's level of competence, which constitutes a protective factor, stress inhibitor and promoter of well-being. Such variables serve to minimize stress responses and maximize the subjects' well-being.
4. A large number of models are focused on the negative pole of the behavioral continuum. Thus, they aim to analyze the predictive and constitutive factors of stress responses (Hoge et al., 2023). However, the positive pole or behavior that promotes well-being is not defined in the same terms.

3.1.2 Advances of the new model

The proposed Conceptual Utility Model (de la Fuente et al., 2022a,b,c; de la Fuente and Martínez-Vicente, 2023a,b,c) aims to address and overcome the above limitations in an integrative heuristic based on prior evidence (de la Fuente, 2021). It seeks to provide a general model applicable in different psychological fields, and to be both protective and predictive of stress and psychological wellbeing:

1. In terms of *presage* var*iables*, this model starts from the 3P model (Biggs, 1999) which affirms the existence of presage (predictive)

variables, process (mediating) variables and product (dependent) variables. To complement the 3P model in terms of presage variables, *the Self- vs External-Regulation Behavior Theory* model (de la Fuente et al., 2017, 2021a,b; de la Fuente et al., 2022a,b,c) has proposed *Regulatory/Non-Regulatory/Dysregulatory* levels for the individual and the context, based on biomedical models of dysregulation (Shields et al., 2017).

2. In terms of *process* var*iables*, the 3P model has been complemented by the personal competence model (Gagné, 1965; de la Fuente et al., 2018a,b). This conceptual model has established different types of learning that a human being must present in order to be competent in the management of *stress and psychological wellbeing,* namely: (1) conceptual; (2) procedural; (3) attitudinal.
3. In terms of product or predictive *final variables*, we have incorporated the model of *experience* of academic stress (Stallman, 2010; de la Fuente et al., 2015a) and *psychological wellbeing* (Ryff and Keyes, 1995; Ryff and Singer, 1996).

3.2 Foundational conceptual model underlying the utility model

The proposed heuristic, *Conceptual Model for the Management of Stress and Psychological Wellbeing*, *CMMSPW*™, integrates and synthesizes prior conceptual models.

3.2.1 Biggs' 3P model

The Ps in the name of this model stand for Presage-Process-Product (Biggs, 1993, 1999). As a sequential model, it is a good representation of academic reality at university and enables us to understand and assess the factors inherent to university learning. It has generated copious evidence (Zhang, 2000; Zeegers, 2001; Rosário et al., 2005; Sarzoza, 2023) and continues to do so (Yang and Lin, 2023) (see Figure 1).

A strength of the 3P model is that it allows us to determine probabilistic relationships within the model among various significant variables that may be predictive of and mediate the ultimate variable of academic performance:

1. In terms of *predictive factors* (presage), it identifies as factors that predict a student's learning style:
   a. The learner's *individual characteristics*, such as age, gender (Cano-García, 2000; Cano-García and García-Berbén, 2009; de la Fuente et al., 2013), expectations of self-efficacy (Prat-Sala and Redford, 2010), notions about learning (Richardson, 2011), personality traits (de la Fuente et al., 2020a,b,c,d), as predictive and causal factors of university learning. It also determines relationships involving the self-regulatory traits of students and their learning focus (Heikkilä and Lonka, 2006; de la Fuente et al., 2008; Rosário et al., 2010).
   b. Characteristics of the *context* in which learning takes place, such as the nature of the institution (Bliuc et al., 2011) and the nature of the course content and teaching methods (Trigwell and Prosser, 1991; Rosário et al., 2014) as factors that are propitious for university learning. Initially, in the study of the stress and well-being model, this variable was not considered. Subsequently, the importance of introducing this category of variables was confirmed.
2. In terms of *process factors*, the model initially focused on the analysis of individual learning factors, to the detriment of contextual factors:
   a. The *learner's individual characteristics* the model identifies as factors likely or probable to varying degrees to mediate the process, students' habitual study methods (Thompson and Lake, 2023). And the student's motivation and study strategies (Valle-Arias et al., 1998; Cano-García and Hughes, 2000). Alongside that, learning focuses have been compared with learning styles, with consistent results (Gargallo-López et al., 2013).
   b. The initial model did not consider characteristics of the context or the interaction between teaching and learning to explain the type of cognitive, motivational and behavioral strategies during learning.
3. Finally, and in terms of *product or outcome factors*, academic performance and satisfaction with the learning process (Zapata, 2013) are essential variables. In this case, relationships were established between self-regulatory characteristics and the focuses of self-regulation in learning with the type of performance (de la Fuente et al., 2008). Also in specific areas of learning (Cano-García et al., 2014).

3.2.2 The DEDEPRO model

The 3P model was subsequently improved and completed in terms of process or mediating factors in the form of the Design-Development-Product, DE-DE-PRO (from the initial letters of the Spanish words) conceptual model (de la Fuente et al., 2006, 2011; de la Fuente, 2011), in the field of university education to provide greater explicitness about factors that affect design, implementation and outcome of the *teaching-learning process* in a university context (de la Fuente et al., 2006, 2014a,b; Cheng, 2022). Although the original 3P model (Biggs, 1999) implicitly identified variables involved in teaching and learning, it did not provide an exhaustive or explicit description of the possible relationships among the variables in the original model. In fact, the model helped to define the interaction among those variables (see Figure 2):

1. In terms of *presage*, it identified as *predictive factors* learning style, (1) the *personality* of the individual learner, and their age, sex and personality type and (2) the characteristics of the *context of learning*, such as the type of institution, course content and methods of delivery and effective teaching, in terms of the way in which course content and delivery regulates teaching and learning (de la Fuente et al., 2011).
2. In terms of *process*, it identified as *mediating factors* the habitual learning style or *learning focus* of each student (Karagiannopoulou et al., 2020; Xie et al., 2022). And the motivation and learning strategy of the individual (Dinsmore et al., 2020) and *effective teaching*, in terms of the way that course delivery regulates teaching and learning (de la Fuente et al., 2011, 2016b).
3. Finally, and in terms of *product or outcome factors*, academic performance and satisfaction with the learning process (Littman-Ovadia and Freidlin, 2022).

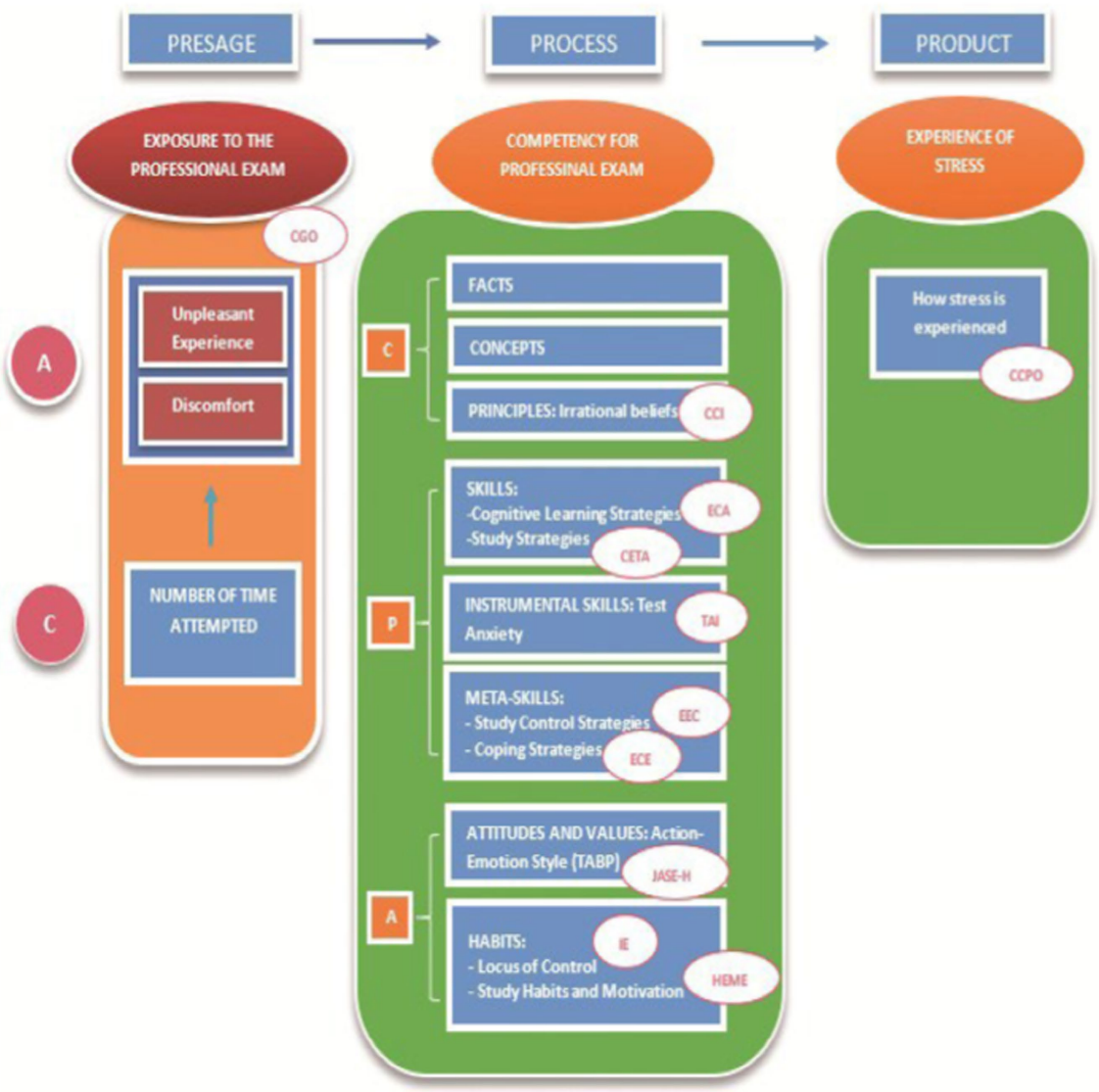

FIGURE 1
Competency model for studying, learning and performing under stress (de la Fuente et al., 2015a,b,c), showing variables and some of the assessment instruments used. Reproduced with permission.

3.2.3 The internal and external regulation of learning SRL-ERL model

As a third stage in this process, the *Self- vs External Behavior Learning Theory*, SRL-ERL (de la Fuente et al., 2017) was put forward to explain the different types of interaction between types of *self-regulated learning* (Regulated/Unregulated/Dysregulated) and *regulatory teaching* (Regulatory/Non-regulatory/Dysregulatory). It arises in the psychology of education to create a heuristic capable of making specific predictions concerning the combination of the degree of regulation of learning by a student and by the teaching process in terms of how that combination affects academic performance (de la Fuente et al., 2012a,b).

Against that theoretical background, in a similar way to metacognitive variables intrinsic to self-regulated learning (Zimmerman and Martinez-Pons, 1986; Zimmerman, 1990, 1998, 2000; Zimmerman and Risemberg, 1997; Zimmerman and Schunk, 2001; Moohr et al., 2021; Zachariou and Whitebread, 2022), which have generated a large volume of evidence concerning their impact on learning, we have postulated the existence of different levels of regulation in students: regulation/non-regulation/dysregulation (SR-NR-DR).

Having examined the role of effective teaching practice, we also postulated equivalent levels for teaching: external regulatory/external non-regulatory/external dysregulatory (ER-ENR-EDR). The empirical confirmation of the theoretical and empirical significance of those three combined levels produced large amounts of evidence (de la Fuente et al., 2017, 2019). That in turn led us to formulate the theory of internal and external regulation of learning, the *SRL vs ERL Theory* (de la Fuente et al., 2017).

Following confirmation of the correspondence between theory and data in that area, we started to test the importance of personal and contextual factors of stress and psychological wellbeing in other contexts. Considerable evidence led to the conclusion that the

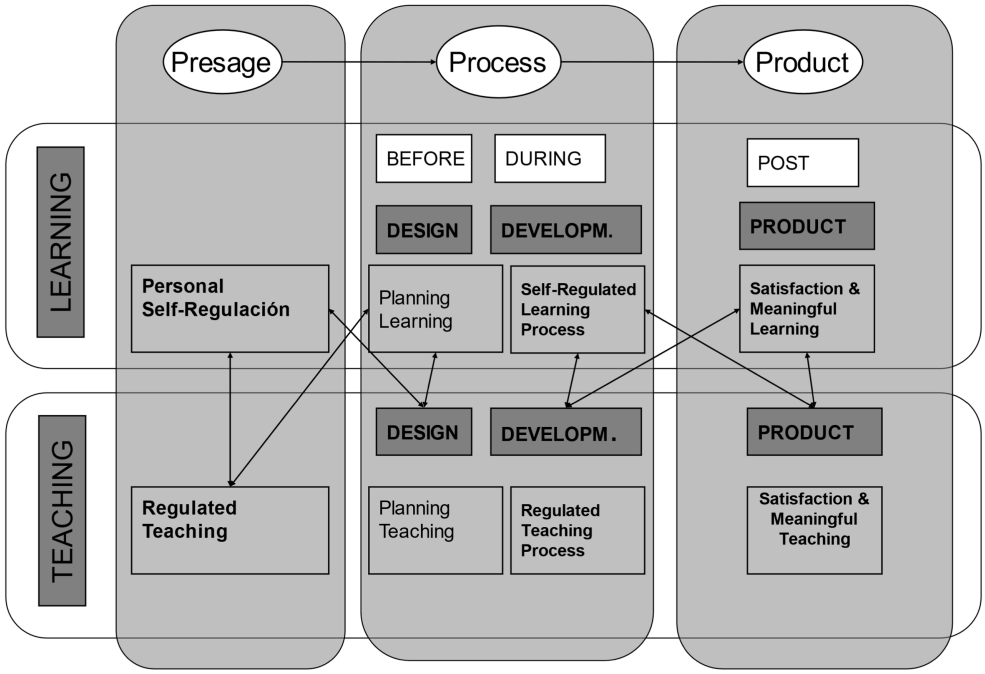

FIGURE 2
The DIDEPRO model, in the context of 3P Model and the teaching and learning models. Reproduced with permission.

variability of many recent research variables are predicted and determined by the combination of levels of internal and external regulation. That is the case for resilience, academic emotions, degree of procrastination, levels of stress and academic performance itself (de la Fuente et al., 2017, 2018a,b, 2019). We finally put forward an integrated predictive model, with protective and risk factors for academic stress relating to the individual and their context (de la Fuente et al., 2021a,b).

3.2.4 The self-regulatory vs external regulatory behavior theory

However, that model was very specific and was created specifically for the field of the psychology of education. Having shown that it accurately modeled the phenomena addressed, it was decided to extrapolate the model to other contexts. That led to the need to devise a theoretical model that adequately determined the *person x context* interaction in general terms in different contexts.

From that starting point, the new model sought to extrapolate the specific model from the field of education to other psychological contexts, leading to the model in *Self- vs External-Regulation Behavior Theory* (de la Fuente et al., 2021a,b, 2022a,b,c), as a *general model of regulatory behavior* that could apply to different fields: Psychology of education and ICT, Clinical and Health Psychology, Social and Organizational Psychology, and other contexts (de la Fuente et al., 2016a, 2022a,b,c). To that end, we created and validated specific evaluation tools for use in the different fields (de la Fuente et al., 2022a,b,c; de la Fuente, 2024a,b).

Thus the significance of this new—more general—model is that it allows the identification and assessment of personal and contextual regulation as a predictive (presage) variable for purposes of psychological assessment and treatment in the fields mentioned (see Figures 3, 4).

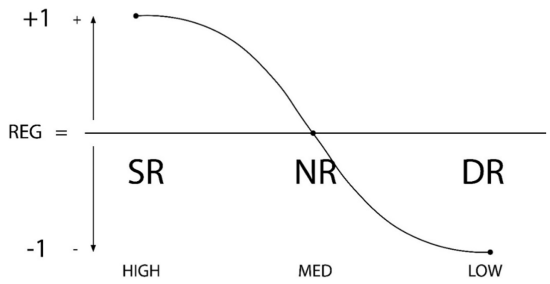

FIGURE 3
Graphic representation of individual regulation types: SR (Self-regulation), NR (Non-regulation or De-Regulation) and DR (Dys-Regulation). The X axis represents the degree of regulation (high-medium-low), while the Y axis shows directionality (+1, 0, −1). Reproduced with permission (de la Fuente et al., 2022a,b,c, p. 17).

3.2.5 Competence for human learning

Since Gagné (1965) introduced his *instructional model of teaching and learning* of differential learning which allows a human being to be competent in a given field of learning and development, that model has been extrapolated to other areas. This comprehensive holistic model allows us to integrate partial contributions from other cognitive-behavioral models of stress and other issues. Thus, researchers have described competence to interact with alcohol (de la

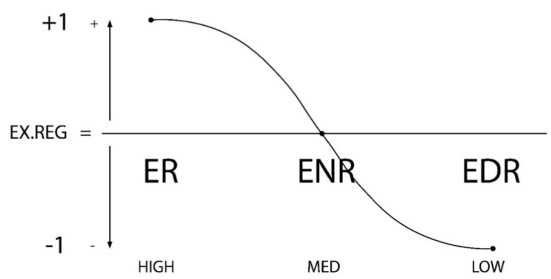

FIGURE 4
Graphic representation of external or contextual regulation types: ER (External Regulation), ENR (External Non-regulation or De-regulation) and EDR (External Dys-Regulation). The X axis represents the degree of external regulation (high-medium-low), while the Y axis shows the directionality of the external regulation (+1, 0, −1). Reproduced with permission (de la Fuente et al., 2022a,b,c, p. 17).

TABLE 1 Structure of learning of competencies (de la Fuente et al., 2015a), based on R. Gagné (1965).

KNOWLEDGE (Knowledge)	Knowledge of facts about the learning domain
	Familiarity with concepts concerning the domain
	Knowledge of principles concerning a domain
KNOW-HOW: (Capacity)	Self-management skills in a given behavioral domain
	Self-management metaskills in the relevant behavioral domain
KNOWING HOW TO BE: (Wanting)	Attitudes particular to a domain
	Values particular to a domain
	Habits particular to a domain

Fuente et al., 2017) and competence in avoiding and dealing with academic stress (de la Fuente et al., 2015a,b,c).

Evidence has emerged from our field of investigation of the relationships between different levels of variables inherent to competency. In essence, the model summarizes the levels of learning that a person needs to have in a given domain: KNOWLEDGE (FAMILIARITY) + KNOW-HOW (ABILITY) + KNOWING HOW TO BE (WANTING). However, this schematic or heuristic, despite its power as a tool to bring together different strands of research, has not been taken up in full by different fields in psychology to assess and intervene in relation to the competencies of individuals in connection with a given behavioral problem (see Table 1).

1. In the case of *stress-management competence*, a person is said to be competent to manage stress when they present with three levels of behavior referred to above, to adequately manage stress situations in different settings: academic, health, personal.
2. In a similar way, in the case of *competence for the management of psychological wellbeing*, a person is said to be competent to achieve a state of psychological wellbeing when they present the three levels of behavior referred to above, to adequately manage experiences and states of psychological wellbeing in different situations (de la Fuente et al., 2022a,b,c).

3.2.6 Model of stress and psychological wellbeing

The assumed *model of stress* arising from negative psychology or psychopathology based on individual risk factors is particular to the responses that constitute and correlate with stress (Stallman, 2010; de la Fuente et al., 2012a).

The assumed *model of psychological wellbeing* which arises from positive psychology, based on individual protective factors is a combination of hedonic models, which focus on the prevalence of emotionally positive wellbeing (Diener et al., 1985; Disabato et al., 2016) and eudaimonic models which focus on the prevalence of teleological wellbeing (Ryff and Keyes, 1995; Ryff and Singer, 1996).

4 Structure: *conceptual utility model for Management of Stress and Psychological Wellbeing*, CMMSPW™ in different settings

The proposed utility model (de la Fuente and Martínez-Vicente, 2004, 2023a,b) is an integrative heuristic based on prior evidence (de la Fuente, 2021). It seeks to provide a general model applicable in different psychological fields, and to be both protective and predictive of stress and psychological wellbeing (See Supplementary Appendix S1). In this previous empirical synthesis work, a joint structural predictive model of personal and contextual factors that significantly probabilize a final experience of well-being or psychological stress was shown. It reflects, structurally, individual and contextual factors, which have served as structural support for the current utility model.

This article reflects the specific structural variables used in the *psychoeducational context* (see Supplementary Appendix S2):

1. In terms of *presage variables*, this model affirms that presage or distal predictive variables can be individual or contextual:
   Individual variables: based on the results of previous research, the variables of students' age and gender, personality (Big Five), positive and negative affect, and level of regulation were considered in the model. Taking the perspective of the Theory of Self- vs. External-Regulation Behavior (de la Fuente et al., 2017, 2021a,b, 2022a,b,c), the model distinguishes Regulatory/Non-Regulatory/Dysregulatory levels for the individual, based on biomedical models of dysregulation (Shields et al., 2017).
   Contextual var*iables*: the level of external contextual regulation has also been identified by the Self- vs. External-Regulation Behavior Theory (de la Fuente et al., 2017, 2021a,b, 2022a,b,c; Pachón-Basallo et al., 2022): externally regulatory / external non-regulation/externally dys-regulatory. Additionally, the family support variable has been taken into consideration in the educational context, due to its great relevance.
2. In terms of *process or mediating variables*, the model includes two levels of variables that previous research has shown to be very relevant:
   Individual variables. This conceptual model claims that a human being must acquire different types of learning in order to be competent in managing their stress and psychological well-being (de la Fuente, 2023a), namely: (1) conceptual; (2)

procedural; (3) attitudinal. These three levels are essential to a self-regulatory, meaningful learning process (de la Fuente and Eissa, 2023), and to the competence of managing stress and well-being, especially at the level of meta-skills (de la Fuente et al., 2023b), as will be explained in the next section.

Contextual var*iables.* An important contribution of this conceptual model is the integration of teaching processes, as contextual factors that may promote stress responses and that mediate the students' state of stress or well-being (de la Fuente et al., 2015a). This contribution has been possible thanks to the continued study of academic stress, in the context of teaching-learning processes (de la Fuente et al., 2023a,b).

3. *Product* or *predictive final* var*iables*. The model has focused its attention on the final experience of the subjects:
Individual variables: we have incorporated students' *experience* of *academic stress* (Stallman, 2010; de la Fuente et al., 2015a) and their *psychological wellbeing* (Ryff and Keyes, 1995; Ryff and Singer, 1996).

In summary, the structure proposed in the new conceptual utility model makes it possible to work at two levels:

1. A *multidimensional structure* at the molar level (de la Fuente et al., 2021a), which furthers multidirectional and interactive analysis, building on the partial proposals of previous models at the molecular level (3P, SR-ER model, DIDEPRO or Competence models).
2. A *multidisciplinary structure*, addressing stress and psychological well-being across different areas of psychology. As has been noted, this manuscript presents only the relationships in the field of educational psychology. Current research is analyzing the model's empirical functioning in the different areas it addresses: educational psychology, health-related psychology and organizational psychology. Future research will determine, based on evidence, whether the model presented is sufficiently robust in its current form.

5 Functionality: the conceptual model as a heuristic for professional decision-making in different settings

Based on the heuristic or the Utility Conceptual Model™ (see Supplementary Appendix S1), we have proposed the assessment and improvement of specific variables, applying in each context the variables that evidence has shown to be essential (de la Fuente and Martínez-Vicente, 2023b,c). Here, we provide an explanation-synthesis of these variables only in the context of educational psychology (see Supplementary Appendix S2).

5.1 Functional analysis based on the heuristic in the sphere of the educational psychology at university

5.1.1 General functionality

The main contribution of the conceptual utility model is that it provides a general conceptual map (see Supplementary Appendix S1) and other specific maps according to area (see Supplementary Appendix S2). These allow the psychologist to identify, evaluate and intervene in the variables established therein (see the full proposal: de la Fuente and Martínez-Vicente, 2023b,c). It is thus possible to:

1. Conceptualize and test the hypothesized relationships, and so provide empirical evidence of such relationships in a given study population: students, patients, workers. An example of recent research contributions and research in progress can be found on the Project website: https://www.inetas.net/stress/seccion.php?ididioma=1&idseccion=6&idproyecto=10
2. Conceptualize and carry out explanatory predictive hypotheses, in an analysis of a given case, to make an assessment and subsequently intervene in the selected variables.

5.1.2 Specific functionality in the educational psychology context

Based on the 3P model (Biggs, 1999), noted above, the heuristic has selected variables on the basis of ample prior evidence that are of significance to this field of investigation:

5.1.2.1 Presage (predictive) variables

5.1.2.1.1 Personal presage variables

The age and sex of each individual student have been seen to be relevant differentially predictive factors of learning behaviors (Weis et al., 2013; Rubin et al., 2018; López-Madrigal et al., 2021; Rubach et al., 2022; de la Fuente et al., 2023a). As such they are important to the determination of cognitive and emotional differences among students in learning processes.

Another individual variable that research has shown to be relevant is *Personality*, specifically the Big Five model, as a distinctive personal characteristic of students (Poropat, 2009; Backmann et al., 2019; Sander and de la Fuente, 2022; Spielmann et al., 2022). This predictive factor has appeared as a significant variable in the prediction of cognitive-emotional characteristics of learning: conscientiousness has been shown repeatedly to be associated with and positively predictive of better performance and better strategic learning, whilst neuroticism (lack of emotional stability) is negatively predictive. Now, some works have proposed a sliding scale in personality traits depending on how pro-regulatory each trait is (de la Fuente and Martínez-Vicente, 2004).

Self-regulation as a personality trait among students has also shown itself to be predictive and causative of adaptive vs. non-adaptive behavior in the course of learning (Matthews et al., 2000). There is very extensive evidence of its value in the prediction of the performance of learning behavior by students. The positive association and predictive relationship between self-regulation and subsequent learning behaviors is very consistent (Umerenkova et al., 2022). In fact, it has been found to be predictive of deep, meaningful learning processes (de la Fuente et al., 2015a), and to be predictive of emotional maladjustment in learning (Moohr et al., 2021). Hence the importance of assessing and improving self-regulation (Bittner et al., 2022). In complementary manner, a clear relationship has emerged between self-efficacy and self-regulation (Lin et al., 2023).

More recently, the concept of types of internal and external self-regulation (Self-Regulation/Self-non-regulation/Self-dysregulation

SR-NR-DR) has helped to distinguish the types and levels of self-regulatory behaviors in students. Recent evidence has been very consistent in relation to its association with, and linear prediction and determination of, learning focuses amongst students and of other strategic aspects and learning metaskills (de la Fuente et al., 2017, 2022a,b,c).

5.1.2.1.2 Contextual presage variables

The construct *internal or external regulation* (ER/ENR/EDR) has helped to order the desirable and undesirable regulatory effects of students' contexts. Evidence provided by this construct has shown the importance of regulatory versus non-regulatory and dysregulatory educational or teaching contexts to different learning behaviors during the learning process. They can be identified as protective or risk factors in the learning process (de la Fuente et al., 2021a,b, 2022a,b,c). The *general design of education* has been seen to be a predictive factor (de la Fuente et al., 2020a). Family context has also been shown to be an essential component of context, with a clear role in promoting and facilitating or interfering in processes of motivation and learning (Ross and Hill, 2000; Tapia et al., 2013; Núñez et al., 2015; Boncquet et al., 2022).

5.1.2.2 Process (mediating) variables

5.1.2.2.1 Personal process variables

5.1.2.2.1.1 Conceptual variables (knowledge: concepts)

Learning focus has been shown to be an essential variable to understand cognitive-motivational beliefs and underlying strategies in the course of learning (Shum et al., 2021). With extensive evidence, the model allows us to distinguish academic learning focuses that are more or less adaptive (Heikkilä, 2011; Karagiannopoulou et al., 2018; Panadero et al., 2021; Asikainen et al., 2022).

Alongside that, the variable learning styles also significantly assists us to understand conceptualizations, beliefs and actions concerning academic learning, because that variable tells us about elaborative processing and conceptualizations of the learning process (Entwistle and Ramsden, 1983; Cassidy, 2004; Gargallo-López et al., 2013; Martínez-Fernández and Vermunt, 2015; Vermunt and Donche, 2017).

5.1.2.2.1.2 Procedural variables (know-how)

Skills applied in the learning process have been shown to be essential instrumental elements for adequate learning in an academic context. Skills such as oral expression, note-taking, study techniques and teamwork have been seen to be *basic learning tools* (Sewell et al., 2022). Although they make a relatively small contribution to regulation, they are essential first-order tools in school and university learning. And for that reason, they should be assessed and improved.

At the level of *metaskills or skills in management and regulation of instrumental skills* (de la Fuente et al., 2015a), recent research has generated a large volume of evidence concerning these higher order or *strategic metacognitive* skills in academic learning (Cano-García and Justicia, 1993; Basu and Dixit, 2021; Cai et al., 2022; Krieger et al., 2022; Küçükaydın, 2023; Paz-Baruch and Hazema, 2023). Thus, there have been added to traditional—mostly cognitive—learning strategies, regulatory strategies for the regulation of motivational-affective processes, in other words: *metamotivational and meta-affective strategies.*

1. *Resilience* has been seen as a factor in metamotivational regulation (Grossman, 2014; Artuch-Garde et al., 2017; Dray et al., 2017).
2. *Coping strategies* as a factor in meta-affective management (Banerjee et al., 2019; Freire et al., 2020; de la Fuente et al., 2021b).
3. Self-regulation as a factor in behavioral metaregulation (Blair and Raver, 2015; de la Fuente et al., 2015b).

Research is also providing evidence concerning the pernicious effects of the absence or dysfunction of those skills. Such is the case (4) of *procrastination* as an example of regulatory failure or dysregulation (Garzón-Umerenkova et al., 2018; Netzer-Turgeman and Yehuda Pollak, 2023) and *emotional dysregulation* as difficulty in emotional control (Coifman and Aurora, 2022; de la Fuente et al., 2022b).

5.1.2.2.1.3 Attitudinal variables

Achievement emotions are an attitudinal variable which has been shown by copious evidence to be predictive of learning, positive or negative learning experience and final achievement (Reindl et al., 2020; de la Fuente et al., 2020c; Pekrun et al., 2023; Wang and Zheng, 2023). In association with those emotions, academic confidence has emerged as a first-order attitudinal factor which is predictive of learning focus, satisfaction and achievement (de la Fuente et al., 2013; Sander and de la Fuente, 2022; Lu and Wen, 2023).

Action-emotion style has consistently been shown to be predictive and discriminating in relation to learning focuses, emotions, coping strategies and work habits (de la Fuente et al., 2008, 2016c).

Maladaptive perfectionism has emerged as an important mediating factor that modulates motivation and emotional dysregulation in learning (Hill et al., 2020; Lee and Anderman, 2020; Moreno-Peral et al., 2020; Zeifman et al., 2020; de la Fuente et al., 2022c; Sepiadou and Metallidou, 2022; Kahn et al., 2023). On the other hand, adaptive perfectionism correlates with self-expectation and adaptive improvement in different contexts (Flett and Hewitt, 2020).

Personal strengths have emerged as essential (attitudinal) learning variables that comprise numerous emotional-affective skills to undertake the effort required by ongoing university education (Villacís et al., 2021; de la Fuente et al., 2022a).

5.1.2.2.2 Contextual process variables

The effectiveness of the teaching process has proved to be functionally protective against stress by promoting a deep learning approach, learning strategies, problem-focused coping strategies, positive emotionality and, finally, satisfaction with the teaching-learning process, hence, less stress and more well-being (de la Fuente et al., 2021a,b). Previous research has also shown this functional predictive directionality (Mastrokoukou et al., 2022).

5.1.2.3 Product (outcome) variables

Academic performance, in the sense of not just an average grade but of the acquisition of skills as applied to a given field of knowledge and practice. This dependent variable has—for obvious reasons—been examined by many researchers (de la Fuente et al., 2010; Barattucci et al., 2021; Casiraghi et al., 2022). Some models have assumed that *academic performance* entails the acquisition of learning or conceptual,

procedural and attitudinal subcompetencies in an integrated way (de la Fuente et al., 2005).

Academic satisfaction has also been much studied and is considered to be a final or outcome variable, at least as important as academic performance (if not more so) as a correlate of experiences of wellbeing (de la Fuente et al., 2015a).

Academic stress has also been seen as a variable, that is predicted by groups of many of the variables previously described. It has been shown to be negatively correlated with experience of satisfaction (de la Fuente, 2021).

Flourishing, academic health and psychological wellbeing have been seen as process outcome dependent variables of great contemporary importance (Garzón-Umerenkova et al., 2018; de la Fuente et al., 2022a).

6 Applicability of the conceptual utility model: psychoeducational assessment and intervention

The model is being applied in two aspects:

1. This new utility model is guiding the work of our current Knowledge Promotion R&D Project (see Project reference) and will serve to open future avenues of research. Conceptual and predictive relationships inherent to the model have been empirically tested, to determine the precise directionality of the relationships. The model has been partially validated by the preliminary evidence (de la Fuente et al., 2021a,b; see previous sections).
2. Complementarily, an *online self-help tool* has been developed for professional use (see Proof of Concept Project). We consider this an example of how the R&D&I value chain in Psychology can make relevant contributions to the profession (de la Fuente et al., 2018a).

6.1 Assessment of each variable in the model

However, this conceptual utility model (de la Fuente and Martínez-Vicente, 2004, 2023a,b,c) allows us to formulate *precise assessment and intervention hypotheses* to support decision-making in professional contexts concerning the psychology of university education. It is a powerful conceptual tool for decision-making in the field of University Guidance supported by the *e-Self-Help Tool, e-Coping with Academic Stress* (de la Fuente et al., 2015c). This model has already been used with educational psychologists for training in assessment, through case studies, in the 2023 academic year. In the same program, based on the real-case approach, variables have been identified and pertinent assessment instruments have been proposed (See Supplementary Appendix S3).

6.2 Evidence-based intervention for each variable in the model

Along the lines of evidence-based psycho-educational intervention (Slavin, 2017, 2019; de la Fuente et al., 2023a), proposed interventions and improvement measures have been put forward as strategies for external assistance to improve the specific behavioral variables analyzed.

On the basis of empirical evidence concerning the variables analyzed in the model, the *e-Self-Help Tool, e-Coping with Academic Stress* (de la Fuente et al., 2015c) suggests actions for progressive improvement to address each subcompetency in question. The intervention proposal has been made through the self-help tool or the behavior improvement proposal, through training activities for the subjects (de la Fuente, 2024a).

7 Limitations

The *conceptual utility model* presented here has limitations that must be mentioned. Firstly, although it represents a conceptual and empirical advance with respect to the previous models mentioned, and has an omnibus nature, applicable to different fields of psychology, it does not integrate all the possible variables in the areas of stress and psychological well-being. The variables included are very representative, typical of our lines of research. This means that present or future research should continue to incorporate other variables.

Secondly, this model has not yet integrated—although it has the potential to do so—all the relevant recent evidence on the role of emotion regulation variables (Milenios et al., 2021). One future line of work should be precisely the integration of the plentiful, varied evidence, integrating it into the utility model.

Finally, the model has an important limitation referring to the samples used in defining the proposed empirical relationships. The large proportion of university students requires that, in the near future, these analyzes and relationships be tested with other educational, health-related, and organizational samples outside the university environment.

8 Conclusion

Evidence-based conceptual utility models—such as the model put forward in this report—should be seen as first-order tools for the transfer of scientific knowledge to the field of applied psychology. They represent in themselves a significant advance in knowledge of the Psychological of Education and they allow:

1. The identification of complex problems on the basis of prior research and the construction of hypotheses that are explanatory and predictive of those problems. That is an essential professional competence for those working in the psychology of education. These models allow account to be taken of predictive and risk factors for university students and their contexts (de la Fuente, 2021).
2. The deductive identification of factors or variables to be assessed, associated with assessment instruments (translated and validated) tested in the population in which they are to be used. That represents an unequivocal advantage, in light of the research tools that the model brings to research in the psychology of education that have originated in the Anglosphere, such that they must be adapted for use in other cultural contexts.

3. The putting forward of discrete interventions, based on the direction determined by evidence and adjusted to each variable under analysis (de la Fuente et al., 2023a,b).

In summary, this model allows the three essential stages of any professional psychological intervention to be brought together: (1) Explanatory determination of the problem; (2) Assessment and diagnosis of the problem; (3) Intervention using specific techniques and actions. That competence is included in international professional standards (EuroPsych, 2022).

It also contributes to the R&D&I value chain (Research + Development + Innovation) through specific models of wide professional application in the practice of the Psychology of Education (de la Fuente et al., 2012a, 2018a). Specifically, this conceptual model has served to support the e-Coping Tool for Academic Stress (de la Fuente, 2023b).

Data availability statement

The original contributions presented in the study are included in the article/Supplementary materials, further inquiries can be directed to the corresponding author.

Author contributions

JF: Conceptualization, Funding acquisition, Project administration, Writing – original draft, Writing – review & editing. JM-V: Conceptualization, Formal analysis, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The author(s) declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2023.1299224/full#supplementary-material

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Dynamic insights into research trends and trajectories in early reading: an analytical exploration via dynamic topic modeling

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Introduction: Early reading has gained significant attention in the academic community. With the increasing volume of literature on this subject, it has become crucial to assess the current research landscape and identify emerging trends.

Methods: This study utilized the dynamic topic model to analyze a corpus of 1,638 articles obtained from the Web of Science Core Collection to furnish a lucid understanding of the prevailing research and forecast possible future directions.

Results: Our in-depth assessment discerned 11 cardinal topics, among which notable ones were interventions' impacts on early reading competencies; foundational elements of early reading: phonological awareness, letters, and, spelling; and early literacy proficiencies in children with autism spectrum disorder. Although most topics have received consistent research attention, there has been a marked increase in some topics' popularity, such as foundational elements of early reading and early literary proficiencies in children with autism spectrum disorder. Conversely, other topics exhibited a downturn.

Discussion: This analytical endeavor has yielded indispensable insights for scholars, decision-makers, and field practitioners, steering them toward pivotal research interrogatives, focal interest zones, and prospective research avenues. As per our extensive survey, this paper is a pioneering holistic purview of the seminal areas of early reading that highlights expected scholarly directions.

KEYWORDS

early reading, dynamic topic model, topic identification, topic evolution analysis, visualization

1 Introduction

Early reading has received global recognition due to its paramount importance and profound connection with young children's academic trajectories and subsequent life outcomes (García and Weiss, 2017). A robust body of research has consistently indicated that early proficiency in reading skills predisposes children to academic excellence (Young and Dolzhenko, 2022; Muroga et al., 2023). In contrast, those encountering early reading challenges often experience Matthew effects, where initial reading difficulties lead to increasingly pronounced disparities in both reading proficiency and broader academic accomplishments (Stanovich, 2009).

Despite the global consensus on the significance of early reading, a comprehensive review that encapsulates the knowledge structure and thematic evolution of early reading

at an international level is noticeably lacking. This lack not only hinders a holistic understanding of the field but also limits the potential for identifying emergent trends and critical topics that could guide future research and practice. Addressing this gap is not merely an academic endeavor but a crucial step in influencing the trajectory of early reading research and its practical applications. Therefore, the present study was driven by the following fundamental research question: Which key topics and trends define the knowledge structure and topic evolution in early reading?

To explore this question, we employed the dynamic topic model (DTM) to critically assess relevant scientific literature. This method allowed us to delve into prevalent knowledge topics and their evolutionary patterns within the early reading field. Compared to traditional systematic literature reviews, the DTM, which is grounded in text mining techniques, enables a more comprehensive and dynamic analysis of domain-specific knowledge (Xiong et al., 2023). It is particularly adept at capturing and analyzing long-term trends and gradual shifts in knowledge structures, thus providing deeper insights into the historical development, current state, and potential future directions of early reading.

Through this inquiry, we aimed to furnish the early reading discipline with invaluable insights and offer a discerning perspective on its prospective future directions. This study sought to not only fill a critical gap in the literature but also serve as a foundational resource for scholars, educators, and policymakers dedicated to enhancing early reading outcomes across diverse contexts.

2 Literature review

Early reading refers to the process in which young children develop foundational language skills during the preschool and early primary school years through word recognition and comprehension of written text. It plays a crucial role in language acquisition and in young children's overall development (Niklas et al., 2016). This stage encompasses all experiences and encounters young children have with oral and written conversations, stories, books, and printed materials. It is essential for their development of a rich vocabulary, self-expression, and reading comprehension abilities (Barron, 1986; Lennox, 2013). Early reading not only lays the foundation for young children's school readiness and lifelong learning but also profoundly affects their cognitive, emotional, and social development. It establishes the groundwork for acquiring knowledge in other subject areas (Vanbecelaere et al., 2023) and significantly influences future academic achievements and educational attainment (Cunningham and Stanovich, 1997; Duncan et al., 2007). Therefore, gaining a comprehensive understanding of early reading's multidimensional construction and its pivotal role in language learning and child development holds paramount significance in designing effective educational strategies and intervention measures.

Precisely due to early reading's pivotal role in language acquisition and child development, the academic community has paid close attention to this field and has conducted extensive research on the various internal and external factors that influence early reading development. Researchers have specifically examined the impact of cognitive abilities (Hernández Finch et al., 2014), language skills (Clayton et al., 2020), reading motivation and interest (Altun, 2019), and reading strategies and techniques (Bojczyk et al., 2016) on early reading skills development. These studies have revealed internal factors' significant influence on the formation of early reading abilities and have provided profound insights into the fundamental elements of early reading development. Concerning external environmental factors, scholars have focused on the impact of the school environment (Taylor et al., 2010), the home environment (Hamilton et al., 2016), gene–environment interaction (Olson et al., 2014), and reading materials (Luo et al., 2020) on early reading abilities. These studies have emphasized the external environment's crucial role in nurturing early reading development and have highlighted the school and family environments' supportive role in facilitating early reading progress.

In recent years, some scholars have conducted review studies of the early reading field that describe its current state and development characteristics. For instance, Allington and McGill-Franzen (2021) reviewed the relationship between reading volume and reading achievement. Ostiz-Blanco et al. (2021) systematically reviewed the use of electronic interventions to improve early first-language reading. Arciuli and Bailey (2021) systematically organized the factors affecting early reading development in children with autism spectrum disorder (ASD). Lorio et al. (2022) systematically reviewed intervention strategies for infants and toddlers who engage in reading with their parents. Hall et al. (2023) systematically reviewed the impact of kindergarten writing instruction on literacy skills. Although these review papers have provided valuable insights into the development of knowledge topics in the field of early reading, they also have certain limitations. For example, they have tended to focus on specific areas (e.g., the type of book media) or specific groups of children (e.g., children with ASD). Additionally, they have relied on qualitative meta-analyses or systematic review methods and used small sample sizes; the research results therefore lack persuasive power. Furthermore, the use of manual coding methods for literature screening, classification, and analysis means that the research results depended on the researchers' subjectivity, which may have resulted in untrustworthy research outcomes. Therefore, to assess early reading development trends more accurately, use of advanced quantitative research methods and more comprehensive data sources is needed.

With the rapid progression of artificial intelligence technologies, traditional analysis methods based on external features (e.g., keyword and citation networks) are now ill-equipped to handle high-dimensional data and address intricate challenges. Consequently, researchers have begun to adopt newer natural language processing (NLP) methodologies to investigate scientific documents in a more nuanced manner. These methods are

Abbreviations: ASD, autism spectrum disorder; DHH, deafness or hard of hearing; DTM, dynamic topic model; EF, executive function; fMRI, functional magnetic resonance imaging; HLE, home literacy environment; LDA, latent Dirichlet allocation; LS, letter–sound; NLP, natural language processing; SSD, speech sound disorder; WOS, Web of Science.

better suited to address the challenges of high-dimensional data and intricate issues as they facilitate profound analyses and understanding of scientific documents and thereby offer comprehensive support to scientific inquiry. For instance, Chen et al. (2020) employed the structural topic model to identify topics in 3,342 articles published in *Computers & Education*, a leading educational technology journal, with the aim of identifying major research topics and potential future directions in educational technology. Kaushik et al. (2023) utilized the latent Dirichlet allocation (LDA) model to mine topics from 3,844 articles related to social entrepreneurship that were obtained from the Scopus and Web of Science (WOS) databases and identify latent research topics and future development trends in social entrepreneurship studies. Wang et al. (2023) also used the LDA to mine topics from 8,197 articles related to health-promoting behaviors among miners that were obtained from the WOS database to assist researchers with grasping the core research topics and potential future directions in that domain. Evidently, NLP techniques have been embraced across various research domains, and the feasibility of using topic modeling to extract and observe the distribution of topics and research trends in extensive literature has been empirically validated.

Hence, this study employed an NLP-based dynamic topic modeling approach to extract key information from paper titles, keywords, and abstracts and autonomously generate research knowledge topics within the dataset and facilitate a comprehensive analysis of topic distribution characteristics and evolving trends in early reading. The research outcomes are expected to aid researchers, educators, and policymakers in gaining a deeper understanding of hotspots, trends, and potential future directions in early reading. This paper provides profound insights and holistic support for scientific investigations in the early reading domain and further propels the advancement of early reading education through the refinement of educational content and the shaping of related policies.

3 Methods and materials

3.1 Research approach

This study utilized journal articles obtained from the WOS Core Collection as a data source and employed the DTM to dissect the characteristics of the knowledge structure and the topic evolution process in early reading research data from two dimensions. The detailed research steps were as follows. Firstly, literature retrieval entailed retrieving scholarly early childhood reading literature from the WOS database. Secondly, data preparation entailed extracting titles, keywords, and abstracts from the literature to serve as the corpus data, then cleaning the data and segmenting them into chronological time windows. Third, topic analysis entailed determining the number of topics by assessing topic consistency and conducting a horizontal analysis of the initial results of the DTM. Fourth, the evolution of trends was ascertained by calculating the topic heat for the various time windows, visualizing topic evolution trends, and analyzing the evolution path of topic keywords at a granular level.

3.2 DTM

Traditional largescale literature analysis methods often employ co-citation and keyword networks for content mining and analysis. However, co-citation network analysis fails to capture the latest research content as co-citation relationship formation requires time. On the other hand, keyword network analysis faces the issue that many articles do not include keywords, or the keywords are selected from a predefined list. Hence, the displayed keywords may not always accurately reflect the articles' content.

To overcome these issues, we opted for the topic modeling approach. Compared to co-citation and keyword analysis, topic modeling has demonstrated greater adaptability and efficiency in providing comprehensive content analysis (Kuhn, 2018). The topic modeling method involves inferring and modeling latent topics from textual data, which enables the automatic discovery of topics present in the text and reveals their distribution across different documents. This approach does not rely on predefined keywords or co-citation relationships but rather extracts topic information directly from the textual data, enabling more accurate capture of the text's semantic and contextual aspects (Vayansky and Kumar, 2020).

Although the classical LDA has been effective at identifying topics, the incorporation of a temporal dimension through the DTM offers a superior capability to trace research topics' developmental trajectory and evolution over time. This temporal analysis is crucial, particularly in fields such as early reading where discourse and thematic emphasis may shift significantly over the years. For instance, the discussion surrounding early reading practices in 1995 is likely to differ substantially from contemporary discourse in 2023. Despite the constancy of the overarching topic of early reading, its nuanced representation and focal areas might evolve. To capture this dynamic nature, we adopted the DTM that Blei and Lafferty (2006) proposed. Building upon the foundation the LDA has laid, the DTM introduces temporal sequencing to the analysis, making it particularly suited to our study, which sought to dynamically identify anticipated developments and transformations within the early reading domain. The practical value of this text mining technique has been widely recognized and applied in the academic community, as evidenced by recent studies (Yao and Wang, 2020; Gao et al., 2022). In our methodology, we began by discretizing and chronologically segmenting the textual data, namely titles, keywords, and abstracts, obtained from the early reading literature. We then hypothesized as to the evolution of topic and content distributions in adjacent time slices, which allowed for the identification of a sequence of continuous topics within the collected abstract data. The specific process of DTM-based topic modeling, which captures these temporal nuances and thematic shifts, is illustrated in Figure 1, where w represents a word, and z denotes the topic to which word w pertains in the collection of documents d within the time slice. Θ follows a Dirichlet distribution with parameter α to determine the topic distribution in the document collection. B is the Dirichlet prior and records the probability of generating a word under a specific topic. The number of words, N, was determined using a Poisson distribution within the time slice. A represents the number of documents within the time slice, and K indicates the number of time slice

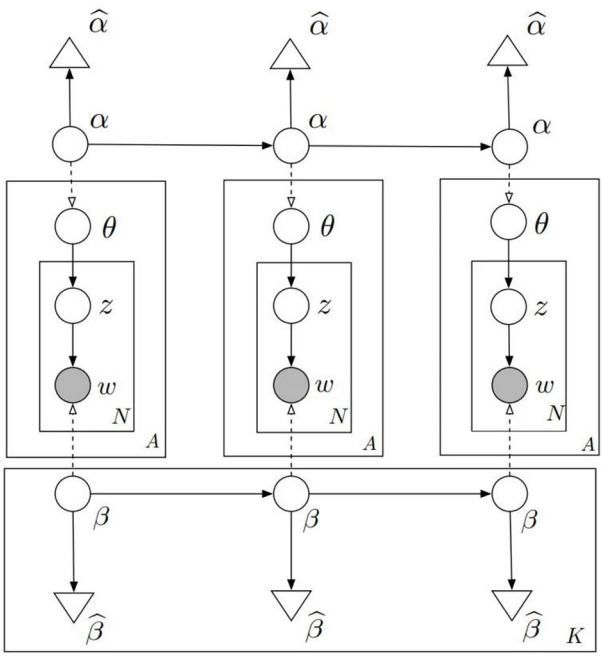

FIGURE 1
DTM.

partitions. For each word in N, the topic z was selected from a multinomial distribution with a parameter value θ, and the word w was chosen based on a multinomial distribution conditioned on z and β. At time t, the topic distribution in the document collection, denoted as α_t, and the word distribution under each topic, denoted as β_t, would depend on the previous moment's α_{t-1} and $\beta_{t-1,k}$, respectively. The dependency relationships between these were acquired using the dynamic model. The generative process for a sequence of continuous textual documents within the time slice t was as follows:

1. To generate a word distribution: $\beta_t|\beta_{t-1} \sim N(\beta_{t-1,k}, \delta^2 I)$
2. To generate a topic distribution: $\alpha_t|\alpha_{t-1} \sim N(\alpha_{t-1}, \delta^2 I)$
3. For each document:

(a) Generate $\eta \sim N(\alpha_t, \alpha^2)$
(b) For each word:
(i) Generate $Z \sim Mult(\pi(\eta))$
(ii) Generate $W_{t,d,n} \sim Mult(\pi(\beta_t, z))$

Note that π maps the multinomial natural parameters to the mean parameters. The formula is as follows:

$$\pi((\beta_{k,t})\, w) = \frac{\exp(\beta_{k,t,w})}{\sum_w \exp(\beta_{k,t,w})}$$

In this study, we employed Mimno et al. (2011) concept of "coherence" to determine the optimal number of topics. This involved considering frequently occurring and high-scoring words under a topic and calculating the semantic similarity of their co-occurrence in documents. A higher coherence score indicated stronger model interpretability. The formula is as follows:

$$C\left(k; V^{(k)}\right) = \sum_{m=2}^{M} \sum_{l=1}^{m-1} \log \frac{D\left(v_m{}^{(k)}, v_l{}^{(k)}\right) + 1}{D(v_l{}^{(k)})}$$

where $D(v)$ represents the number of documents containing at least one occurrence of word v; $D(v, v')$ denotes the number of documents where words v and v′ appear together; and $V_{(k)} = (V_{(k)1}, \ldots, V_{(k)m})$ represents the list of words most likely to be associated with topic k.

3.3 Data collection

To ensure the accuracy and authority of our research sources, we selected Social Sciences Citation Index and Science Citation Index journal articles from the WOS Core Collection to comprise the dataset for this study. The WOS Core Collection is renowned for providing a high-quality literature dataset and is frequently utilized in scientific research (Martín-Martín et al., 2021; Xu et al., 2022). Our search query was constructed as TS = ("early literacy" or "early childhood literacy" or "early reading" or "early childhood reading"), covering the period 1 January 1995 to 31 July 2023, with the latter date being the date of the last search. The year 1995 was selected as the starting point because it is the earliest year available in the WOS Core Collection, as accessed through the Ningbo University Library; hence, the earliest possible retrieval date was set to 1 January 1995. The initial retrieval yielded 1,848 articles. Subsequently, bibliometrics and content analysis were employed to exclude conference abstracts, editorial materials, and other irrelevant types of documents. This refined selection process yielded 1,638 journal articles. Finally, we extracted and synthesized the articles' publication years, titles, abstracts, and keywords to serve as the data source for topic identification.

3.4 Analysis of trends in article and citation counts

Variation in academic paper quantity over time is an important indicator for assessing development trends in a particular field (Xu et al., 2022). Considering that this study focused on evolution in the early reading field, an occurrence-based statistical method was employed for each time window to obtain the publication volume for each calendar year, as shown in Figure 2, where the red line represents the changes in publication volume in early reading over the years, and the blue line represents the cumulative citation count of publications within each time window. Overall, the total annual publication volume showed a general increasing trend, with the final year's statistics differing from those of the initial year by a factor of over 100. Starting from 2014, there has been a rapid increase in the annual publication volume in the later period of the timeline, indicating significant growth in early reading research in recent years. Furthermore, upon closer examination of the distribution pattern of the cumulative citation count in Figure 2, a consistent year-by-year

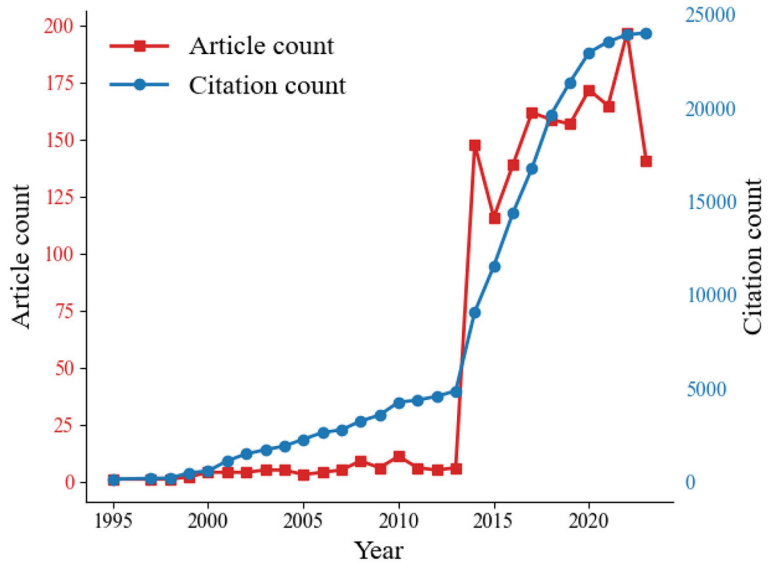

FIGURE 2
Number of publications and citation counts over the years.

increase can be observed in the citation frequency of research achievements in early reading, with nearly 25,000 citations by 2023. This demonstrates the increasing influence of early reading research within the academic community. However, the slight decrease in the data for the year 2023 should be noted, which may be attributed to the choice of the retrieval time point in this study.

3.5 Data cleaning and preprocessing

Prior to engaging in topic modeling, it is imperative to enhance the quality of the data through rigorous preprocessing. This foundational step ensures that the subsequent optimal topic identification is both accurate and insightful. Data preprocessing in this study entailed the following steps.

Step 1 entailed novel word discovery and synonymous substitution. In early reading research, we often encounter terms that intersect with complex fields such as neuroscience. Such terminology is typically intricate and frequently presented in abbreviated forms, such as "executive function (EF)." In this study, we meticulously identified and tagged these specialized terms first to ensure that they could be accurately recognized and processed in tokenization and handling, thereby preserving their original academic significance. Following the identification and tagging process, we proceeded with synonymous substitutions. To maintain the integrity of the original semantic meanings, we replaced certain longer terms with their widely accepted abbreviations; for example, we substituted "functional magnetic resonance imaging" with "fMRI," "deafness or hard of hearing" with "DHH," and "speech sound disorders" with "SSD." Consequently, even after tokenization and processing, the nuanced meanings of these terms were retained and emphasized.

Step 2 entailed tokenization, stop-word removal, and lemmatization. Before applying the DTM for topic modeling, the text must first be tokenized to construct a vocabulary. Following tokenization, we filtered out non-informative stop words to refine the dataset. Subsequently, utilizing the Natural Language Toolkit library's lemmatize method, we performed lemmatization to restore the words to their base or dictionary form, focusing primarily on nouns and adjectives. This step was crucial for reducing the data's complexity and enhancing interpretability.

Step 3 entailed text vectorization, which is the process of converting text into numerical values to facilitate computational analysis. In this study, we employed the Gensim library's "corpora" module. We adopted the bag-of-words model and represented the tokenized text as frequency vectors. This transformation was pivotal for applying mathematical and statistical operations in the subsequent topic modeling phase.

By meticulously executing these preprocessing steps, we ensured a robust and clean dataset and laid the groundwork for effective optimal topic identification. This sequential approach not only enhanced the study's academic rigor but also ensured a seamless transition from data preparation to in-depth topic analysis, which culminated in a comprehensive understanding of the underlying textual topics.

3.6 Optimal topic identification

In topic modeling, determining the optimal number of topics is an important and challenging task. This study identified the ideal number of topics by accurately calculating the model's coherence. Specifically, we set the topic number range as 1–20 and iterated the calculation in steps of 2. The coherence score, ranging between 0 and 1, indicated the quality of topic segregation, with a higher score representing better quality. The topic coherence

results are presented in Figure 3. When the number of topics was set to 11, the model exhibited the highest coherence score, leading us to determine that the optimal number of topics was 11. We further designated that each topic would contain ten primary terms (Table 1). Utilizing the multidimensional mapping relationship between the literature topics and the topic terms, we conducted a comprehensive analysis of different reading topics and their corresponding topic terms for each sub-period. This method allowed us to track and analyze the evolution of topics with fine granularity, which resulted in insights into understanding the text.

4 Results

4.1 Topic content analysis

As shown in Figure 4, we visually displayed the top ten feature words for each of the 11 topics. This visualization aided in our understanding and analysis of the corresponding topic content. Additionally, we selected representative literature from the document–topic distribution graph to provide an in-depth analysis of topic content. The results by topic are as follows.

4.1.1 Topic 1: Interventions' impacts on early reading competencies

Under this topic, key terms like "literacy," "child," "reading," "early," "teacher," "read," "student," "study," "intervention," and "skill" emerged as especially representative. The breadth of academic inquiry in this area spans the effectiveness of various instructional strategies to the significance of the home literacy environment (HLE). Key considerations include the design and implementation of teacher-led interventions (Carta et al., 2014; McConnell et al., 2014), the continuous evolution of these strategies to keep pace with changing educational landscapes (Kaminski and Powell-Smith, 2017; Phillips et al., 2021), and dynamic evaluations regarding the success and challenges of such interventions (Gustafson et al., 2014; Greenwood et al., 2017). Within this overarching topic, three primary facets stood out.

Firstly, teacher interventions in early reading play a pivotal role in early reading development. In environments with limited resources and diverse linguistic backgrounds in particular, the strategies teachers employ are crucial. Comprehensive literacy guidance in early reading classrooms can greatly enhance students' literacy skills. For instance, Putman (2017) highlighted the impact of teacher support on preschool literacy achievements. Similarly, Mihai and van Staden (2019) emphasized educators' vital roles and noted the varied effectiveness of strategies across different cultural and resource settings. It is therefore imperative to consider both cultural and resource disparities when designing these strategies.

Secondly, the HLE plays a central role in early reading development. Sénéchal and LeFevre (2014) conducted a 2-year longitudinal study involving 110 children that delved deep into the continuous influence of and changes in the HLE on the children's early vocabulary and reading abilities at different junctures. The research findings revealed that stability and variations in the HLE serve as key predictors for early vocabulary and reading growth. Further supporting this point, Zhang S.-Z. et al. (2023) evaluated 553 Chinese kindergarten third-graders and examined family factors to investigate the direct and indirect effects of the family reading environment on the children's early literacy skills. The research results demonstrated that the family reading environment both directly and indirectly influences early literacy skills. Moreover, the differences in these influences between affluent and impoverished societies were found to be minimal, suggesting the universality of the family reading environment's impact on early literacy abilities. These research findings have provided valuable insights for the development of educational strategies and family support programs aimed at promoting early literacy skills.

Thirdly, regarding targeted reading interventions, in addition to traditional early reading interventions, there has been significant scholarly interest in specialized child populations with reading disabilities, and researchers have proposed specific intervention methods to enhance early literacy skills in these specialized groups (Pace Miles et al., 2019). For a salient example, consider the tailored interventions designed for children with Down syndrome. Studies have evaluated the feasibility and potential impacts of these bespoke interventions and reported promising outcomes (Lemons et al., 2017). Such focused research underscores the importance of customizing strategies to cater to distinct needs within varied child populations. This brings a fundamental question to the forefront: How should interventions be tailored to meet specific requirements? To address early reading challenges, strategies should not only be culturally sensitive but also tailored to individual needs. Consistent collaboration between families and educational institutions is imperative in this process. This synergistic approach ensures that reading interventions are both continuous and consistent, thus creating a comprehensive learning environment for children.

4.1.2 Topic 2: Foundational elements in early reading: phonological awareness, letters, and spelling

Reading is the cornerstone of early learning and cognitive development, a status that renders understanding its key components crucial for education. The core terms under Topic 2, such as "awareness," "phonological," "word," "reading," "letter," "Chinese," "read," "vocabulary," "child," and "spelling," have illuminated an inherent nexus between preschool children's reading proficiency and their phonological awareness, grasp of the alphabetic principle, and orthographic knowledge. Assiduous ongoing scholarly scrutiny in this domain seeks to elucidate the determinants shaping precocious reading aptitudes.

Regarding phonological awareness, Diamanti et al. (2017) evaluated 104 preschoolers' early phonological awareness skills and researched its predictive power on reading and spelling outcomes at the end of Grade 1. Those scholars found that phonological awareness played a vital role in assessing the preschoolers' fluency in reading text as well as their comprehension of the text. These findings align with those of Kargiotidis et al. (2023), who administered early reading development tests to 141 first-graders to examine the impact of their vocabulary knowledge, phonological awareness, and morphological awareness on their early reading skills and Greek spelling consistency and found

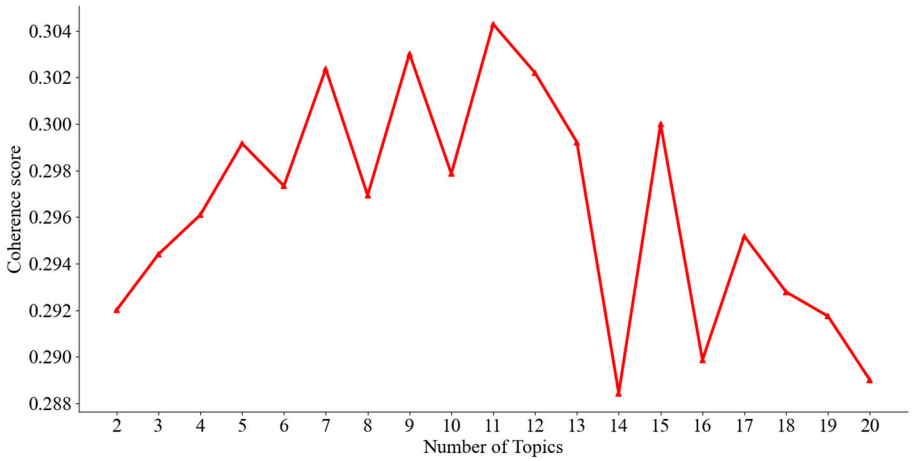

FIGURE 3
Coherence scores.

TABLE 1 Topic–word mapping within each time period (partial).

Topic	(Time = 1995).....(Time = 2022)	(Time = 2023)
Topic 1	…	Literacy, child, reading, early, teacher, read, student, school, book, intervention
Topic 2	…	Awareness, phonological, word, Chinese, reading, read, letter, study, vocabulary, child
Topic 3	…	Achievement, mathematic, EF, early, academic, executive, skill, reading, mediate, child
Topic 4	…	Writing, write, skill, child, early, letter, preschool, literacy, composition, teacher
Topic 5	…	Language, child, English, literacy, Spanish, bilingual, skill, early, study, use
Topic 6	…	Library, family, public, story time, book, program, librarian, literacy, child, community
Topic 7	…	Speech, SSD, sound, production, phonological, child, age, auditory, DHH, difficulty
Topic 8	…	Dyslexia, reading, read, child, risk, word, phonological, awareness, early, development
Topic 9	…	Genotype, imputation, study, data, genetic, reading, ability, twin, longitudinal, variable
Topic 10	…	Synapse, energy, spike, SNN, device, stochastic, hardware, VOT, SOT, visual
Topic 11	…	Child, autism, early, spectrum, skill, age, study, parent, school, ASD

that phonological awareness is a significant predictor of word reading accuracy.

Regarding letter knowledge, Plewko et al. (2018) proposed that learning letter–sound (LS) association, or letter knowledge, is a significant determinant of reading ability. However, whether the disruption of LS association leads to reading impediments remains uncertain. To explore this, those scholars employed functional magnetic resonance imaging (fMRI) to probe the relationship between LS association and reading proficiency and found that variations in LS association can predict future reading issues in children. This finding complements those of Kuvač-Kraljević et al. (2019), who conducted a cross-sectional study involving 764 children to delve into the interrelation and inherent structure of phonological awareness and letter knowledge during the early literacy phase. Their findings have proffered valuable insights for educational policies in the realm of early literacy.

Focusing on spelling, Ouellette and Sénéchal (2017) examined the "invented spelling" abilities of 117 children, positing it as a predictor of subsequent reading and spelling competencies in Grade 1. Their research has indicated that the invented spelling approach influences children's subsequent reading capabilities and explains variations in their literacy outcomes. Additionally, Ye et al. (2022b) longitudinal study found an interconnection of early spelling and reading abilities in children transitioning from Cantonese kindergartens in Hong Kong to primary schools, with early spelling and reading performances influencing each other.

FIGURE 4
Visualization of topic–word distribution.

In summary, phonological awareness, alphabetic knowledge, and spelling are undoubtedly the foundational pillars of early reading. Although numerous studies have examined these elements individually and sometimes in tandem, a holistic understanding of their dynamic interplay, especially in multilingual contexts, remains relatively underexplored. Notably, the intricate relationships among these components, as they manifest across diverse linguistic landscapes, might offer vast research potential.

4.1.3 Topic 3: Early mathematical ability and reading achievement

Within the purview of Topic 3, pivotal terms such as "mathematic," "EF," "achievement," "executive," "early," "academic," "skill," "math," "child," and "function" underscored the complex intersectionality between early mathematical competencies and reading milestones. Of particular intrigue is the modulatory role executive functions (EFs) seem to play in shaping academic outcomes. Although there exists a consensus on the synchronicity between mathematical and reading proficiencies, the nuanced pathways through which the former informs the latter, especially in diverse linguistic or pedagogical contexts, have not yet been comprehensively delineated.

Venturing into this relatively uncharted domain, Purpura et al. (2017a) assessed 125 preschoolers' mathematical literacy and cognitive landscapes to distill the mechanisms underpinning how early mathematical prowess might serve as a prognosticator for emergent literacy milestones. Their analysis unveiled a nuanced interface between early mathematical literacy and reading proficiencies, accentuating the mediating role of mathematical language skills therein. To better understand the nexus between early mathematical abilities and early reading skills, Purpura et al. (2017b) extrapolated how EFs' multifaceted elements interweave with math and reading skillsets in preschoolers. Their illuminative outcomes not only demystified the intricate interrelationships but also spotlighted the anticipatory weight of early math skills vis-à-vis reading evolution. Additionally, Ten Braak et al. (2022) further substantiated EFs' significance in elucidating the relationship between toddlers' early math skills and their elementary school mathematical and reading achievements. In summary, the intricate tapestry that interlinks early mathematical cognition, reading attainment, and EFs remains a profound area for academic exploration.

4.1.4 Topic 4: Supporting early literacy skills and fostering preschoolers' writing abilities

Central keywords under Topic 4 were "writing," "write," "child," "skill," "letter," "early," "literacy," "print," "support," and "preschool." These terms highlighted scholarly interest in preschool-aged children's writing abilities. Although early writing proficiency is a crucial component of literacy development, limited research has been conducted on promoting its growth in early educational settings, despite recent studies and policy reports underscoring the significance of early writing support. Nonetheless, some scholars have delved into this area.

For instance, Gerde et al. (2015) focused on establishing a reliable and effective set of instructional standards for preschool writing skills and utilized these criteria to evaluate teaching practices in writing and their correlation with early writing performance. Bingham et al. (2017) further explored the subject, emphasizing how educators support child writing in classrooms and the relationship between this support and child writing development. Their findings have indicated that educators frequently concentrate on early handwriting and spelling, often sidelining writing content. However, children whose writing received attention demonstrated enhanced writing skills, a finding that has offered insight into potential instructional strategies and policy considerations. As Bingham et al. (2017) pointed out, although focusing on handwriting and spelling predominates, this does not negate the importance of studying other aspects of early writing. In response, Quinn et al. (2021) voiced some criticisms, noting that recent research on preschool writing skills, although increased in quantity, still leans excessively toward handwriting and spelling. Consequently, those scholars examined preschoolers' compositional abilities to identify the various factors influencing their performance. The study found correlations between early compositional capabilities, writing complexity, reading proficiency, and cognitive skills and has offered valuable insights into understanding early creative abilities and their relationship with early literacy skills.

In summary, although the scaffolding of handwriting and spelling remains an undeniable focal point in teaching, the broad realm of early writing in preschool-aged children, intertwined with creativity, cognition, and literacy skills, calls for more comprehensive, in-depth academic reflection and pedagogical innovation to support a robust future literacy base.

4.1.5 Topic 5: Cultivating early reading skills in bilingual children at the intersection of the Spanish and English linguistic spheres

Under Topic 5, the top ten keywords were "language," "English," "Spanish," "child," "literacy," "skill," "early," "bilingual," "speak," and "study," suggesting that the central focus of this topic has been bilingual children's early reading abilities, particularly in the context of Spanish–English bilingualism. The intellectual dialogue surrounding this domain is notably augmented by Cummins (1981) influential common underlying proficiency model, which postulates a linguistic synergy, indicating that when children acquire academic knowledge and skills in their native language, they concurrently obtain language-independent information that can be applied when learning a second language. Supported by this theoretical framework, Goodrich et al. (2016) conducted an empirical study involving 554 native Spanish-speaker children and further endorsed Cummins' (1981) assertion with findings indicating that reading skills in a child's native language indeed positively influence their acquisition of writing skills in a second language. In this regard, Goodrich and Lonigan (2017) utilized confirmatory factor analysis to evaluate the common underlying proficiency model's relevance to the early literacy skills of 858 preschoolers whose native tongue was Spanish and found that the preschoolers shared a set of foundational competencies encompassing both language-related and language-independent skills. This finding suggests that foundational abilities such as reading skills can traverse distinct languages and facilitate knowledge transfer. These results have provided more tangible empirical support for Cummins' (1981) model. However, language learning is not solely influenced by intrinsic linguistic factors. Wackerle-Hollman et al. (2022) studied 313 Spanish–English bilingual preschoolers and found that both cultural aspects and classroom language instruction methods are correlated with early reading performance. In summary, although the common underlying proficiency model offers a robust scaffolding for interpreting bilingual literacy, it is imperative to appreciate that early reading in bilingual contexts is a confluence of both intrinsic linguistic cadences and extrinsic pedagogical and cultural nuances.

4.1.6 Topic 6: Building an early reading environment for young children involving public libraries, the family, and the community

Key terms under Topic 6, such as "library," "story time," "public," "family," "literacy," "program," "book," "librarian," "child," and "early," underscored public libraries' pivotal role in fostering early literacy environments, as well as the significance of community outreach programs. Under this topic, scholars have focused on strategies to cultivate an environment conducive to early childhood literacy development. For instance, Kociubuk and Campana (2019) found that current story time activities predominantly employ narrative-driven books and feature fewer expository and informational stories. They have advocated for diversifying story genres in public libraries and incorporating contemporary narratives to bolster children's early literacy development. Furthermore, Cahill et al. (2020) found a strong correlation between parents' willingness to participate in library story time and their children's interest in reading. Such findings have presented compelling evidence to enhance the early reading environment and kindle children's interest in reading by emphasizing collaboration between communities and families.

4.1.7 Topic 7: Early phonological awareness training for children with deafness or hard of hearing and/or speech sound disorders

Children with hearing impairments face substantial challenges in acquiring early phonological awareness, which can have profound implications for their subsequent reading abilities. Central terms under Topic 7, such as "speech," "child," "phonological," "sound," "DHH," "deaf," "hear," "hearing,"

"age," and "SSD," highlighted the intricate relationship between these children's phonological awareness and early reading skills development.

Cupples et al. (2014) seminal study found that children with deafness or hard of hearing (DHH) who received an early cochlear implantation displayed heightened phonological discernment, a potential harbinger of their evolving reading proficiencies. Interestingly, this research elucidated a spectrum of convergences between DHH children and those with normal hearing and has bridged domains such as phonological prowess, alphabetic cognition, and lexicon acquisition. Pedagogical innovations aimed at improving this cohort's literacy outcomes have come to the forefront. Lederberg et al. (2014) pivotal exploration has attested to the efficacy of certain tailored educational strategies in nurturing reading proficiencies among DHH children. Parallelly, speech sound disorders (SSD) loom large and have been marked as potential crucibles for impediments in reading and phonological synthesis. Navigating this complex topography, Tambyraja et al. (2020) analytically assessed a cohort of young students spanning kindergarten to Grade 2 to map the risk contours associated with SSD vis-à-vis reading adversities and decipher the intricate web interlinking these risk profiles with reading hurdles.

In summary, as we traversed the multifaceted landscape of early phonological awareness in children with DHH and SSD, it became manifestly clear that their literacy pathways, though riddled with challenges, are also replete with possibilities. This dynamic interplay beckons a deeper, more nuanced academic introspection and proactive pedagogical recalibration to facilitate optimized literacy trajectories for these young children.

4.1.8 Topic 8: Disentangling early dyslexia through proactive detection and the identification of neurobiological underpinnings

Keywords under Topic 8 were "reading," "dyslexia," "read," "child," "risk," "word," "early," "skill," "phonological," and "development," indicating that the topic centers around the early identification of reading dyslexia in preschoolers. Several studies have provided valuable insights, including Saygin et al. (2013), who initially attracted attention for employing neuroimaging techniques to investigate white matter development in children at risk for familial dyslexia. Surprisingly, they discovered a close relationship between white matter development and reading abilities, particularly the integrity of the left arcuate fasciculus white matter structure, which plays a crucial role in reading ability. This finding has provided a neurobiological basis for predicting early reading difficulties.

Powers et al. (2016) further explored the relationship between preschoolers at risk for familial dyslexia and their family cultural environment, phonological processing, and neural activation. Those scholars' findings revealed significant differences in family environment and neural activation between children at genetic risk for dyslexia and typically developing children. This not only confirmed Saygin et al.'s (2013) findings but also emphasized the importance of early intervention and family support in preventing reading difficulties. Kraft et al. (2016) addressed the challenge of accurate prediction and early intervention by combining cognitive measurements and neuroimaging techniques in an attempt to identify early markers of reading difficulties in preschoolers. Those scholars concluded that such an approach significantly improves the accuracy of predictively identifying children at risk for dyslexia, and their research has provided a powerful tool for developing early intervention measures that could alleviate the impact of reading dyslexia. In essence, the multifaceted research on early dyslexia underscores the paramount importance of combining advanced neurobiological insights with proactive pedagogical strategies to produce optimal child reading outcomes.

4.1.9 Topic 9: Interactive factors in early reading: genetics and the environment

Individual differences in early reading abilities are associated with the interplay between genetic and environmental factors. Key terms under Topic 9, such as "genetic," "twin," "environmental," "influence," "reading," "sample," "read," "ability," "pair," and "comprehension," indicated that scholars have actively explored the impacts of genetics and the environment on the development of early reading abilities. Several pivotal studies have offered insightful perspectives on that relationship. Firstly, Taylor and Schatschneider (2010) examined a sample comprising 1,401 kindergarten twin pairs and 1,285 elementary school twin pairs aged 5–7 years, controlling for factors such as family income and ethnicity. Their findings have suggested a potential association between socioeconomic environment and the etiological structure of early literacy abilities. Building on previous studies, Petrill et al. (2010) analyzed latent growth curve models derived from measurements of 314 twin pairs participating in Western Ohio's preparatory reading program. Those scholars focused on the relationships between reading level growth rates at different developmental stages and genetic and environmental factors. Furthermore, Schenker and Petrill (2015) employed both univariate and multivariate quantitative genetic models to measure data obtained from 284 pairs of children with an average age of 9.81 years. Their study found a strong correlation between reading motivation and reading ability in the presence of non-shared environmental factors. Collectively, these investigations have underscored the importance of the interaction between genetics and the environment in the development of early reading abilities and have provided valuable insights into the mechanisms underlying individual differences.

4.1.10 Topic 10: Early reading development: visual and neural activation

Under Topic 10, core keywords such as "letter," "visual," "neural," "activation," "word," "read," "brain," "print," "string," and "reading" underscored researchers' commitment to examining the intricate relationships among specific visual regions, neural activations, and early reading development. Gaillard et al. (2003) employed fMRI and echo-planar imaging techniques to investigate the neural network patterns associated with cognitive development in 16 native English-speaking children with an average age of 7.2 years. Notably, the findings highlighted pronounced activity in the left temporal–occipital junction, middle frontal gyrus, and

supplementary motor area, suggesting that in children aged 6–7 years, the neural networks responsible for reading processes exhibit significant lateralization and region-specificity. Gaillard et al.'s (2003) research paved the way for further investigations and enriched our understanding of neural activations in early reading development. Maurer et al. (2005) further enriched the understanding of the connection between specialization for letter strings and early literacy skills. The study found that printed word letter strings activate specific visual areas in the brain. Based on neural physiological recordings of brain activity, this response was hypothesized to be a form of plasticity change, underscoring the close link between early literacy skills and letter string specialization. Furthering the narrative, Malins et al. (2018) harnessed fMRI techniques to delve deeper into the nexus between individual reading capabilities and variabilities in neural activations within reading networks. Their findings have shown that inter-trial variations in neural activation positively impact an individual's reading prowess, thus offering fresh insights into neural plasticity in early reading development. Cumulatively, these investigations have reinforced the intertwined relationships among visual perception, neural activation, and reading skills and have provided substantial backing for a profound understanding of early reading evolution.

4.1.11 Topic 11: Early literacy proficiencies in children with ASD

Topic 11 encompassed popular keywords such as "child," "early," "skill," "autism," "study," "age," "parent," "year," "school," and "literacy," indicating a focus on analysis of literacy skills in children with early ASD that has yielded crucial information for future interventions as well as support for early literacy abilities in children with ASD. For instance, Davidson and Ellis Weismer (2014) examined the characteristics and predictive factors of early reading abilities in 152 children with ASD and emphasized the significance of early language skills in their development of reading abilities. Solari et al. (2022) analyzed the development of early reading skills in 616 preschool-aged children who had been diagnosed with ASD educationally and found heterogeneity in their early preschool-level reading skills. These research findings have important implications for early educational interventions and literacy education for children with ASD in preschool settings.

Furthermore, Kiliç-Tülü et al. (2023) conducted a comparative study on the early literacy skills of children with ASD and those of typically developing children, with a focus on the influence of the HLE in the Turkish language context. The study revealed the characteristics of early literacy skills development in children with ASD with a Turkish language background and highlighted the significant predictive role of the HLE, non-verbal cognitive abilities, and working memory. The study further emphasized the importance of effectively teaching early literacy skills to children with ASD. In essence, although children with ASD may traverse unique developmental paths, the interplay of the HLE, cognitive faculties, and linguistic foundations profoundly shapes their early literacy narratives.

4.2 Analysis of topic popularity and the evolution of core keywords

As time progresses, the research focus within the same topic undergoes significant changes at different stages of development. To gain a deeper understanding of this evolutionary process, this study utilized the DTM to comprehensively analyze thematic evolution and trends in the field of early reading. We have identified and presented the document distribution characteristics of each topic over different time periods, as depicted in Figure 5. We also obtained a topic–word matrix for each stage, as shown in Table 1. By analyzing the top ten keywords with the highest occurrence probability at each stage, we clearly delineated the evolution of research focuses over time. This not only aids in our understanding of past research trends but also provides a solid foundation for predicting future research directions.

We found consistently increasing research interest in Topics 1, 2, 5, 6, and 11. Topic 1 in particular has always been a prominent research hotspot in early reading. Although an overall trend of increased research interest was found for the remaining four topics, changes have been relatively moderate. The keyword evolution analysis showed that "literacy," "children," "early," "reading," and "teacher" have always constituted the core of Topic 1, highlighting early childhood reading's significance and educators' crucial role (Snell et al., 2022). However, recent trends have revealed a notable shift within Topic 1, characterized by the increased frequency and prominence of the keyword "book." Accompanied by an escalating focus on shared book reading (Miller-Goldwater et al., 2022; Shen and Del Tufo, 2022), picture books (Shimek, 2021; Zhang R. et al., 2023), and digital books (Kim, 2022; Korat et al., 2022), this change has indicated a paradigmatic transition from traditional reading strategies toward a more integrated approach that embraces modern digital tools and methodologies in educational practices, reflecting a broader shift in pedagogical paradigms and research interests within the field. Under Topic 2, the addition of the keywords "Chinese" and "vocabulary" reflects growing emphasis on early reading in the Chinese linguistic context (Hemelstrand et al., 2023; Lin and Zhang, 2023). Although we found increased research interest in Topic 5, the evolution of its keywords did not demonstrate significant new trends or shifts, suggesting that research in this area may still be focused on longstanding core issues or that fresh perspectives and innovations may be needed to stimulate new momentum and directions. Results for Topic 6 revealed recent research attention to "family," "community," and "partnerships," highlighting families' and communities' roles in early reading (Gillanders and Barak, 2022; Smith et al., 2023). The latest hotspots under Topic 11 were identified as "parents," "teachers," and "schools," indicating increasing interest in families' impact on early skills development among children with ASD (Gasamis et al., 2023) and teacher-driven early in-school reading interventions for children with ASD (Macdonald et al., 2022). Notably, Topics 11 and 1 are highly interconnected, and their potential combined future trajectory might become a central focus in the field of early reading.

Conversely, Topics 7, 9, and 10 have exhibited a downward trend in research interest. Recent changes in publication volume reflect limited research outcomes for these topics, suggesting

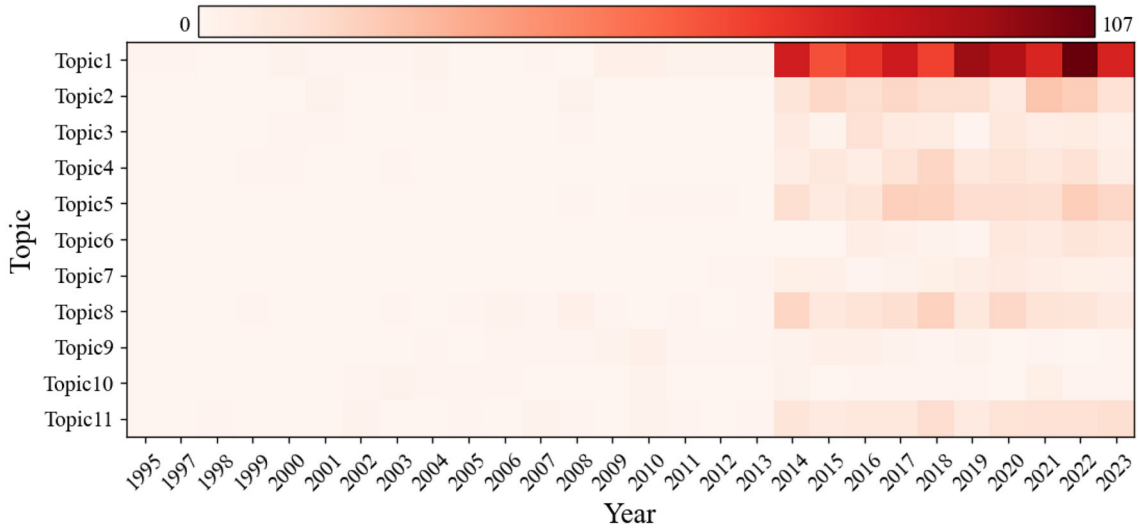

FIGURE 5
Topic evolution heatmap.

declining academic focus. Without new research perspectives or opportunities, interest in these topics is likely to continue diminishing. Moreover, the keyword evolution analysis did not identify any emergent research foci in these topics in recent years.

Topics 3, 4, and 8 exhibited relatively stable trends. Although Topic 4 showed a slow upward trajectory, the overall increase was modest, indicating a stable overall pattern. This suggests that although these topics may have some research basis, the likelihood of them gaining further attention and becoming hot topics in the future is relatively low. The keyword evolution analysis showed contemporary research interest under Topic 3 in "reading," "media," and "children," emphasizing the media's role in early reading. Under Topic 4, we found increased focus on "early childhood education," "composition," and "teachers," indicating the growing recognition of the importance of early education and the teacher's role (Rylak et al., 2022; Tortorelli et al., 2022). Additionally, under Topic 8, increasing interest in "phonological awareness," "vocabulary," and "reading" has highlighted growing attention to cognitive linguistic processes in individuals with reading disorders. The similarity with Topic 2 suggests a potential joint trajectory for future research.

In summary, this comprehensive analysis revealed the document distribution characteristics of each topic across different time periods and identified the continuously evolving research focuses. Although the keyword evolution of certain topics, such as Topic 5, did not show significant new trends or shifts, these results highlight the need for new perspectives and innovation to drive development in those areas.

5 Discussion

Utilizing literary data obtained from the WOS Core Collection, this study delved into the textual data of topics related to early reading using the DTM and visually analyzed the characteristics and evolutionary patterns of early reading topics. From a quantitative perspective, this study interpreted the characteristics and evolutionary trends of academic attention to early reading and derived the following main findings.

Firstly, academic discussions on early reading have primarily focused on 11 major topics: interventions' impacts on early reading competencies (Topic 1); foundational elements in early reading: phonological awareness, letters, and spelling (Topic 2); early mathematical ability and reading achievement (Topic 3); supporting early literacy skills and fostering preschoolers' writing abilities (Topic 4); cultivating early reading skills in bilingual children at the intersection of the Spanish and English linguistic spheres (Topic 5); building an early reading environment for young children involving public libraries, the family, and the community (Topic 6); early phonological awareness training for young children with DHH and SSD (Topic 7); disentangling early dyslexia through proactive detection and the identification of neurobiological underpinnings (Topic 8); interactive factors in early reading: genetics and the environment (Topic 9); early reading development: visual and neural activation (Topic 10); and early literacy proficiencies in children with ASD (Topic 11). Among these, Topics 1, 2, 5, 6, and 11 have received particular attention, which reflects their significant standing in the field. In contrast, Topics 7, 9, and 10 have seen limited research outputs in recent years, suggesting a possible shift in research focus or a need for new perspectives and innovations in these areas.

Secondly, as time progresses, individual topics exhibit a unique developmental trajectory and dynamic changes. Time-series analysis of core thematic words revealed varying degrees of stability, with some key terms such as "literacy" and "reading" remaining stable, whereas emerging keywords like "book" have begun to make significant appearances under Topic 1, indicating an ongoing evolution of research perspectives and foci. This is exemplified in the results of analyzing the evolution of core keywords under Topic 1, as reported in Section 5.2 (see Table 1). Specifically, the results have highlighted the growing importance of modern digital tools in early childhood reading interventions.

Moreover, computational analysis has revealed emerging research frontiers across various topics, providing valuable insights for scholars, policymakers, and practitioners in the field of early reading. This not only deepens the understanding of the knowledge structure and evolutionary patterns within the field but also emphasizes the importance of comprehensively grasping early childhood reading developmental trends by capturing these dynamic changes.

5.1 Implications of the study

5.1.1 Theoretical implications

This study is the first comprehensive quantitative analysis of the early childhood reading field using the DTM for text mining. It thoroughly assessed the current state and developmental trends of research in this area. Theoretically, this study is distinguished by the following features.

Firstly, the study is notable for its objectivity and innovative research methodology. Unlike traditional systematic reviews in the field, this study was grounded in quantitative analysis via text mining, which significantly reduced subjective bias and ensured the objectivity and replicability of the results. The study's demonstration of such an innovative approach provides a new perspective and a scientific tool for exploring the knowledge structure in the field of early childhood reading more precisely and scientifically.

Secondly, this paper comprehensively discusses intervention strategies. The study delved into various aspects of early reading interventions, including teacher interventions, the HLE, and customized educational plans for children with special needs. The findings underscore the necessity of considering the interplay of educational settings, family backgrounds, and individual differences in children for successful early reading interventions. This provides new theoretical support for designing effective early reading intervention strategies in diverse cultural and economic contexts.

Thirdly, the research has expanded cross-cultural and bilingual reading theories. By analyzing bilingual children's early reading abilities, this research has revealed the complexity of language skill interactions in bilingual environments, an insight that is significant for developing cross-cultural and bilingual reading theories, especially in non-English-dominant linguistic contexts. Hence, the study offers educators and researchers a critical framework for assessing and enhancing early reading abilities in bilingual children.

Fourthly, this study draws attention to applying neurobiology to identify early reading disorders. The study highlights the importance of understanding the neurobiological underpinnings of early reading disorders, such as dyslexia. For early detection of familial reading disorders in particular, these findings provide new directions for future research using neurobiological methods to predict and intervene in early reading difficulties, thereby advancing scientific progress and theoretical innovation in this field.

Fifthly, the study provides guidance for future research. The findings highlight major trends and unresolved issues in the current research, thereby offering comprehensive guidance and an agenda for future early childhood reading research. These insights are crucial for directing future studies' focus.

5.1.2 Practical implications

At the practical level, this study provides valuable references for practitioners in the field of early childhood reading. Firstly, the findings emphasize the importance of implementing personalized and culturally sensitive educational strategies in practice. In particular, children with special reading needs, such as those with hearing impairments or those from diverse cultural backgrounds, would benefit from educational plans tailored to their specific needs. This study highlights the need for educators to consider individual differences and cultural backgrounds when designing curricula and teaching strategies.

Second, the study shines the spotlight on policy support for diverse educational environments. The research indicates that policymakers need to focus on and support the creation of diverse and inclusive early reading environments by investing in public libraries, community centers, and home reading projects and strengthening these environments through educational policy. Such policy support is essential to ensure that all children have access to high-quality early reading resources.

Thirdly, this study promotes interdisciplinary research. The study's results emphasize the importance of interdisciplinary research in the development of early reading. For instance, the findings have revealed the crucial roles of mathematical abilities, writing skills, and visual and neural activation in early reading development, urging researchers to adopt an interdisciplinary approach that combines knowledge and techniques from linguistics, psychology, neuroscience, and other fields to fully understand reading development.

5.2 Future research directions

Based on an in-depth analysis of 11 key topics in the field of early reading, we propose the following future research directions.

One potential future research direction is the digital age and the reading experience. Under Topic 1, we discovered that in the digital age, electronic books, animated books, applications, and online reading platforms can provide children with a brand new reading experience (Pettersen et al., 2022). Research revolving around books is an emerging hot topic in the field of early reading. Although the academic community has already proven that digital technology can cultivate early reading skills in children, it is currently unclear how various factors influence the effectiveness of digital reading intervention measures, such as the type of technology, training content, and integration level. Therefore, further research is needed to explore how early reading interventions' effectiveness is modulated by the latest digital tools, such as augmented reality and virtual reality, as well as game features (Vanbecelaere et al., 2023).

Another potential future research direction is cross-cultural and multilingual reading. With the deepening of globalization, the significance of cross-cultural and multilingual reading has become increasingly prominent. In this context, China, as an emerging global power, has witnessed its culture and language becoming

increasingly vital among international scholars. As illustrated regarding Topic 2, recent years have seen a growing focus on the study of Chinese reading and the early reading habits of Chinese children in the academic realm. This attention not only signifies curiosity toward Chinese children's early reading developmental characteristics but also highlights the heightened international recognition of Chinese as a significant language. On the other hand, Topic 5 predominantly explores reading capabilities in a bilingual environment, a topic of pressing importance in today's multilingual and multicultural world. Notably, although research on reading in multilingual contexts, especially those involving English, is abundant, studies on children's reading in a Chinese–English bilingual setting are relatively scarce. Given that both Chinese and English rank among the most influential languages globally, research on their cross-linguistic transfer, bilingual reading development, and cross-cultural reading competencies is undeniably of profound significance to researchers, educators, and globalization itself (Ye et al., 2022a). Therefore, in light of the aforementioned scenarios, future research should place greater emphasis on integrating insights from Topics 2 and 5 to delve deeper into the cross-linguistic reading capabilities and cross-cultural understanding of children in a Chinese–English bilingual context. Such investigations could aim to provide a more in-depth and forward-looking theoretical foundation for bilingual education and cultural exchanges in a globalized setting.

Integrated learning approaches constitute another potential future research direction. In the future, early reading practices will no longer be perceived solely as an isolated activity. As the studies classified under Topics 3 and 4 have illustrated, scholars are increasingly intrigued by the integration and simultaneous development of reading skills and mathematical competencies (Inoue et al., 2023), writing abilities (Otsuka and Murai, 2023), and other associated proficiencies. Such interdisciplinary research approaches aim to amalgamate various learning skills to offer a more holistic and ecological learning system. However, although these domains' convergence presents numerous innovative research opportunities, there is still a notable gap in comprehensive exploration of how such integrated learning methods impact children's holistic development. Thus, the potential effects of an integrated learning approach on children's well-rounded growth will undoubtedly emerge as a pivotal focus in future academic investigations.

Another recommended future research direction is reading performance in special populations. Our research analysis has shown that the core topics, namely Topics 8 and 11, have prominently focused on the reading performance characteristics of two specific child groups: children with early reading disabilities and children diagnosed with early ASD. This research has yielded invaluable data and insights for interventions targeting these special populations' early literacy skills. Presently, the majority of scholars predominantly emphasize the reading characteristics of children with reading disabilities and delve into the prospects of phonological interventions as a means to enhance their reading skills (Lemons et al., 2018). Concurrently, based on observations made regarding Topic 6, there appears to be burgeoning research interest in understanding how external community environments influence reading interventions for children. Although studies in this particular direction are still in their infancy, considering the potential impact of community environments on children with early reading disabilities and early ASD, coupled with the prospective effectiveness of community-based interventions, this research area undoubtedly holds significant promise (Piasta et al., 2023). Consequently, future research endeavors should further investigate how community environments interact with the reading performance characteristics of these unique child groups and develop effective intervention strategies tailored to these characteristics.

Our final recommended future research direction is neuroscience in early reading. Based on the results for Topics 8, 10, and 11, neuroscience methods have evidently been widely applied to study brain activity characteristics during early reading processes. For example, the use of fMRI technology can help us better understand the bidirectional relationship between reading skills and brain speech processing (Wang et al., 2023) and explore the association between early reading skills and the organization of the ventral occipito–temporal cortex (Chyl et al., 2023). The application of neuroscience methods has obviously brought innovation to early reading research. However, we should not overlook the complexity and cost associated with the use of neuroscience techniques. Future research efforts could focus on identifying methods to optimize the cost of using neuroscience technology in the early reading field. Additionally, most scholars engaged in early reading research come from the social science discipline and may be unfamiliar with the procedures and standards for using neuroscience methods. Therefore, it is necessary to conduct a specialized and systematic review of the relevant literature on neuroscience and early reading to fully demonstrate neuroscience technology's application value in early reading.

6 Conclusions and limitations

Utilizing the DTM, this study identified and analyzed 11 primary research topics in the field of early reading and revealed a diverse array of subjects and evolving focuses in scholarly inquiry. The research has underscored the profound influence of the digital age on methodologies, tools, and theoretical approaches in early reading research. It has emphasized the critical importance of personalized and culturally sensitive educational strategies in practice and affirmed the necessity of interdisciplinary research for a comprehensive understanding and the promotion of early reading development. Moreover, this study has charted a course for future research by suggesting paths such as exploring reading experiences in the digital age, investigating cross-cultural and multilingual reading practices, and applying neuroscience to early reading. Ultimately, the insights and directives derived from this research have significantly enriched the early reading domain, laying the groundwork for enhanced exploration and deeper investigation into these pivotal topics, thereby promising to shape the future trajectory of early reading research.

However, this study has certain limitations. The research focused solely on literature obtained from the WOS Core Collection, without investigating non-Core Collection literature and that from other databases such as Scopus. Future research could expand the time span and data sources to comprehensively understand the knowledge structure and developmental trends in the field of early reading.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

Author contributions

TW: Writing – review & editing, Visualization, Methodology, Conceptualization. HX: Writing – original draft, Formal analysis, Methodology, Writing – review & editing. CL: Data curation, Visualization, Writing – original draft. FZ: Data curation, Visualization, Writing – original draft. JW: Formal analysis, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Career construction theory: tools, interventions, and future trends

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With the emergence of the borderless career era in the 21st century, career coaching has experienced a change from career guidance and career education to career counseling. Career construction theory has been widely used in career counseling and has substantial application value. Introducing career construct theory's assessment tools and intervention strategies is necessary and meaningful. In this mini-review, the qualitative assessment tools and intervention approaches of career construct theory are introduced and analyzed; the qualitative assessment tools include the Career Construction Interview and "My Career Story" workbook, and the intervention approaches include the Computer-Assisted Career Counseling System, workshops, group counseling, and individual counseling. Finally, future research directions are proposed, including an analysis of what kinds of career construction interventions are most effective for which groups and under what conditions, career intervention in the digital age, and the standardization of assessment tools. The novelty of this paper lies in the fact that it purposefully proposes future directions for career construction theory from the perspectives of assessment tools and intervention approaches and that research on the assessment tools and intervention approaches of career construction theory still needs further attention.

KEYWORDS

career construction theory, My Career Story, career construction interview, career intervention, future trends

Introduction

Career counseling has changed from career guidance and career education to career counseling. In the 19th century, career counseling was centered on the matching career guidance model, which is making rational decisions based on self and career information. After entering the 20th century, career counseling is based on career development theory, focusing on how individuals make decisions, a process-oriented career intervention. Furthermore, beginning in the 21st century, career counseling centers on career construction theory, focusing on vocational personality, career adaptability, and life theme, emphasizing constructing careers. These three theoretical models are the career guidance model to determine the person-job match, career education to promote career development, and career counseling to design work-life.

Career construction theory

Savickas (2005) proposed the career construction theory based on personal constructivism, social constructionism, and post-modernity. Career construction theory believes that the essence of individual career development is the dynamic construction process of pursuing mutual

adaptation between the subjective self and the external objective world, and different people construct different stories. Career construction theory provides a dynamic perspective to give personal meaning to memories, present experiences, and plans, constructing careers through a sense of meaning and clarifying future directions. The theory includes three parts: vocational personality, career adaptability, and life theme. Occupational personality refers to an individual's career-related abilities, needs, values, and interests. Career adaptability is described as "a psychosocial construct that denotes an individual's resources for coping with current and imminent vocational development tasks, transitions, traumas" (Savickas and Porfeli, 2012, p. 662). The difference between occupational personality and career adaptability is that occupational personality emphasizes the content of a career, while career adaptability emphasizes the coping process of constructing a career. Career adaptability deals with how individuals construct careers, while occupational personality deals with what careers they construct. Career adaptability deals with how individuals construct their careers, while occupational personality deals with what careers they construct. Unlike vocational personality and career adaptability, life theme is a dynamical system that primarily explains why individuals make career choices and the significance of those choices and expresses the uniqueness of the individual in a particular context, which provides a way of looking at the world. Career counseling, developed from career construction theory, focuses on vocational personality, career adaptability, and constructing meaning in life themes (Savickas, 2013). Vocational personality focuses on the "what," career adaptability is about the "how," and life theme responds to the "why" (Guan and Li, 2015).

Compared to other career theories, career construction theory helps students adapt to the future's complex and changing career world and inspires a richer perspective on career development (Gao and Qiao, 2022). Meta-analysis has shown that social construction theory is more effective than individual-environmental matching theory (Langher et al., 2018). Career construction theory seeks to explain the interpersonal process in which individuals construct the self, establish the direction of career behavior, and assign meaning to careers, providing a unique perspective on how to view the subject of career counseling (Hou et al., 2014). Career construction theory provides specific ideas to help the case make career decisions and enhance work satisfaction (Savickas, 2005). Therefore, this review aims to introduce the tools, interventions, and future directions of career construction theory to help individuals better adapt to the rapidly evolving situation.

To ensure the quality of the literature, the terms "career construction" and "intervention" were used as search terms in this study, both of which appeared in the title, abstract, or keywords. A comprehensive search was conducted on the "Web of Science, PsycINFO, and EBSCO." The search was limited to English-language articles. Specifically, the literature was searched from 2013 to 2023. In addition, only standard research papers were included in this study, excluding review-type articles.

Life design counseling

Life design counseling is based on career construct theory, which gives meaning to life and supports adaptive responses by helping the individual to tell a career story, constructing the past, present, and future to form continuity and consistency. The five assumptions of the life design model of vocational intervention are contextual possibilities, dynamic processes, non-linear progression, multiple perspectives, and personal patterns. Life design counseling is lifelong, holistic, contextual, and preventive. It aims to increase the client's adaptability, narratability, and activism (Savickas et al., 2009).

The life design paradigm relies on story construction and action. The first stage of life design counseling is constructive, which involves clarifying the problem and what one hopes to achieve through counseling. The counselor encourages the client to find the life theme by describing the problem to be solved through a story. The second is deconstruction, which helps the client reflect on and shape the story by allowing them to clearly express experiences, expectations, actions, and expectations for the future. The third stage is reconstruction. The counselor and the client can interpret the story from different perspectives, thus enabling the client to rewrite his or her story. The fourth is the co-construction stage. The issues raised by the client are put into the rewritten story, and a new story is co-constructed as a solution. The fifth stage is action. Assign participation in some of the narrative's possible self-relevant activities. It is necessary to specify what they will do and what this means to help the client make a plan (Savickas et al., 2009).

Career construction interview

The Career Construction Interview is a structured process based on life design counseling designed to help clients tell, hear, and enact their life career stories. Counselors help them to coherently tell their career story, cope with changes in the environment, design a meaningful life, and take action by conducting a qualitative career assessment with a narrative model and methodology. The career construction interview comprises five questions, each leading to a thematic story. Role Models are to identify adjectives that describe self-constructs and concepts. Favorite magazines/TV/websites are to identify the types of environments and activities that interest the client. Favorite stories are understanding the stories or cultural scripts the client might use to envision transformational outcomes. Favorite mottos can give the client some advice. Early recollections can provide insight into how the client perceives the issues presented in the transition narrative (Savickas, 2011).

At the beginning of the second phase, the counselor draws a portrait of life-occupation based on the client's answers to CCI questions, combined with observation and reflection. By reviewing the story together and encouraging reflection and reflexivity in the conversation, the counselor and client construct a powerful new life-career identity that has coherent meaning for the client's life. In the third phase, the client develops an action plan with the counselor. The career interest results obtained from the CCI correlate moderately with the quantitative Career Interest Inventory results, which suggests that the CCI agrees with traditional quantitative assessment tools (Barclay and Wolff, 2012). Barclay (2018) provided three additional ways to use the CCI: written exercises, career collages, and career portfolios. Lindo and Ceballos (2019) developed the Child and Adolescent Career Construction, which includes the development of appropriate expressive arts to promote self-expression and career exploration in children ages nine and older. The CACCI includes a socio-emotional focus that encourages clients to explore self-concepts, life themes, and career awareness.

My Career Story

"My Career Story" is a career autobiographical workbook developed based on the Life Design Paradigm and contains written exercises and goal-setting activities essential to successful career planning (Brown and Ryan Krane, 2000). It corresponds to the construction, deconstruction, reconstruction, co-construction, and action of life design counseling (Hartung and Santilli, 2017).

MCS is designed to help clients tell, hear, and enact their life-career stories about who they are, who they want to be in the world of work, and how they can connect themselves to careers they might enjoy. Individuals, groups, and educators can use MCS to guide self-reflection to increase narrative identity, intentionality, and adaptability in career planning, career choice, and work adjustment. The MCS workbook consists of three sections to guide clients in telling their life stories. The first section, "Telling My Story," begins by defining the participant's problem, listing the careers they have considered pursuing and how they would like the workbook to benefit them. Next, participants answered questions related to life-career topics: (1) role models they admired while growing up, (2) favorite magazines and television shows, (3) stories from favorite books or movies, (4) favorite mottos. The second part is "Listening to My Story." Portrait their lives by integrating smaller stories into a more cohesive career story. Including (1) Who will I be? (2) Where do I like to be? (3) The portrait summarizes (4) Rewrite my story. The third section, "Enacting My Story," involves creating a realistic plan to implement the story (Santilli et al., 2019). The MCS can be used by clients alone or with the counselor's assistance. As an adjunct to career counseling, the MCS can be used in one-on-one individual and group counseling and career development learning activities in the classroom or other settings (Hartung and Santilli, 2017).

Career intervention

Twenty-two studies published between 2013 and 2023 met all criteria and provided the necessary data for the systematic review. Databases included Web of Science, PsycINFO, and EBSCO. Two authors screened all titles and abstracts. In addition, they considered the eligibility of full-text articles. First, the databases were searched with the keywords "career construct theory" and "intervention." Furthermore, a citation search was conducted for key papers, and reference checking was performed as suggested by Tuttle et al. (2009). Thus, the search strategy was iterative and multi-stage, including computerized and manual searches. Therefore, it can be concluded that these searches were adequate for a systematic review. Finally, 22 studies were identified, including three qualitative and 19 quantitative studies. The two authors evaluated these studies against the selection criteria and agreed on the final 22 studies. Figure 1 depicts the process of selection.

These studies review intervention research on career construction theory, as shown in Table 1.

Career group

Career Group is based on group counseling theory and can promote the cognitive, emotional, and behavioral aspects of an

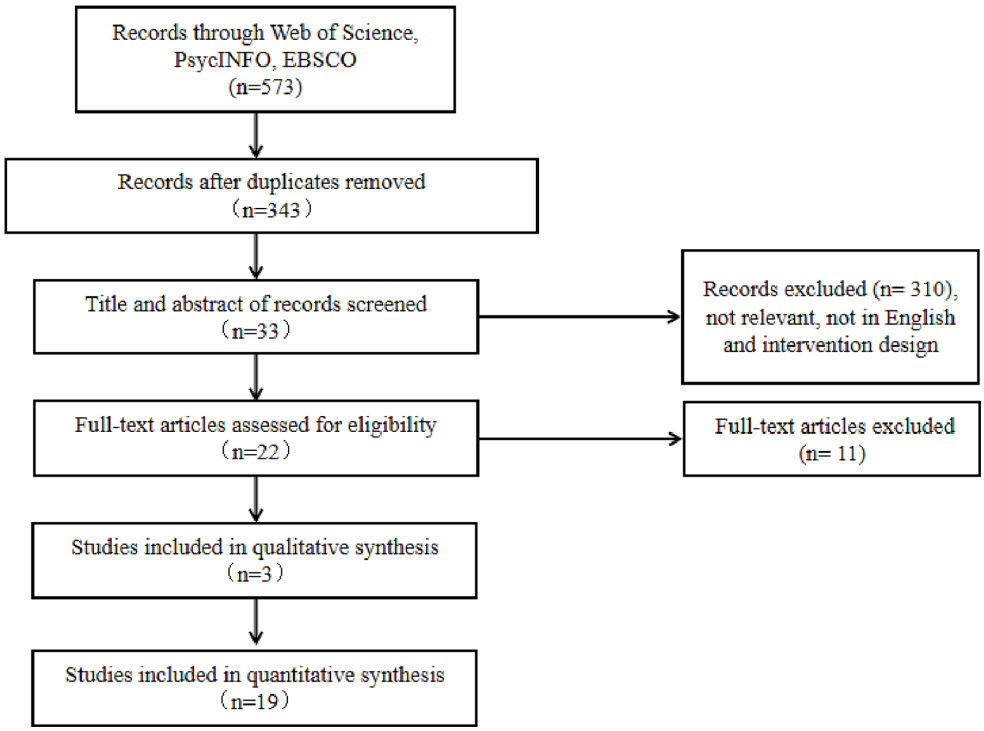

FIGURE 1
PRISMA flow chart.

TABLE 1 Intervention studies.

Authors/date	Method	Quantitative data	Strategies
1. Cardoso et al. (2022)	Group	Vocational identity, Career adaptability	Life Design counseling
2. Maree (2019)	Group	Career adaptability	Life Design counseling:Career Construction Interview
3. Maree et al. (2019)	Group	Career adaptability	Life Design counseling:Career Construction Interview
4. Gai et al. (2022)	group	Career adaptability	Motivational interview: engaging, focusing, evoking, and planning
5. Cook and Maree (2016)	Group	Career adaptability	Life Design counseling:Career Construction Interview
6. Maree et al. (2017)	Group	Career adaptability	Life Design counseling:Career Construction Interview
7. Obi (2015)	Seminar	Indecision, Anxiety, Uncertainty	Life Design counseling
8. Maree and Symington (2015)	Seminar	Career adaptability	Life design counseling:Career Construction Interview
9. Cadaret and Hartung (2021)	Seminar	Vocational identity, Career adaptability	"My Career Story" workbook
10. Ginevra et al. (2017)	Seminar	Career adaptability	"My Career Story" workbook
11. Peila-Shuster et al. (2021)	Seminar	Career adaptability	"My Career Story" workbook
12. Da Silva et al. (2022)	Seminar	Career adaptability, Vocational identity, Student career construction inventory	Career Construction Interview
13. Santilli et al. (2019)	Seminar	career adaptability, hope, optimism, resilience, future orientation	"My Career Story" workbook
14. Cardoso et al. (2018)	Seminar	Vocational certainty, Career maturity, Career decision self-Efficacy	"My Career Story" workbook
15. Nota et al. (2016)	Online	Career adaptability, Life satisfaction	Life design counseling
16. Pordelan et al. (2018)	Online	Career development	Life design counseling:Career Construction Interview
17. Pordelan et al. (2021)	Online	Career decision, Career decision-making self-efficacy	Life design counseling:Career Construction Interview
18. Zammitti et al. (2023)	Online	Resilience, Subjective risk intelligence, Career adaptability, Self-efficacy, Optimism, Hope, Life satisfaction	Life design counseling
19. Camussi et al. (2023)	Online	Career adaptability, Courage, Time perspective, Resilience	Life design counseling
20. Maree and Twigge (2016)	Individual		Career Construction Interview
21. Maree and Gerryts (2014)	Individual		Career Construction Interview
22. Maree (2016)	Individual		Career Construction Interview

individual's career development. Career group guidance and career group counseling are two forms of career groups. The difference is that career group guidance has more participants and focuses on transferring knowledge. Career counseling has fewer members and emphasizes interaction and communication between members (Jin, 2007).

Researchers examined the effects of life design group guidance on 9th grade. Findings supported the effects of life design group guidance on career identity, career adaptability, and career decision-making self-efficacy (Cardoso et al., 2022). Maree (2019) used quantitative and qualitative research methods to conduct group career construct counseling with 11th-grade students. The Career Adaptability Scale was used for quantitative analysis. Career interest analysis and Maree Career Matrix were used for qualitative intervention. The findings revealed that students significantly improved career adaptability. Maree et al. (2019) explored the impact of life design group counseling on unemployed young adults' career adaptability. First, the Career Interest Profile was used to obtain information about career choices: work-related information, five most and least preferred career preferences, six career choice questions, and 15 career story narrative questions. Career counseling techniques such as career genealogy charts, interviews, and personal statements were used. Results indicated that life design group counseling increased participants' career adaptability.

Recently, Gai et al. (2022) used career construct theory to develop a peer motivational interview that included engagement, focus, arousal, and planning. The research involved senior students conducting one-on-one career motivational interviews with junior students. Results indicated that the intervention increased students' career control and career confidence. Cook and Maree (2016) compared the effects of career construction group counseling and a life-oriented curriculum on 11th-grade students in different educational settings. The group counseling included Collage, the Career Interest Profile, and the lifeline technique. Participants demonstrated higher career adaptability after participating in career construction group counseling. Maree et al. (2017) used career construction group counseling. The experimental group completed narrative questions in the Career Interest Profile. They created career

collages depicting how they see their future. In addition, "My Lifeline" was drawn to mark essential themes in their lives. The quantitative study results indicated that life design group counseling did not increase participants' career adaptability compared to the traditional program.

Seminar

Seminar is another form of group counseling. Seminars are less frequent and intensive than group counseling, with more fixed topics and less interaction between members, making them an efficient method (Jin, 2007).

Life design counseling can reduce indecision, anxiety, uncertainty, and insecurity among college students (Obi, 2015). Maree and Symington (2015) designed eight life design workshops with five 11th-grade students in a private school. The students demonstrated increased effort to address issues related to career concern, control, curiosity, and confidence, suggesting that the intervention facilitated the development of their career adaptability. Cadaret and Hartung (2021) designed career construction group counseling using the workshop format combining individual reflection and group discussion. The workshops were based on the My Career Story (MCS) workbook. The first session was "Telling My Story," which included role models, favorite magazines/TV shows/websites, favorite books/movies, and favorite mottos. The second was "Hearing My Story," which included describing myself and my interests, scripting roles, making suggestions, and constructing a life portrait. The third session, "Enacting My Story," included co-setting goals, seeking more information, and exploring pathways to select and identify career goals. Results indicated that the career construction intervention increased students' career control and confidence. Ginevra et al. (2017) used a life design approach to develop resources that help cope with career transitions, encourage thinking about the future, identify one's strengths, and plan future projects. It is divided into three phases. Participants were encouraged to tell, revise, and construct their career stories in the first phase. In the second phase, participants were administered an online questionnaire on hope, optimism, resilience, future direction, and career readiness. Consider their strengths in response to the career change in the third phase. Results indicated that the life design approach improved their career adaptability.

Peila-Shuster et al. (2021) used career construct theory to conduct career workshops with adults who had been unemployed for more than six months. Workshops included current status, describing role models, favorite mottos, rewriting stories, reflections, and action plans. The counseling utilizes the My Career Storybook to help participants cope with their problems and prepare for their job search by facilitating narratability, intentionality, and career adaptability. Da Silva et al. (2022) conducted career construct interviews with students. The interview consisted of three workshops that (1) discussed role models, television shows, books or movies, mottos, and early memories; (2) Exploring participants' answers to career construct interview questions; (3) Discuss the steps needed to implement a new career plan. The study showed that the Career Construct Interview promotes the development of students' career adaptability and remains stable 3 months after the intervention. This suggests that the intervention of the Career Construct Interview has a good latency. Santilli et al. (2019) compared the impact of life design and traditional career counseling on adolescents. Life design group counseling utilized the "My Career Story" workshop format. The results showed that the intervention promoted the development of career adaptability in the Life Design group. This suggests that "My Career Story" may be an effective means of developing career adaptability in adolescents.

However, the study yielded inconsistent results. Researchers examined the impact of the life design workshop on 9th and 12th-grade students. The intervention utilized the "My Career Story" life design methodology. The results showed that the life design intervention did not impact students' career adaptability (Cardoso et al., 2018).

Online career group

The advantage of online interventions is the availability of audiovisual materials, including videos, slideshows, and animations, which help students explore values, interests, and skills independently. Online career counseling is more accessible than traditional career guidance, and students can access various practical information (Chen et al., 2022).

Nota et al. (2016) compared the validity of online life-based design and traditional test interpretations. All students received personalized feedback, including suggestions for future schools and jobs related to their interests, values, and motivation. Results indicated that the online life design group demonstrated higher career adaptability, life satisfaction, and future aspirations. The researchers compared online and face-to-face life design counseling on career development. The online interventions included an introduction to online books, bilingual career videos, short animations, access to a virtual library, an introduction to similar websites that promote career development, and online chats with career counselors. The results showed that online and face-to-face career interventions improved students' career development (Pordelan et al., 2018). Later, they compared life design digital storytelling and face-to-face storytelling, and the study found that the digital storytelling group had higher career decision self-efficacy than face-to-face storytelling (Pordelan et al., 2021).

Zammitti et al. (2023) conducted a life design paradigm online career intervention with college students to enhance their psychological resources. The online intervention consisted of career workshops and 13 online activities. The study showed that an online group career intervention in the life design paradigm promotes the development of resilience, subjective risk intelligence, career adaptability, self-efficacy, optimism, hope, and life satisfaction. Camussi et al. (2023) foster the development of student's skills to face complexity and unpredictability, transforming their time perspective into optimism to face the future. The intervention was based on the theoretical model of Life Design. The intervention themes were "My future, why?" and "Who am I and who do I want to be?." The intervention consisted of two online workshops. It included reflections on conscious life design and current global contextual challenges. The study demonstrated that the Life Design online intervention facilitated

the development of students' levels of career adaptability, courage, time perspective, and resilience.

Individual career counseling

Individual career counseling is usually a one-on-one approach that assists with career confusion to enhance career adaptability. Individual counseling has the highest cost but significantly impacts the client and the counselor.

The value of individual career counseling is to help all those challenged by unemployment and poverty (especially emerging adults) to become employable, find decent work, and increase their sense of self, and in the process, promote the idea of a fair and just society (Maree and Twigge, 2016). Maree and Gerryts (2014) conducted narrative counseling with a newly young male engineer based on career construct theory. Methods included collage, Career Interest Profile, life chapters, lifeline, early recollections technique, and Career Construction Interview. Participants demonstrated an increase in willingness to cope with challenges and adaptive strategies. This suggests that narrative counseling can facilitate the development of career adaptability. Maree (2016) conducted career construction counseling with a mid-career Black man to construct, deconstruct, reconstruct, and co-construct the client's life story. The interview included role models, favorite magazines/TV/websites, favorite stories, early memories, and favorite mottos. The client demonstrated an improved self-awareness and a willingness to be more flexible in dealing with challenges related to the career.

Discussion

Career assessment

The Career Construction Interview and MCS workbook are two qualitative assessment tools under the Career Construction Theory. The groups for which the tools are applicable may be different. The adult population may be more suitable for the Career Construction Interview, and most individual counseling uses the Career Construction Interview (Maree and Gerryts, 2014; Maree, 2016; Maree and Twigge, 2016). Quantitative tools for career construction intervention mostly use a career adaptability scale (Maree and Symington, 2015; Ginevra et al., 2017; Maree et al., 2019).

Quantitative assessment is a standardized and scientific measurement tool but has certain disadvantages. The advantage of qualitative assessment is that it facilitates the discussion of group career counseling and can improve the shortcomings of quantitative tools. The case study of self-narrative can help the researcher to sort out the main conflicts and critical variables in career development (Guan and Li, 2015). Integrative Structured Interview, based on the system's theoretical framework, is a method that combines qualitative and quantitative measures to advance storytelling. Using Hollander's interests as the basis for quantitative assessment, integrating assessment results with storytelling, the integrative structured interview facilitates this integration through quantitative score-based career storytelling that focuses not on the scores but on facilitating participants' understanding of their scores, career decisions, and transitions (McMahon et al., 2020). Therefore, it is necessary to develop a hybrid standardized assessment method based on career construction theory.

Career intervention

Career construction theory has been widely used in the field of career counseling. Career group counseling is guided by the theory of career construction, and career intervention programs are designed for the career construction process of different groups, which can effectively solve the problems faced by different groups in career development. Individual career counseling can help cases to link their self-concept with their work through the self-construction of work so that individuals can become the creators of their work and actively construct the meaning of their careers to be prepared for the new changes in the work pattern.

Brown and Ryan Krane (2000) meta-analysis identified five critical elements of career counseling: written exercises and workbooks, individualized explanations and feedback, career world information, role modeling, and building support. The MCS workbook corresponds to the written exercises and workbooks among the key elements. Another meta-analysis indicated that the three critical elements of career counseling are counselor support, value clarification, and psycho-educational intervention (Whiston et al., 2017). The career construction interview gained direct counselor support and clarification of specific values. Combining the MCS manual and supporting materials may effectively develop career adaptability in adolescents (Santilli et al., 2019). However, some research suggests that ninth graders show more difficulty than twelfth graders in recounting their own experiences (Cardoso et al., 2018). This may be because the career construction interview is more helpful for lower grades, which require direct support and clarification of specific values from the counselor.

Currently, the primary interventions of career construction theory are computer-assisted career counseling systems, workshops, group counseling, and individual counseling. Career courses are the most effective (Oliver and Spokane, 1988). Therefore, converting life design counseling into a career course is warranted, and a career construction orientation curriculum needs to be developed to enrich the career construction intervention. A meta-analysis by Whiston et al. (2003) demonstrated that intervention effectiveness significantly increases using a computerized career guidance system in counseling. Various career intervention approaches are often integrated into practice, mainly using computerized career guidance with other modalities. The study found that a comprehensive intervention combining online life design and written exercises was more likely to increase students' career adaptability and life satisfaction (Nota et al., 2016).

Future research trends

Career assessment

Although the assessment tools for career construct interventions have been enriched in recent years, the stability, validity, and applicability of the assessment tools still need to be tested in the further. Career construction interventions focus on the reconstruction of life stories. Some studies have found that career construct

interventions did not increase students' career adaptability (Maree et al., 2017; Cardoso et al., 2018). This suggests that relying on the Career Adaptability Scale as a quantitative study is insufficient, some questionnaires should be designed to measure whether students can articulate and identify what is important to them before and after the intervention. Assessment tools for career construction intervention mainly consist of qualitative or quantitative tool, but standardization still needs to be improved (Di Fabio, 2016; Cardoso et al., 2022). Some studies utilize quantitative and qualitative assessment tools (Maree, 2020), but they need more cross-cultural validation.

Therefore, future research in assessment tools can consider the following aspects: In terms of assessment content, special assessment tools must be prepared for different and unique groups. Savickas (2011) developed a complete set of guidelines for career construction counseling. Online guidelines and assessment tools could be developed in the future, incorporating technologies such as computer networks and multimedia. In particular, comprehensive assessment tools that include quantitative and qualitative aspects should be developed to meet the needs of large-scale research with different groups and achieve standardization and stability of assessment methods.

Career intervention

First, there is a question of what groups and career interventions are most effective under what conditions. The economic benefits of career interventions in different modalities, age groups, and various intervention goals are critical. The meta-analysis result indicated that the career course was the most effective but required the most intervention time. Individual counseling produced more benefits per session than other interventions (Oliver and Spokane, 1988). Subsequently, meta-analysis yielded different results. Individual career counseling was the most effective, followed by group career counseling, with career courses coming in third. Computerized online systems were the most cost-effective (Whiston et al., 1998). A recent meta-analysis indicated that individual counseling was the most effective, while group and individual counseling and computer-based interventions varied widely (Whiston et al., 2017). Meta-analyses have not yet yielded consistent conclusions. In addition to the results, individual and group counseling are effective methods. However, at the same time, it is essential to consider the number of people and the economic benefits that professional interventions can bring (Whiston, 2011).

Additionally, the results showed differences in intervention impact based on the participants' grades. Ninth graders only improved at the level of career certainty, while twelfth graders showed more significant development on all measured variables. This may be because higher-graders can better understand what is important to them and what they strive for. Therefore, it is essential to consider the characteristics and needs of different groups to maximize the effectiveness of career construction interventions in future research. Different intervention modalities affect individuals' career development, which is best for group counseling and which works best for individuals. These issues must be better understood, requiring meta-analysis or systematic review to explore in the further.

Second, digital technology is essential for career interventions. In particular, Online interventions allow alternative experiences and role modeling to be more readily available through websites where short videos of successful people can be viewed and inspired. Therefore, career construction theory may benefit career interventions in the digital age. Online career construction interventions are very efficient and likely to be used more and more. Online career construction can present stories in short films, slideshows, or photographs, allowing the client and the counselor to discover hidden stories and help the client gain new concepts. The advantage of online career construction intervention is convenience, where stories can be opened on a computer or other electronic device. In the storytelling process, information technology is utilized as a platform for digital storytelling, where one's life story is expressed as a photo, movie, or audio (Pordelan et al., 2021). In the future, personalized interpretation and feedback procedures can be added to the computer-based online intervention to maximize the usefulness of the career construction intervention.

Finally, developing new content and a short career construction interview are necessary. Using career construction theory, the researcher developed a peer motivational interview for at-risk students that included engaging, focusing, evoking, and planning (Gai et al., 2022). Questions include "What do you want to obtain from your future occupation? Why?" "What occupations are you likely to pursue in the future? What occupations are you unlikely to pursue? What occupations are you not sure about whether to pursue? How can you become certain?" Future research needs to focus on particular groups as subjects, focusing on those severely hindered in their career development or career transition, and test the effectiveness of career interviews through group interventions to maximize the effects of career interventions.

However, completing the career construction interview typically requires two 90-min sessions, which hinders its practical use with many students in school. Therefore, Rehfuss and Sickinger (2015) developed a short form of the career construction interview. Only three initial career construction interview questions were used in the short form. "Who did you admire when you were growing up? What are your favorite magazines, TV shows, or websites? Tell me your favorite saying or motto." These three questions were used to learn about the students' role models, self-advice to help solve current problems, and preferences for the work environment. In addition, there is a need to develop a short form of the Life Design Group Counseling and MCS. Also, some form of screening is necessary to determine what questions of the career construction intervention will benefit the individual the most.

Conclusion

Career construction theory applies to the current borderless career era, and such a career theory perspective is more helpful for individuals to adapt to the complex and changing career world in the future. Currently, the tools of career construction theory mainly include the structured career construction interview and the qualitative assessment manual of MCS. The interventions of the theory mainly include workshops, group counseling, online group counseling, and individual interviews. This study identified several challenges to the career construction tools and interventions.

Therefore, it offers some suggestions on how to deal with these challenges: Future researchers need to pay attention to the development of comprehensive quantitative and qualitative

assessments to standardize and stabilize assessment methods for the tools. For the interventions, there is a need to examine the question of what groups and under what conditions career interventions are most effective. Second, future research should develop personalized interpretation and feedback procedures for computerized online interventions in the digital age. Finally, developing new content and a short career construction interview are necessary.

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DW: Writing – review & editing, Writing – original draft. YL: Writing – review & editing.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Foreign language anxiety research in *System* between 2004 and 2023: looking back and looking forward

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With the deepening of the research on emotional factors, foreign language anxiety (FLA) has become the focus of researchers in the field of foreign language learning (FLL) and teaching. This paper aims to provide an overview of the historical trajectory of FLA research that has been published in *System* between 2004 and 2023. While examining the retrieved 49 studies, focus has been laid on the methodologies including research instruments, methods, participants, major themes and key findings of FLA research. Although almost all of the studies employed quantitative and mix-methods methodologies, questionnaires and semi-structured interviews were the most preferred research methods. FL learners from 21 countries/regions were represented, but a significant number of the studies came from China, Japan and Iran. And an overwhelming majority of the studies focused on FLA among the learners learning English as a foreign language (EFL). The review concluded with some research lacunae and possible directions for future research on FLA.

KEYWORDS

foreign language anxiety, foreign language learning, English as a foreign language, foreign language learners, literature review

Introduction

FLA, prevalent among foreign language (FL) learners (Dewaele and Macintyre, 2014; Li, 2020), is a very special and complex psychological phenomenon during the process of FLL (Gardner, 1985; Macintyre and Gardner, 1994). FLA is regarded as the biggest emotional obstacle during the process of FLL (Arnold and Brown, 1999), which may undermine students' confidence and motivation in FLL (Macintyre, 2017). Horwitz (2010) considered FLA as one of the strongest predictors of success or failure in FLL. Previously, anxiety in FFL, as an auxiliary variable in FLL research, had only drawn scarcity of attention from researchers (Chastain, 1975; Dewaele and Li, 2021). It was not until 1986 that Horwitz et al. (1986), for the first time, proposed the concept of FLA, reckoning that FLA is a unique synthesis of self-perception, belief, emotion and behavior associated with FLL. Meanwhile, Horwitz et al. (1986) developed the Foreign Language Classroom Anxiety Scale (FLCAS), which has become the most widely accepted FLA scale. Since then, researchers have conducted a plethora of studies on the connotations (Macintyre and Gardner, 1994; Oxford, 1999), categorization (Horwitz et al., 1986; Ellis, 1994; Macintyre and Gardner, 1994), impacts (Steinberg and Horwitz, 1986; MacIntyre and Charos, 1996), sources (Young, 1991; Macintyre, 2017), and measurement tools (Macintyre and Gardner, 1994; Satio et al., 1999; Kim, 2000; Elkhafaifi, 2005; Woodrow, 2006; Cheng, 2017) of FLA.

System, one of the most influential and prestigious international journals devoted to FL teaching and learning, has stayed abreast of the development of FLA research. The articles having been published on FLA in *System* represent to a large extent the development trajectory of FLA research. Therefore, this review paper chooses *System* as the material to provide the historical trajectory of FLA research and suggest some under-researched topics and future directions of FLA research.

Foreign language anxiety

FLA, a principal learner emotional factor in foreign language learning (FLL), has become one of the significant research focuses in FLL since the 1970s. Originating from psychology, anxiety is defined as "an unpleasant state of mind that is characterized by individual perceived feelings like nervous, fear, and worry, and is activated by the autonomic nervousness system" (Spielberger, 1972). FLA is a unique form of anxiety in the specific context of foreign language learning (Horwitz et al., 1986; MacIntyre, 1995). Horwitz et al. (1986) conceptualized FLA as "a distinct complex of self-perceptions, beliefs, feelings, and behaviors related to classroom language learning arising from the uniqueness of the language learning process."

Horwitz et al. (1986) first studied FLA as an independent phenomenon. In order to resolve the deficiency and insufficiency of traditional research tools in respect of FLA, Horwitz et al. (1986) framed the Foreign Language Classroom Anxiety Scale (FLCAS), putting an end to the history of FLA study having no standardized measurement tools (Guo and Xu, 2014), foreboding that FLA research entered a period of relative maturity when researchers began to focus on the overall performance of FLA and its relationship with a variety of variables (Young, 1986, 1992; Aida, 1994), as well as the relationship between FLA and some basic language skills like listening, speaking, reading and writing (Gungle and Taylor, 1989; Vogely, 1998; Sellers, 2000).

Simply put, FLA is the feeling of tension, fear and nervousness in self-consciousness, emotions, beliefs, and behaviors (Aida, 1994) associated with a context which requires an individual to use a foreign language he or she is not proficient with (MacIntyre and Gardner, 1991).

Research design

In order to present a systematic analysis of FLA research published in *System*, a narrative approach of systematic review was adopted. Systematic review involves "a clearly formulated question" and adopts "systematic and explicit methods to identify, select, and critically appraise relevant research, and to collect and analyze data from the studies that are included in the review" (Cochrane Collaboration, 2003). A narrative approach relies "primarily on the use of words and text to summarize and explain the findings," and is considered helpful to systematically review topics that have been studied differently researchers (Popay et al., 2006), highlight the strengths and limitations of studies being reviewed (Wong et al., 2013).

The review aims to provide a systematic analysis of FLA research during the past two decades between 2004 and 2023 by answering the following questions:

Question 1: What is the overall trend in FLA research published in *System* during the past two decades?

Question 2: What are the major themes and the key findings of FLA research?

Question 3: What are the existent gaps in the current research and the potential directions for future research?

Data collection

Following the PRISMA guidelines (Moher et al., 2009), an extensive literature search was conducted to ensure a comprehensive analysis of the current FLA research published in *System*. The data selection criteria and collection process are summarized in Figure 1.

Firstly, relevant studies published until and including December 15, 2023 were searched in the database of Elsevier ScienceDirect. The author conducted advanced searches in the database with the following searching parameters: *In this journal or book title* = (*System*) AND *Title, abstract, or author-specific keywords* = (anxiety). Overall, the database returned 185 publications, among which 95 were published in journals other than *System* and therefore were deleted. Then, 2 book reviews and 1 review article were deleted. The remaining 87 publications were evaluated for the eligibility by reading and analyzing the titles, abstracts and full texts, and 38 publications were excluded based on the following criterion that the studies focused on topics other than FLA.

Data analysis

This review first conducted a bibliometric analysis of the retrieved records. A coding analysis was then performed through iterative reading with the highlights on the following categories that guided the data analysis: year of publication, characteristics of samples, research methodologies, and key findings.

Results

Descriptive characteristics of studies

Publishing years

There is a dynamic upward trend in the number of studies on FLA over the past two decades (see Figure 2). 2021 witnessed a surge in the number of publications, reaching an all-time peak of 8 papers. There is a gradual downward trend in the following 2 years, but compared with the average of about 2 papers per year, there is still an increase in the number of papers in 2022 and 2023.

Countries/regions of research

There was diversity of countries/ regions where the studies took place, with 21 countries/regions represented. Twenty-one papers (42.86%) came from China, followed by 6 papers (12.24%) from Japan and 4 papers (8.16%) from Iran. Three papers were conducted in Korea and USA each, followed by 2 papers from Saudi Arabia, and 1 paper from Canada, Australia, Indonesia, Austria, Germany, Switzerland, Italy, Slovakia, Macau, Chile, Thailand, Turkey, and UK each.

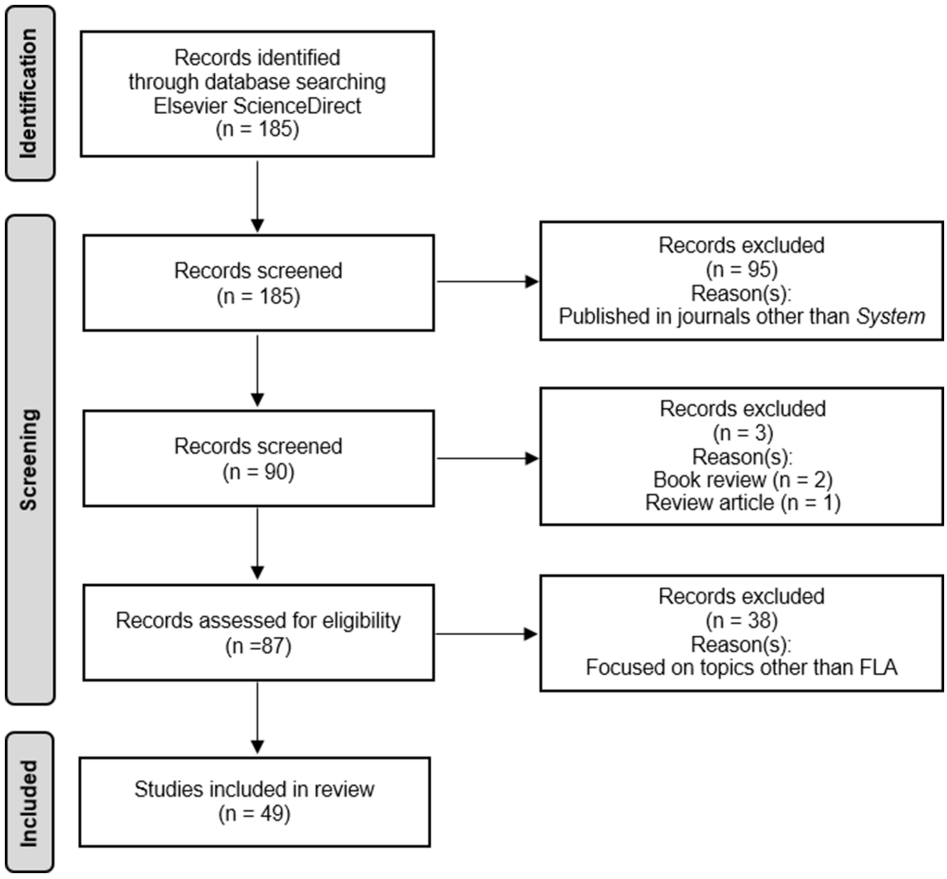

FIGURE 1
PRISMA flow chart.

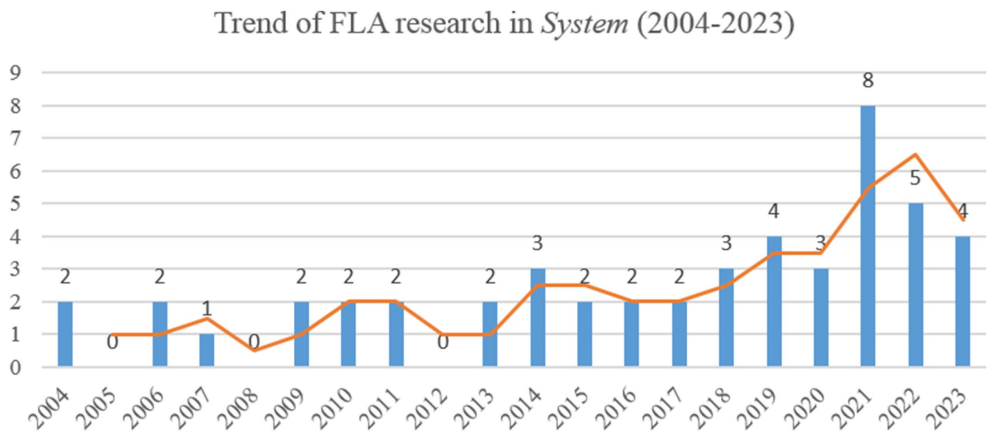

FIGURE 2
Trend of FLA research in *System* (2004–2023).

Research participants

The overwhelming majority of the studies ($n = 43$, 87.76%) focused on FLA among university students, with 3 papers focused on primary school students and 5 on secondary school students. It is noteworthy to point out that there were 3 studies which focused on PhD students, adult students, and vocational high school students, respectively.

Foreign languages studied

Since the status of English as a universal language is beyond doubt, almost all the studies examined FLA in the context of EFL learning. Among the 49 papers, there were only 4 papers focusing on FLA in the context of FLL other than EFL learning. These foreign languages included Korean, Arabic, German and Chinese. There was

1 paper comparing the possible FLA differences between the contexts of German as L1 learning and English as LX learning.

Research methodologies

Of the retrieved records, 38 were cross-sectional studies and 11 were longitudinal studies. The average length of time for the longitudinal studies was approximately 11.36 weeks, ranging from the shortest length of 1 week to the longest length of 18 weeks. The studies adopting quantitative methods ($n = 24$, 48.98%) and the studies using mix-methods ($n = 24$, 48.98%) markedly dwarfed the only one study using qualitative methods (2.04%).

Questionnaires were the most common research method in both quantitative studies and mix-methods studies. The FLCAS was the most frequently-used scale ($n = 22$, 48.83%), which a significant number of studies used directly ($n = 7$, 14.58%), adapted ($n = 4$, 8.33%), modified ($n = 6$, 12.50%) or translated ($n = 5$, 10.42%). Besides, a number of studies used questionnaires that adopted, modified or translated other scales such as the FLRAS (Satio et al., 1999), the FLLAS (Elkhafaifi, 2005), and the S-FLCAS (Dewaele and Macintyre, 2014) among many others. Notwithstanding, some researchers devised targeted questionnaires (Hurd, 2007; Woodrow, 2011; Lee, 2016; Li, 2018; Wang H. et al., 2021; Alrabai, 2022).

With regard to qualitative methodology, the research methods frequently used to measure FLA embraced interviews ($n = 15$, 62.50%), classroom observations ($n = 5$, 20.83%), students' reflective journals ($n = 5$, 20.83%), open-ended questions ($n = 3$, 12.50%). Of note, Hurd (2007) employed audio-recorded think-aloud protocols combined with questionnaires and one-to-one semi-structured telephone interviews to explore FLA in a distance learning environment. Dryden et al. (2021) used linguistic ethnography to investigate how four migrant EFL learners in Australia experienced FLA.

Research themes and key findings

Level of FLA

Twelve papers (24.49%) were found to investigate FLA level of FL learners, however, no consensus has been reached on the level of FLA among FL learners, possibly due to the fact that the participants of the retrieved studies were different. For example, Jiang and Dewaele (2020) found 1,031 university freshmen in China experienced a moderate level of FLA. Zuniga and Simard (2022) and Lee et al. (2023) had similar findings. However, Jiang and Dewaele (2019) found a higher level of FLA among 564 EFL university freshmen in China than the counterpart participants in the study of Dewaele and MacIntyre (2014). Similarly, Bekleyen (2009) found the language teacher candidates in Turkey experienced a high level of FL listening anxiety.

Dynamicity of FLA drew attention from some scholars. Koga (2010) investigated the dynamicity of FLA among 88 first-year university students in Japan and found FLA decreased significantly at the end of the 15-week English courses. Veenstra and Weaver (2022) investigated 341 students from two private universities in Japan and a continuum of FL speaking anxiety showed that the participants' overall level of FL speaking anxiety decreased after finishing an English presentation course lasting 15 weeks.

Some studies explored some potential differences of FLA among different participants or among the same participants in different contexts. For example, Chen et al. (2022) found Chinese undergraduates had a higher level of EFL reading anxiety than Spanish undergraduates. Resnik and Dewaele (2020) found the participants experienced a higher level of FLA in English (LX) classes than in German (L1) classes.

Sources of FLA

Nine studies (18.37%) explored sources or causes of FLA. Bekleyen (2009) revealed some major sources of FL listening anxiety, including low priority of listening in previous FLL, and failure to recognize the spoken form of word, phrase or sentence. Jiang and Dewaele (2019) uncovered a number of factors contributing to FL class anxiety, including exams and quizzes, speaking in front of the class without preparation, challenging classroom activities, and teacher questioning. Bashori et al. (2021) identified insufficient vocabulary knowledge as one of the factors provoking FL speaking anxiety. Besides, speaking strategies, willingness to communicate, speaking self-efficacy and speaking proficiency were found to have positive direct effects on FLA (Sun and Teng, 2021). Of note, Zare et al. (2022) focused on FLA outside the traditional face-to-face classroom and found that autonomous learning was the source of the participants' anxiety during the data-driven FFL.

Correlation of FLA with other variables

Some studies ($n = 5$, 10.20%) explored the correlation of FLA with demographic variables of the participants. Park and French (2013) found female students had significantly higher levels of FLA than male students. However, Jiang and Dewaele (2020) found gender and ethnic affiliation were not correlated with FLA while geographical background and experience in traveling abroad had a weak correlation with FLA. Similarly, Matsuda and Gobel (2004) found EFL learners with overseas experience experienced lower anxiety when speaking English and gender did not have a significant effect on FLA. However, Yim (2014) found gender had a significant effect of FLA. The discrepancies in the correlation with demographic variables may be attributed to the different samples or the possibility that male learners are not inclined to willingly admit anxiety than female learners (Williams, 1996; Pappamihiel, 2002).

A number of studies ($n = 9$, 18.37%) explored the correlation of FLA with academic performance/ achievement. For example, Pyun et al. (2014) found that oral achievement of the participants was negatively correlated with FLA. However, Tsang and Lee (2023) found FL speaking anxiety was not significantly related to speaking proficiency. Hamada and Takaki (2021) found FL reading anxiety had significantly direct effects on course achievement. Woodrow (2011) and Li et al. (2023) found FL writing anxiety was significantly negatively correlated with writing performance, but FLA did not have a significant prediction on writing achievement (Li et al., 2023). Besides, In'nami (2006) found that test anxiety did not affect FL listening test performance.

Many studies ($n = 19$, 38.78%) focused on the correlation of FLA with other student-specific variables, including learning motivation (Tsai and Liao, 2021), willingness to communicate (Lee and Hsieh, 2019; Wang H. et al., 2021), language proficiency (Jiang and Dewaele, 2020) and trait emotional intelligence (Resnik and Dewaele, 2020; Li et al., 2021) among many others. Several studies ($n = 5$, 10.20%) focused on the correlation of FLA with teacher-specific variables, such as teachers' oral corrective feedback (Lee, 2016), perceived teacher

emotional support (Jin and Dewaele, 2018), and teaching styles (Briesmaster and Briesmaster-Paredes, 2015).

Ways to relieve FLA

Ways to relieve FLA was also a topic of immense interest to researchers. Ten studies (20.41%) explored how to relieve or alleviate FLA. Jin et al. (2021) and Alrabai (2022) applied positive psychology intervention to reduce leaners' FLA. Alrabai (2022) revealed that the integration of positive and negative emotions in FLL could result in alleviation of FLA among Saudi EFL learners. Jin et al. (2021) uncovered that reminiscing about language achievements significantly mitigated the levels of FLA among Chinese EFL learners. Similarly, Lee et al. (2023) found that constructing learners' growth language mindset relieved their FLA.

Besides, Tsai and Liao (2021) found using machine translation systems had a positive effect on lowering FLA among EFL learners in Taiwan. Bashori et al. (2021) investigated the potential effects of Automatic Speech Recognition-based websites on EFL learners' vocabulary, FLA and FLE. Other studies found that self-regulatory strategies (Guo et al., 2018), recasts (Li, 2018), and translanguaging (Dryden et al., 2021) had a significant effect on mitigating the levels of FLA among EFL learners. Of note, Kralova et al. (2017) employed psycho-social training as a strategy to alleviate FLA among 68 Slovak EFL learners.

Discussion

During the past two decades between 2004 and 2023, *System* has been an ardent supporter of FLA research, committed to probing into and resolving FLA-related problems of foreign language teaching and learning. However, based on the review, some research lacunae are discerned concerning samples, methodologies and themes of FLA research, and some possible directions for future FLA research are also suggested.

Research samples

Notwithstanding the FLA studies in *System* involved a variety of FL learners as the participants, there was a serious polarization phenomenon concerning the diversity of the research samples. An overwhelmingly large number of the studies focused on FLA among the FL learners in school and few studies focused on FLA among non-school FL learners. Moreover, a majority of the studies explored FLA among undergraduate students, especially the non-English-major university students, and there is a scarcity of studies investigating FLA among students in primary schools, secondary schools, vocational colleges as well as postgraduate students. In terms of geographical distribution of the research samples, most studies focused on FL learners from Asian countries including China, Japan and Iran among many others, and less attention was paid to FL learners from Europe, North America and South America. And no studies on FLA involving FL learners in Africa have been found. Meanwhile, most participants were from urban places, and only a couple of studies explored FLA among rural FL learners (Hamada and Takaki, 2021; Li et al., 2023). Last but not the least, with regard to the types of FL, a plethora of studies concentrated on English as a FL. Of the 49 retrieved studies, only 4 studies focused on FLA among the participants learning Korean, Arabic, German and Chinese as a FL, respectively.

Future research should diversify the research objects and focus increasing attention on the FLA research among primary school students, secondary school students, vocational college students and non-school FL adult learners, and moderate attention should be paid to the FLA research among preschool children and postgraduate students, so as to avoid the polarization of research samples. Besides, the dominance of English as a *lingua franca* has made English the FL taught in schools around the globe (Rose et al., 2020), facilitating FLA studies among EFL learners. However, recent years has witnessed frequent calls for conducting research on teaching and learning of foreign languages other than English (Zhang et al., 2019; Guo et al., 2021). Future studies can also focus on FLA among learners of foreign languages other than English as well as FL learners in countries and regions outside Asia.

Research methodologies

Notwithstanding an increasing number of studies combined quantitative methods and qualitative methods in recent years, questionnaires were still the staple tool for quantitative data collection, and semi-structured interviews for qualitative data collection. A few mix-methods studies used classroom observation, student journals, field investigation and case studies for qualitative analysis. In addition, the FLCAS was the most popular scale for quantitative data collection and analysis, and only a few studies devised target questionnaires for their research. Moreover, cross-sectional studies far exceeded longitudinal studies, and the average length of time for longitudinal studies were relatively short, lasing about 10 weeks. Finally, there were only three comparative studies on FLA, probing into FLA differences among the participants (Resnik and Dewaele, 2020; Hamada and Takaki, 2021; Chen et al., 2022).

Future FLA research should adopt mix-methods studies with qualitative research not just being confined to semi-structured interviews, but embracing a variety of methods, such as classroom observation, video recording, student journals, field investigation, case study and particularly audio-recorded think-aloud protocols. And path analysis and structural equation modeling analysis should be increasingly employed to analyze the quantitative data. Meanwhile, some advanced techniques such as Event-related Potentials (ERP), Positron Emission Tomography (PET) and functional Magnetic Resonance Imaging (fMRI) can be used in future research to analyze FLA from the perspective of neural mechanism by measuring the electromagnetic, blood flow and neuronal activities of the human brain. In addition, it is necessary to devise localized FLA scale with ideal validity and reliability in accordance with the cultural background and educational environment of the country or region where the research objects are located. Moreover, the dynamic nature of FLA requires more longitudinal studies to explain how FLA changes dynamically and what impacts FLA exerts on FLL. Finally, future studies can pay more attention to the comparative study of FLA differences among different groups, which is more conducive to understanding the characteristics and distribution of FLA among

different groups of FL learners, so as to put forward targeted strategies to mitigate FLA in FLL.

Research themes

Research themes of the studies on FLA in *System* were of rich variety. However, no research has been found on translation anxiety and interpretation anxiety. Besides, there was a scarcity of research on the effectiveness of alleviating FLA. Studies on strategies to reduce FLA were mostly conducted from the perspective of teachers, and few studies revealed how to alleviate FLA from the perspective of learners. And most of the specific strategies to mitigate FLA were only at the theoretical level, lacking sufficient theoretical and empirical evidence, which were not applicable in practical FL teaching.

The following research themes deserve more attention in future research: translation anxiety and interpretation anxiety, types and effectiveness of strategies for alleviating FLA among different groups of FL learners, FLA among learners of heritage languages as well as non-heritage languages, and comparative studies on the effects of regional locations and mother languages on FLA. Moreover, future studies should not only focus on the theoretical research of FLA, but also carry out more empirical studies on strategies on how to alleviate FLA among different FL learners, such as learners from different regional locations, learners in monolingualism, bilingualism and multilingualism, and the effectiveness of FLA-alleviating strategies.

Conclusion

By reviewing the 49 studies on FLA published in *System* between 2004 and 2023, this paper demonstrates that the journal's commitment to FLA research embraces a wide range of research themes being explored with different research methods. Based on the findings of the review, some research lacunae regarding samples, methodologies and themes of FLA research are discussed, and some possible directions for future FLA research are also suggested.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

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Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Clinical experiences of intervention of neurodevelopmental disorders and difficulties in school learning from historical-cultural neuropsychology

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Cultural–historical (CH) neuropsychology proposes the qualitative analysis of neurodevelopmental disorders and learning difficulties through the identification of the neuropsychological factor (NF) that underlies the symptoms and difficulties that arise in cognition and academic performance. The objective of this study is to present clinical experiences of the neuropsychological intervention of unique cases of varying degrees of initial education. Qualitative assessment is a process that reveals the strengths and weaknesses in child development, as well as the possibilities of what children will be able to do for themselves. It assesses their zone of proximal development, not just the zone of current development. Neurodevelopmental and learning disorders present particular manifestations during life, so a qualitative analysis can account for their subtle changes during the course of life and schooling. The use of the principles of intervention constitutes the methodological axis for the elaboration of the programs; these programs will be shaped according to the needs of the children. The case study strengthens the expertise of clinical knowledge by contributing to the empirical field on the possibilities and proposals of neuropsychological intervention.

KEYWORDS

neuropsychological intervention, neurodevelopmental disorders, learning disorders, clinical cases, cultural–historical neuropsychology

Introduction

Neuropsychology as a branch of behavioral neuroscience studies the relationships between the brain and behavior in healthy subjects and in those who have suffered some type of brain damage. Specifically, it focuses on understanding higher mental functions (Portellano, 2008). In its beginnings, neuropsychology was aimed at studying the effect of brain lesions on behavior; however, in recent years, neuropsychology also studies the relationships between the brain and behavior in populations of various ages with typical neurological and neurocognitive development called the neuropsychology of the norm or individual differences (Akhutina, 2012). Therefore, the purposes and areas of application of neuropsychology can be diverse for both assessment and rehabilitation or intervention in children and adults. Thus, the purpose of neuropsychological evaluation would be to assess deficits in the face of injuries, to assess

the effects of the therapeutic treatment, or to know the state of cognitive functions for preventive purposes.

Child neuropsychology has a wide field of action, including the educational field, where the fundamental purpose is to evaluate the cognitive performance of children with neurodevelopmental disorders and school learning difficulties, attempting to identify how these possible difficulties in the brain are related to problems at school (Hale and Fiorello, 2004; Fletcher and Miciak, 2017). In turn, the results will be useful for determining the forms of treatment based on the identification of strengths and weaknesses in cognition, academic skills, and behavior inside and outside school (Portellano, 2018; Pennington et al., 2019).

School neuropsychology

The classroom is where learning difficulties manifest themselves with greater expression, making clinical neuropsychology an essential discipline for the educational field (Miller and Maricle, 2019), giving rise to school neuropsychology as a potential source of scientific knowledge that has the methods and strategies necessary to overcome them (Murphy and Benton, 2010; Rhenals-Ramos, 2021).

The evaluation uses various clinical, psychometric, or neurological techniques to understand the characteristics of cognitive processing in both normal children and those who present some disorder, injury, or dysfunction of the nervous system (Portellano, 2008). However, the assessment of cognitive processes could be controversial because such assessments are not related to effective identification practices or forms of treatment (Burns et al., 2016). It has been pointed out that neuropsychological assessment has added value to psychometric assessments of academic skills since scores do not represent a child's ability to learn but reflect the same processes that lead to poor performance (Fletcher and Miciak, 2017); thus, such assessments would not be related to effective forms of treatment (Burns et al., 2016). In this regard, Vygotski (1996) had already pointed out that a different form of analysis is required for the difficulties that occur during child development and in school learning, where the task of the researcher is not only limited to verifying the difficulties but also to establishing their dynamic relationships and the mechanism that underlies them to intervene with the best strategies to help children.

On the other hand, the forms of intervention for developmental and learning difficulties are derived from central approaches in the history of psychology, such as behaviorist, cognitivist, and cognitive-behavioral theories. The first proposes the use of reinforcers, i.e., stimuli from the outside, to provoke changes in behavior. The second focuses its intervention based on the explanation of how the brain processes information. Finally, the third integrates behavioral techniques and cognitive strategies to achieve the expected changes (Trápaga Ortega, 2018). In general, intervention strategies are aimed at reducing errors in various school skills, but they are not aimed at correcting the cause that conditions them (Quintanar, 2009).

Therefore, does neuropsychology from the cultural–historical (CH) paradigm constitutes an alternative neuropsychological diagnosis to explain the positive and negative aspects of development? Based on the diagnosis, is it possible to develop methods and strategies to overcome the difficulties presented by children or adolescents, considering the complexity of the functional organization of the brain in childhood? Do intervention strategies apply equally to all cases of children with developmental difficulties?

The objective of this brief review is to show the usefulness of historical–cultural (CH) neuropsychology in the assessment and intervention of neurodevelopmental disorders and school learning. I share some of my clinical experiences of unique cases of various degrees of initial education.

Theoretical methodological foundation

The neuropsychological assessment of children should provide a functional diagnosis based on the principle of dynamic organization and systemic localization of mental functions (Luria, 1995) as a continuous process of corticalization of mental functions in the child, the functional brain organization of a particular mental process throughout life, and the presence of circular functional connections in the different brain structures (Akhutina, 2012). The hierarchical and dynamic organization between these levels is broad and complex; therefore, it is susceptible to manifesting symptoms due to functional deficits. For this reason, neuropsychological diagnosis, except in cases of obvious disorders that require a thorough medical assessment, is based on a functional analysis to identify strengths and weaknesses in child development. For these purposes, CH neuropsychology proposes a qualitative analysis of neuropsychological assessment (Eslava-Cobos et al., 2008).

Qualitative assessment is a dynamic structural process where the evaluator creates the necessary conditions to discover the strengths and weaknesses in development through systemic or syndromic analysis (Quintanar, 2009; Manga and Ramos, 2011); it refers to identifying the cause of present difficulties, which share a common neuropsychological factor (NF), while the best-developed strengths or skills do not require that factor. The psychophysiological mechanisms of the activity called neuropsychological factor (NF), resulting from the research on cortical and subcortical areas, are analyzed. Luria et al. have pointed out the need to identify the NF that suffers primarily and how this process leads to an insufficient development of both the determined psychological function and other higher psychological functions (HPF) (Korsakova et al., 1997). A factorial analysis establishes its particularities and integrations into complex functional systems (CFS) during child development (Glozman and Nemeth, 2020). An NF can participate in various CFS, such as attention, memory, and writing, so that a factor with insufficient functional development will lead to the presence of errors in the various CFS in which it participates, which is called the systemic effect of the primary factor (Luria, 1995).

The concepts of NF and CFS form the psychophysiological basis of HPF; at the same time, CFS are formed during the life of the individual; they are made up of various cortical and subcortical structures (Luria, 1970). Therefore, child neuropsychological diagnosis is directed to the precision of functional and non-anatomical elements in brain activity (Akhutina and Pylaeva, 2008; Glejzer et al., 2017) from the analysis of the functional status of weak and strong NFs. Table 1 shows the types of NF that are studied in CH neuropsychology, its function, and the brain area to which it corresponds.

TABLE 1 Neuropsychological factors (NFs) in cultural–historical neuropsychology.

Neuropsychological factor (NF)	Job/role in the writing process	Zone corresponding brain
Phonematic hearing	It enable the differentiation of verbal sounds of the language according to phonemic oppositions.	Left hemisphere temporals
Kinesthetic	Ensures fine tactile sensitivity, precise positions, and poses. In the articulation of language, it ensures the differentiation of verbal sounds according to where and how they are produced.	Parietals of the left hemisphere
Audio-verbal retention	It enables the stability of memory traces in the audio-verbal modality under interference conditions.	Left hemisphere; middle temporal zones
Visual retention	Guarantees the stability of memory traces in the visual modality under interference conditions.	Occipitals
Kinetic	It ensures a smooth transition from one movement to another.	Premotor of the left hemisphere
Regulation and control	Participates in the process of executing an activity by the objective set.	Prefrontals of the left hemisphere
Spatial global	Participates in the perception and appropriate production of the general shape, metric aspects, and proportions of objects.	Temporo-parieto-occipitals (right hemisphere)
Spatial analytical	Ensures adequate perception and production of essential features of the objects; spatial relationships at the graphic level and quasi-spatial relationships in language.	Parietal–temporal–occipital (left hemisphere)
Alertness or cortical tone	It guarantees maintenance and stability for the execution of the action.	Subcortical structures, reticular formation

Source: Eslava-Cobos et al. (2008).

Principles of intervention in neuropsychology CH

Currently, the central objective of neuropsychological assessment is focused on not only the diagnosis of HPF alterations and their consequent cognitive deficiencies but also the investigation of intervention methods and strategies for various conditions during child development. Since the process of maturation of the infant brain, the course of formation of its morphological and functional particularities is determined by the genetic program and by the living conditions of the child during the child's activity under the influence of upbringing and teaching (Venguer and Ibatullina, 2010). In this regard, Vygotski (1995) pointed out that the choice of activities that lead to development is fundamental for the organization of child intervention; in turn, intervention procedures will guarantee the acquisition of dynamic and flexible brain systems (Luria, 1995). The methodology is based on the following five principles.

The identification of weak NF and strong NF constitutes the first principle of diagnosis, qualitative assessment allows one to appreciate the integrity and functionality of all NFs through flexible and dynamic procedures (Solovieva et al., 2021). The components of SFC are analyzed, which can present an uneven development, violating their conformation and functional stability. The causes of this problem could be related to unequal maturation cycles in the cortical and subcortical levels of the brain. The syndromic analysis aims to study the functional level of each of the NF since each child presents a particular development (Bonilla-Sánchez, 2009; Morais et al., 2023); neuropsychological intervention is aimed at stimulating weak NF.

The second principle has to do with the possibility of offering students the appropriate means of work to form the actions that include the weak NF (Talizina, 2009). The therapist chooses the plane of action accessible to the child and, with his external language, constantly directs it until he reaches the plane of mental action, which constitutes the second principle of neuropsychological assessment and intervention. With the theory of the formation of mental actions in stages, it is possible to study and form the HPF from any of its formative planes: (a) material or materialized action; (b) perceptual; (c) external or external verbal to himself; and (d) internal mental (Galperin, 2000). Thus, the formation of new mental actions takes place through a transition from social to individual experience; through a transition from the interpsychological plane to the intrapsychological plane; and through processes that naturally have different brain neurodynamics (Quintino-Aires, 2021).

During the assessment and intervention processes, the help provided to the child to achieve the proposed tasks constitutes the Zone of Proximal Development (ZPD). Vygotski (1996) defined ZDP as what the child is expected to be able to do in collaboration with the adult or a contemporary. The ZPD reveals the child's potential to perform the tasks that are asked of him/her. Help is provided to the child in three stages: in the orientation, which is the model of the action to be carried out, it is carried out through cards with diagrams (Talizina, 2000); in the execution, the therapist adapts the actions to the level of mental action that the child can perform (second principle) and provides operational help, for example, by performing the task jointly with the child. The relationship with "another veteran" is necessary for the presentation of the model for the execution of the action, mainly during the interpsychological phase (Quintino-Aires, 2020). The use of the ZPD constitutes the third principle.

In addition, the actions chosen to integrate the intervention program must meet the needs of the child's psychological age according to the guiding activity of the stage of psychological development in which he or she is. The guiding activity is that which promotes psychological development (Vygotski, 1996). Thus, at preschool age, the guiding activity is the play of social roles; and, at school age, it is the activity of study. Previous studies have pointed out the effectiveness of the application of neuropsychological intervention programs in preschool children using role-playing as a guiding activity for the formation of drawing and internal images in an urban

preschool (Bonilla-Sánchez M. R. et al., 2022; Bonilla-Sánchez M. D. R. et al., 2022), as well as for child psychological development because children learn games to repress their immediate impulses to achieve a specific goal; it also increases self-regulation—an important component of executive functions (Elkonin, 1980; Diamond, 2013; Nemeth and Glozman, 2020). The choice of a program of action according to the psychological age constitutes the fourth principle for clinical work. The use of the guiding activity of the corresponding psychological age promotes the appearance of neoformations and ensures the overall psychological development of children (Bodrova and Leong, 2008; Eslava-Cobos et al., 2008).

Finally, during the intervention, it should be considered that each action that is integrated into the program includes the motive, the aim, the action orientation, the execution, and the control, that is, relying on the psychological structure of the action—fifth principle in CH neuropsychology (Leontiev, 2000; Eslava-Cobos et al., 2008). The therapist will focus on orientation and control since execution is adequate only if there is adequate guidance, which is why it must contain the content of the object to be assimilated, the representation of the final product of the action, and the representation of the order of the actions that will be carried out (Nemeth and Glozman, 2020; Quintino-Aires, 2021). The use of the fifth principle makes it possible to compare the objective with the result obtained and, if necessary, correct possible errors in actions.

The qualitative neuropsychological evaluation allows the identification of the common NF of the difficulties presented by the child once the diagnosis has been determined; the use of the principles of the intervention will lead to the formation of the weak NF in their function and to their gradual integration into the SFC. Principles are the essential methods of intervention. Therefore, if the intervention program is aimed at strengthening the primarily deficient NF, it would be expected to also modify the systemic effect on other types of actions in learning and everyday life. It has been proposed that the methodology of CH neuropsychology is the most comprehensive and flexible one for investigating the factors underlying complex psychological functions (Glozman, 1999; Witsken et al., 2008).

Use of intervention principles is shown in the following therapeutic experiences with children and adolescents who presented various learning difficulties.

Clinical experiences with children

The neuropsychological assessment based on syndromic analysis allowed the identification of positive and negative aspects of school learning; the intervention strategies were appropriate to the particular needs of each child (Glozman and Nemeth, 2020), given the fact that, from the point of view of the CH paradigm, the typical heterochronic maturation of brain structures defined by the genetic program is susceptible to change due to the influence of individual and social experience and the type of activity of the individual (Akhutina, 2000, 2012). The intervention was aimed to stimulate weak NF.

Learning difficulties with severe errors in writing

A 9-year-old boy in the 2nd grade of primary school without a history of neurodevelopmental or psychiatric disorders received neuropsychological intervention for learning difficulties, mainly in writing, where he presented rotation, omission, and inadequate location of letters in words.

The intervention program aimed to strengthen the weak factor of spatial analysis. In the first stage, the spatial relationships of objects and the body schema were strengthened; in the second stage, writing was improved through recognition and orientation in visual perception; the third stage strengthened the learning of basic mathematics, and this work was done on the material and visual perceptual planes (Avilés-Reyes and Bonilla-Sánchez, 2017). In the post-test, the minor managed to carry out the proper construction of complex spatial designs, basic mathematical operations, and sentence writing.

Difficulties in understanding and expressing oral language

A 6-year-old child in 1st grade was treated because he had unintelligible language, restlessness, inattention, and school learning difficulties. A slight delay in language development was reported as a developmental history. The first stage of the intervention program was dedicated to strengthening the primary NF of regulation and control through planning and verification actions. The second stage was aimed at correcting and stimulating kinesthetic NF for phoneme pronunciation and phonemic ear for auditory discrimination. In the third stage, the acquisition of literacy was worked. Finally, in the fourth stage, basic mathematical skills were formed. It was concluded that the child achieved a greater understanding of complex words and instructions and a greater control of their verbal expressions and behavior (Juárez-Barrera and Bonilla-Sánchez, 2014). Intervention of language disorders at an early age can be effective if it is directed at the stimulation of primary NF (Sarmiento-Bolaños et al., 2016).

Clinical experiences with adolescents

Severe difficulties in school learning

A 13-year-old teenager was in the 1st year of secondary school; from the first year of initial education, he had difficulty learning, particularly in mathematics, geography, and history. The first stage of the program was aimed at stimulating the functional level of the kinetic organization of movements and inhibitory control at the visual perceptual level. In the second stage, the spatial organization in the corporal and visual perceptual planes was strengthened. The third stage was dedicated to strengthening the regulation and control of activity through strategy games and the analysis of narrative and scientific texts (Moreno and Bonilla, 2013). The intervention favored the automation of sequences of movements at the motor, graphic, and verbal levels and in the regulation and control of one's activity, as was observed in their writing, reading comprehension, and the retention of audio-verbal information.

Learning difficulties and severe errors in writing and calculation

A 16-year-old male adolescent was in 1st grade of high school; he had low academic performance; his teachers referred to him as "distracted." No psychopathological history or delay in the child's development milestones was reported. The primary NF was that of spatial analysis and synthesis and functional weakness in regulation and control (Pylaeva, 2004). The systemic effect was observed in the

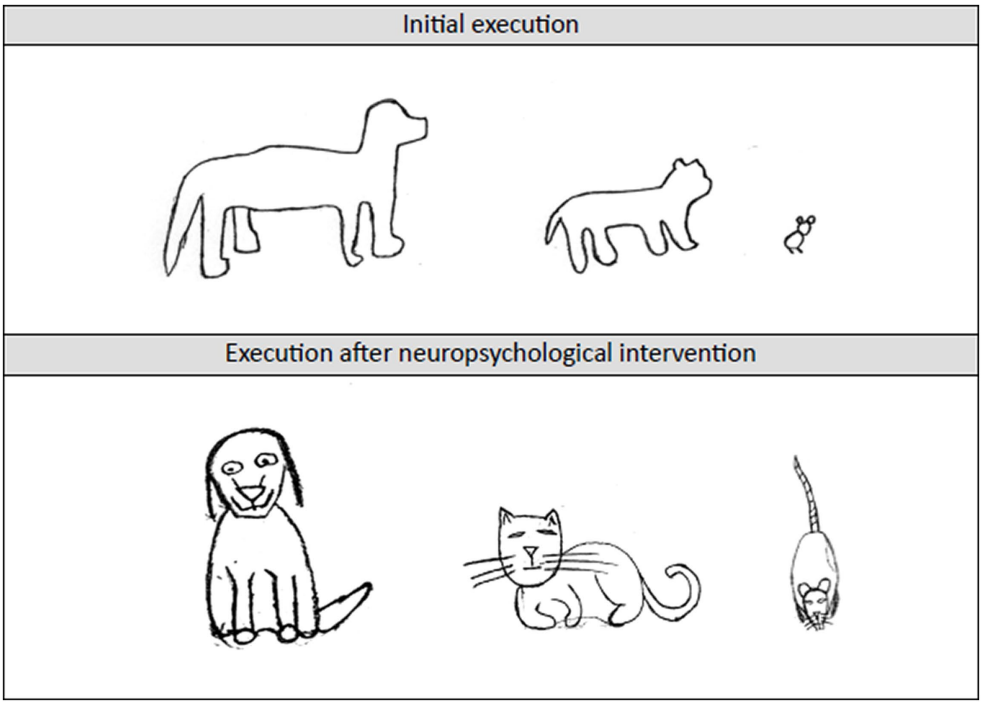

FIGURE 1
Execution of the adolescent in the task of neuropsychological evaluation "Drawing of animals": dog, cat, and mouse. Source: Solovieva et al. (2013).

execution of graphic and motor tasks, in writing, reading, problem solving (Akhutina, 2000). In the first stage of the intervention, the understanding of spatial relationships in the graphic perceptual plane was organized through the analysis and construction of word schemes; in the second stage, the visuospatial image of letters and words was formed (Akhutina, 2002); the third stage was oriented toward the analysis of words and reading of texts; in the fourth stage, the comprehension of literary and scientific texts was worked on; the fifth stage was devoted to forming the understanding of the deep sense of visual images and written composition (Tsvetkova, 1999); finally, the sixth stage was aimed at consolidating independent writing and solving calculation problems (Solovieva et al., 2013). The results of the intervention revealed a better execution of the adolescent in the post-test, mainly in written composition and graphic activity (Figure 1). The importance of the adolescent's motivation to carry out corrective tasks is highlighted, as well as the direction and levels of help that the therapist provided, especially in the most complex activities (Talizina, 2009).

Discussion

The cases presented show the possibility of offering intervention alternatives to overcome difficulties in development and learning, considering the complexity of the functional organization of the brain in the course of individual development (Akhutina, 2012). Another aspect to highlight, in response to the second research question posed at the beginning of this manuscript, is that, by considering individual differences in development, the therapist will be able to provide the necessary strategies and aids for each particular case (Vygotski, 1996; Glozman and Nemeth, 2020).

Qualitative assessment feeds clinical analysis—an aspect that the quantitative-psychometric approach cannot explore because it only allows observing and typifying difficulties but not their causes (Reigosa, 2008; Quintino-Aires, 2020; Solovieva and Rojas, 2021); therefore, this approach directs the intervention toward the reduction of symptoms. It has been pointed out that psychometric batteries do not give the possibility to perform a complete systemic analysis of higher psychological functions in children and adults in normality and pathology (Glozman, 2002). Thus, it would not be possible to describe psychological functioning to determine the level and structure of the alterations (Burns et al., 2016).

The clinical experiences contribute to the empirical field on the possibilities of intervention of neurodevelopmental disorders and learning problems; the theoretical-methodological framework referred to was used with a didactic and illustrative purpose of qualitative analysis that condenses its key concepts. The case study strengthens the expertise of clinical knowledge in neuropsychology since the understanding of human behavior is not only explained using general rules but also by the deployment of this understanding in daily activity and life (Sánchez Vázquez et al., 2017). The results presented not only highlight the importance of applying qualitative assessment and diagnosis procedures—a process that shows what children will be able to do by themselves or with the help of an adult (Vygotski, 1996; Talizina, 2000; Quintino-Aires, 2020)—but also assess the current developmental zone.

The CH neuropsychologist will be able to evaluate the HPF to establish the topical diagnosis of lesions or insufficient development of brain structures; perform early differential diagnosis; describe the clinical picture and determine the level of HPF alterations; determine the causes and prevent different forms of abnormal

psychological functioning or learning disabilities; and develop methods of rehabilitation and intervention (Akhutina, 2012). Only based on a detailed analysis will it be possible to build the intervention program.

Finally, it should be considered that neurodevelopmental disorders and learning difficulties present manifestations during the different stages of life so that qualitative neuropsychological analysis can account for the subtle changes in their clinical manifestations during development and schooling (Quintanar and Solovieva, 2008). Reviewing the empirical evidence on the possibilities of intervention using the principles of CH neuropsychology and case studies should be a constant task for every clinical neuropsychologist in the children's area (Bonilla-Sánchez M. R. et al., 2022; Bonilla-Sánchez M. D. R. et al., 2022; Morais et al., 2023) and with adult patients with various brain affectations (Rodríguez et al., 2011; Mikadze et al., 2019; Bonilla-Sánchez and Martínez-Leija, 2020).

Conclusion

The CH neuropsychology is an alternative for neuropsychological assessment and intervention in children. It offers the possibility of creating programs and strategies adapted to the particular needs of each case, so case analysis is a source of knowledge of the individuality of the subject and expertise in neuropsychology.

The recommendations for neuropsychological intervention can be synthesized in the multidisciplinary work of the specialists involved in the clinical case, and the participation of parents or caregivers from a holistic intervention approach, where the therapist provides them with continuous feedback. The recommendations for the field of clinical neuropsychology research are synthesized as follows: encourage further intercultural and international research; collect qualitative as well as quantitative data; consider behavioral observations as significant alongside numerical observations (Glozman, 2002; Nemeth and Glozman, 2020); and, in particular cases, integrate neuroimaging and/or metabolic studies.

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Conflict of interest

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Indicators of verbal creative thinking: results of a Delphi panel

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Introduction: Creativity is a fundamental competence that manifests itself in various domains of knowledge, including verbal creativity. The main aim of this study was to identify indicators of verbal creativity for the assessment of three writing tasks.

Methods: Sixteen multidisciplinary and international creativity experts participated in a two-stage Delphi panel. The administered questionnaire asked about the measurement or non-measurement of eight indicators of verbal creative thinking in three tasks: problem posing, creative idea generation, and idea improvement. Originality is the most important indicator of creativity. The indicators identified in the first task were fluency, flexibility, originality, elaboration, and sensitivity to problems. The second task measures flexibility, originality, elaboration, opacity, and dynamic integration. In the third task, fluency, flexibility, originality, elaboration, dynamic integration, and refinement of ideas are considered.

Results: The results of this study are key to progress in the field of measuring verbal creative thinking.

Discussion: The identification of indicators of the construct called verbal creativity allows the determination of its components in order to be able to estimate the creative potential in this specific domain.

KEYWORDS

verbal creativity, children, fluency, flexibility, originality

1 Introduction

Creativity is an element that requires potential originality and effectiveness in a dynamic context (Corazza et al., 2022), which has become increasingly important in recent years. Creative thinking not only underpins some of society's most important innovations but is also a universal and democratic phenomenon (OECD, 2020). Currently, the concern to assess creativity has led to its inclusion by the OECD in the Program for International Student Assessment (PISA). Creative thinking has gained the status of a competency that helps individuals achieve better outcomes in more difficult and challenging contexts (OECD, 2020).

Traditionally, creativity measurement has been approached from a domain-general perspective (Guilford, 1950; Torrance, 1974). However, the trend has changed nowadays, as most authors (Kaufman et al., 2017; Baer, 2019; Zyga et al., 2022) understand creativity from the point of view of domain-specificity, and therefore, stating that someone is creative without alluding to the domain of knowledge in which he or she is creative would be an incorrect statement.

Many authors (Amabile, 2018; Lorca Garrido et al., 2021; Krieger-Redwood et al., 2023) agree that verbal creativity is one of the specific domains of creativity, because they do not find correlations between this specific domain and the rest of the specific domains of creativity. Therefore, the measurement of verbal creativity is the domain of interest of the present research, and it is defined as the value of divergent thinking in solving problems with verbal content (Portnova et al., 2020). For their part, López-Martínez et al. (2018) understand verbal creativity as a linguistic act composed of the activation of creative thinking and a process of written reflection that allows the elaboration of a narrative with textual harmony, metaphors, originality and imagination.

The domain in which creativity is manifested is an important moderator of the relationships between creativity and factors such as personality or communication. For this reason, more efforts are needed to develop an instrument capable of assessing creativity, understood from the point of view of the specificity of the domain, since its conceptualization and explanatory theories differ from most of the validated instruments.

Furthermore, it should be noted that creativity, as a psychological construct, is not directly observable, so in the various existing tests for measuring creativity, a set of observable indicators has already been delimited, which allowed to accurately determine the level of creative thinking manifested by each individual (Runco and Acar, 2019). In this sense, Guilford (1950) already established that the indicators that structure creative thinking are fluency, flexibility, originality, redefinition, penetration, and elaboration. Nevertheless, in tests of divergent thinking, only the scores of fluency, flexibility, originality, and elaboration are usually used to estimate the creative potential of individuals (Runco and Acar, 2019; Corbalán, 2022).

First, fluency is considered to be a characteristic of creative minds that consists of the spontaneous flow of ideas and images (Kasirer and Mashal, 2018). Therefore, the minds of creative individuals have a greater ability to generate multiple ideas when approaching a task. Second, flexibility is characterized by the categorization of ideas into different categories, which is a sign of the variety and diversity of ideas contributed by an individual (Acar et al., 2019). Therefore, ideas contributed to different categories are valued more from a creative perspective than those belonging to the same category from an operational perspective (Guilford, 1956).

Third, originality is the most important indicator of creativity. In fact, creativity is understood as intentional originality (Pichot et al., 2022). This indicator refers to the uniqueness and unusualness of the given ideas compared to those of other participants (Forthmann et al., 2021). Currently, one of the methods used to objectively measure originality is latent semantic analysis in text mining, as it provides a computerized originality score based on the cosine of the angle formed between the stimulus word and the word given by the individual (Beaty and Johnson, 2021; Dumas et al., 2021).

Fourthly, elaboration refers to the details that are pointed out when stating an idea, which embellish the idea (Acar et al., 2019). This ability also refers to the degree of difficulty achieved by the individual in defining conceptual structures (Guilford and Hoepfner, 1971). One of the most widely used methods for interpreting elaboration is the unweighted word count, where elaboration is understood as the number of words in each of the verbal responses provided by the subject in a given verbal divergent thinking task (Maio et al., 2020).

Guilford (1968) significantly expanded the above indicators and introduced problem sensitivity as a person's ability to identify problems that not everyone perceives, an indicator also considered by Violant (2006) and Romo et al. (2016). Recently, the OECD (2020) introduced a new indicator to measure creative thinking, which is the refinement of ideas, which consists in the evaluation and improvement of an already completed task, with the aim of facilitating the development of a more appropriate and original response than the one initially posed.

In this sense, Desrosiers (1978) argues that in order to include the divergent aspects of communicative written expression, it is necessary to use figurative language, which is constituted by imagination, originality, flexibility, dynamic integration and a certain degree of opacity. The author alludes to the divergent thinking in this field from the use of an embellished language as it is usually done in poetry. In fact, he raises the indicators of opacity for the use of a language in which the relationship between signifier and signified is diluted and dynamic integration as the factor that alludes to the uniqueness of a text, focusing attention on linguistic aspects.

Currently, tests of divergent thinking are based on creativity from a general point of view, as evidenced by the fact that the indicators of creativity they evaluate are fluency, flexibility, and originality, which are general indicators of creativity. These dimensions are evaluated in the Creative Imagination Test for Children (PIC-N) by Artola et al. (2004) and in the Torrance Test Creative Thinking (TTCT) by Torrance (1974), even in the tasks of these tests, which are considered verbal, the elaboration is left aside, probably because it implies an additional difficulty for its evaluation. Other tests, such as the CREA (Creative Intelligence test) by Corbalán et al. (2003), only measure fluency based on the number of questions elaborated by the students. Likewise, all the tests are aimed at ideational productivity, which is a limitation of the tests because of the absence of the critical and evaluative dimension of ideas (Runco, 2008), so they lack a task in which the evaluation and improvement of ideas is considered.

Later, the Verbal Creativity Test (PCV in Spanish or VCT in English) (López-Martínez et al., 2018) emerged to try to provide an answer to the problem of the lack of consideration of verbal creativity in research on creative thinking. However, its main objection is the subjectivity of its indicators and the small sample with which it has been validated.

In addition, with respect to the context and age to which the creativity tests are addressed, the current research requires tests intended for a psychoeducational context of application and for a population of primary school students who use Spanish as their native language. Also, in order to respond to American Educational Research Association, American Psychological Association, and National Council on Measurement in Education (2018), the objectives of the creativity test to be designed are to identify talents in the field of linguistics, to guide the educational attention of students according to their characteristics and to assess the specific verbal domain of creativity, as well as to determine the starting point of an intervention and monitor their progress. Furthermore, in order to overcome the inconveniences of other creativity tests, the test to be designed must be aimed at assessing verbal creative thinking based on the classical indicators of creativity aimed at narrative and linguistic aspects, as well as others related to the verbal component.

In this test, the tasks must consider the generation of ideas, the elaboration of creative ideas, and the improvement and evaluation of

ideas (OECD, 2020; Matheson et al., 2023), as well as considering problem posing as an important starting point of creativity (Abdulla Alabbasi et al., 2021), in which questions are the backbone of creative thinking (Corbalán et al., 2003). Likewise, it should be taken into account that in a psychometric test to assess verbal creativity, texts must play a fundamental role (López-Martínez et al., 2018), since they can be both the stimulus for a creative activity and the expression of the creative performance in the form of a creative product.

Regarding the universal definition of the construct, the American Educational Research Association, American Psychological Association, and National Council on Measurement in Education (2018) indicated the need to provide an operational, semantic, and syntactic definition of the construct. In this sense, the definitions of the construct proposed in the present study are given below. First, verbal creative thinking operationally can be understood as the observable quantity of the presence of the following indicators of creativity in its verbal domain, which are fluency, sensitivity to problems, flexibility, originality, elaboration, opacity, dynamic integration, and refinement of ideas. Second, the semantic definition of verbal creative thinking is characterized by the following facets, which are problem posing, creative idea generation, and evaluation and improvement of ideas within the verbal domain of creativity from different stimuli in text form. Third, verbal creative thinking in syntactic form is a construct that shows relationships with reading comprehension, intelligence, personality, and emotions.

Finally, following Muñiz and Fonseca-Pedrero (2019), the characteristics of the tasks that make up the test should be specified, that is, the number, length, content, order, and response format. With regard to the tasks, it should be indicated that they correspond to the type called essay, since, due to the nature of the construct of verbal creative thinking, they are those that allow the individual to express themselves freely in order to show their creative capacity (Muñiz, 2018). It should be mentioned that their evaluation involves greater difficulty than the other types of tasks, since the subject is not limited by response alternatives, in addition to the greater effort that must be made to measure verbal creative thinking.

However, it is more correct to refer to the term as reagents or stimuli, instructions, indicators of verbal creative thinking, and examples that are presented in the context of a task or game. In total, there are three tasks with the following order and content: (a) Task 1: problem posing; (b) Task 2: generating creative ideas; (c) Task 3: evaluating and improving ideas.

In addition, the following eight observable indicators of verbal creative thinking are used for evaluation: fluency, flexibility, originality, elaboration, sensitivity to problems, opacity, dynamic integration, and refinement of ideas. The identification of these indicators in each of the tasks could be carried out by consulting the experts who are the most knowledgeable on the subject, by using the Delphi method as the appropriate methodology.

The Delphi method is based on a communicative process in which a group of experts gives an answer to a research problem through an iterative process (López-Gómez, 2018). This process takes place anonymously, iterative questionnaire-results-questionnaire, which leads to feedback from the experts so that they can reach the highest possible consensus among them to achieve the proposed objective (Plans and León, 2003).

The value of this technique for the development creativity is that it makes it possible to coordinate the different preferences, currents, trends, and lines contributed by experts in the field. In this sense, it was decided to use the Delphi method, as it was considered the most appropriate to achieve the objective of this study: to determine which indicators of verbal creativity could be measured in each of the tasks.

2 Materials and methods

A Delphi method was used to reach a consensus among creativity experts in order to determine the indicators of verbal creative thinking.

2.1 Participants

For the selection of the participants, a non-probabilistic purposive sampling was used (Jorrín et al., 2021), since the experts who met the following criteria were selected: availability and interest in participating in this study, at least 5 years of experience in the study of creativity and research activity, accredited by publications of impact (JCR or SJR).

Based on these criteria, 40 experts were invited to participate in a Delphi panel on indicators of verbal creative thinking. Twenty agreed to participate, but only 16 completed the two phases of the Delphi method, resulting in an attrition rate of 20% ($n = 4$). Despite this, the ideal number of experts to participate in the Delphi method was met (López-Gómez, 2018). Table 1 shows the profile of the experts who participated in the present study.

This Delphi panel included experts from nine different fields of knowledge, with 25% of the sample being foreigners. In addition, the percentage of women (62.5%) and the fact that 43.75% of the experts had more than 25 years of experience stood out.

To determine the quality of the expert panel, the Competence (K) index (Cabero and Barroso, 2013) was calculated, which is the sum of the knowledge coefficient (Kc) and the argumentation coefficient (Ka) divided by 2. Both the Kc ($M = 0.84$; $SD = 0.09$) and Ka ($M = 0.81$; $SD = 0.18$) scores were high, which means that K is high ($M = 0.825$; $SD = 0.1$). With an Expert Competence score above 0.8, the Delphi panel is considered to be of high quality for addressing the research problem (Table 2).

2.2 Instruments

To collect information from the participants, we used an *ad hoc* questionnaire developed by our research group. This questionnaire was divided into four parts. The first part was used to collect socio-demographic data that determined the characteristics of the Delphi panel. The rest of the questionnaire was composed of 24 items corresponding to the indicators to be measured in each of task. The latter included a dichotomous scale in which the experts had to indicate whether they would or would not measure these indicators in Game 1 of problem posing, in Game 2 of generating creative ideas, and in Game 3 of improving ideas. The indicators were: fluency, flexibility, originality, elaboration, sensitivity to problems, opacity, dynamic integration, and refinement of ideas.

2.3 Procedure

In the first phase of the Delphi method, the experts received an invitation by e-mail together with the digital version of the

TABLE 1 Expert profiles.

Characteristic		*n*	%
Gender	Masculine	6	37.5
	Feminine	10	62.5
Home University	University of Murcia, Spain	11	68.75
	University Miguel Hernández, Spain	1	6.25
	National University of Rio Cuarto, Argentina	2	12.5
	National University of Jujuy, Argentina	1	6.25
	Drake University, Iowa, USA	1	6.25
Professional category	University Professor	1	6.25
	University Associate Professor	8	50
	University Adjunct Professor	7	43.75
Area of expertise	Educational Psychology	6	37.5
	Language Didactics	1	6.25
	Basic Psychology	1	6.25
	Personality, Psychological Assessment and Treatment	3	18.75
	Psychometry	1	6.25
	Didactics of Artistic Expression	1	6.25
	Philosophy of Education	1	6.25
	Methodology of Behavioral Sciences	1	6.25
	Industrial Psychology	1	6.25
Teaching and research experience	5–15 years	4	25
	15–25 years	5	31.25
	More than 25 years	7	43.75

TABLE 2 Quality of the expert panel.

Expert index	*M*	*SD*
Knowledge coefficient	0.84	0.09
Argumentation coefficient	0.81	0.18
Competence index	0.825	0.1

questionnaire and were given a period of time to complete it. Once all the questionnaires had been returned, the results of this first phase were grouped into percentages and these results, together with the questionnaire, were sent to carry out the second phase of the Delphi method. In this phase, the experts considered the responses from phase 1 to answer the questionnaire, with the aim of reaching a minimum consensus of 80% for each of the indicators. These experts could not interact with each other, and their anonymity was guaranteed in both phase 1 and phase 2.

2.4 Data analysis

Data analysis was performed using IBM SPSS Statistics version 28.0.1. Descriptive statistics and frequencies were used to describe the panel of experts. For each indicator, participants responded with the following options: 1 = Yes and 2 = No. This dichotomous scale was used to reduce ambiguity, for its objectivity and clarity, and to allow the experts to focus more on the relevance of the indicator. Once the degree of agreement at the percentage level among the experts is known through the use of frequencies, it becomes necessary to check whether the agreements reached are statistically significant. Frequencies were used to determine the percentages of expert responses. The Fleiss kappa test was also used to determine the coefficient of concordance between the experts' responses in each of the games and phases of the Delphi method. To interpret the results of Fleiss' kappa coefficient, the Landis and Koch (1977) scale was used to determine the strength of agreement of the experts. This scale has the following values: poor (0), slight (0.1–0.2), acceptable (0.21–0.4), moderate (0.41–0.6), substantial (0.61–0.8), and near perfect (0.81–1). Participants' responses were analyzed in both rounds because they could keep or change their responses.

TABLE 3 Delphi method phase 1 results.

Game	Indicators	Yes (%)	No (%)	Fleiss' kappa (*p*)
Game 1	Fluency	16 (100%)	0 (0%)	0.35 (0.000)
	Flexibility	13 (81.25%)	3 (18.75%)	
	Originality	11 (68.75%)	5 (31.25%)	
	Elaboration	11 (68.75%)	5 (31.25%)	
	Sensitivity to problems	15 (93.75%)	1 (6.25%)	
	Opacity	4 (25%)	12 (75%)	
	Dynamic integration	4 (25%)	12 (75%)	
	Refinement of ideas	3 (18.75%)	13 (81.25%)	
Game 2	Fluency	7 (43.75%)	9 (56.25%)	0.178 (0.001)
	Flexibility	12 (75%)	4 (25%)	
	Originality	16 (100%)	0 (0%)	
	Elaboration	13 (81.25%)	3 (18.75%)	
	Sensitivity to problems	5 (31.25%)	11 (68.75%)	
	Opacity	10 (62.5%)	6 (37.5%)	
	Dynamic integration	14 (87.5%)	2 (12.5%)	
	Refinement of ideas	7 (43.75%)	9 (56.25%)	
Game 3	Fluency	9 (56.25%)	7 (43.75%)	0.114 (0.001)
	Flexibility	12 (75%)	4 (25%)	
	Originality	14 (87.5%)	2 (12.5%)	
	Elaboration	13 (81.25%)	3 (18.75%)	
	Sensitivity to problems	7 (43.75%)	9 (56.25%)	
	Opacity	9 (56.25%)	7 (43.75%)	
	Dynamic integration	14 (87.5%)	2 (12.5%)	
	Refinement of ideas	16 (100%)	0 (0%)	

Global agreement on Delphi panel phase 1 (Fleiss' kappa = 0.232, $p < 0.001$).

3 Results

Table 3 shows the indicators that the experts considered relevant for measuring the construct of verbal creative thinking in each of the three games in phase 1 of the Delphi method. For the indicators of the first game in phase 1, the experts considered that indicators such as fluency (100%), flexibility (81.25%), and sensitivity to problems (93.75%) should be measured, while refinement of ideas (81.25%) should not be measured. The overall agreement achieved by the experts in Game 1 was acceptable and statistically significant (Kappa = 0.35, $Z = 10.853$, $p < 0.01$) with a 95% confidence interval (0.287–0.414).

For the second set of indicators, the experts determined that originality (100%), elaboration (81.25%), and dynamic integration (87.5%) should be evaluated. The overall agreement among the experts was lower because it was manifested at a low level, although statistically significant (Kappa = 0.178, $Z = 5.517$, $p < 0.01$) with a 95% confidence interval (0.115–0.241).

In the third game, it was agreed to measure the indicators of originality (87.5%), elaboration (81.25%), dynamic integration (87.5%), and refinement of ideas (100%). Fleiss' kappa statistic shows a slight and statistically significant agreement among the experts in game 3 (Kappa = 0.114, $Z = 3.518$, $p < 0.01$) with a 95% confidence interval (0.05–0.177), which is the lowest of the three games in this first phase.

Considering all the games simultaneously, that is, all the answers given by the experts in Phase 1, an acceptable and statistically significant level of global agreement was obtained (Kappa = 0.232, $Z = 12.444$, $p < 0.01$) with a 95% confidence interval (0.195–0.268). Although statistically significant agreements were obtained in Fleiss' kappa statistic, these agreements are low and acceptable, which means that they are not sufficient to conclude the Delphi method. For this reason, it was necessary to conduct a second round of Delphi to achieve a higher level of agreement.

In phase 2 of the Delphi method, the experts were able to consider the results of phase 1 in order to modify or maintain their answers. In this second phase, higher levels of agreement were expressed for each of the games, as shown in Table 4. 100% of the experts indicated that the indicators of fluency, flexibility and sensitivity to problems should be measured in Game 1, just as 100% of the experts indicated that the indicators of opacity and dynamic integration should not be measured. In Game 1, the overall agreement among the experts was almost perfect and

TABLE 4 Delphi method phase 2 results.

Game	Indicators	Yes (%)	No (%)	Fleiss' kappa (*p*)
Game 1	Fluency	16 (100%)	0 (0%)	0.821 (0.000)
	Flexibility	16 (100%)	0 (0%)	
	Originality	15 (93.75%)	1 (6.25%)	
	Elaboration	13 (81.25%)	3 (18.75%)	
	Sensitivity to problems	16 (100%)	0 (0%)	
	Opacity	0 (0%)	16 (100%)	
	Dynamic integration	0 (0%)	16 (100%)	
	Refinement of ideas	2 (12.5%)	14 (87.5%)	
Game 2	Fluency	2 (12.5%)	14 (87.5%)	0.688 (0.000)
	Flexibility	14 (87.5%)	2 (12.5%)	
	Originality	16 (100%)	0 (0%)	
	Elaboration	16 (100%)	0 (0%)	
	Sensitivity to problems	1 (6.25%)	15 (93.75%)	
	Opacity	14 (87.5%)	2 (12.5%)	
	Dynamic integration	16 (100%)	0 (0%)	
	Refinement of ideas	3 (18.75%)	13 (81.25%)	
Game 3	Fluency	13 (81.25%)	3 (18.75%)	0.628 (0.000)
	Flexibility	14 (87.5%)	2 (12.5%)	
	Originality	16 (100%)	0 (0%)	
	Elaboration	16 (100%)	0 (0%)	
	Sensitivity to problems	2 (12.5%)	14 (87.5%)	
	Opacity	3 (18.75%)	13 (81.25%)	
	Dynamic integration	16 (100%)	0 (0%)	
	Refinement of ideas	16 (100%)	0 (0%)	

Global agreement on Delphi panel phase 2 (Fleiss' kappa = 0.723, $p < 0.001$).

statistically significant (Kappa = 0.821, $Z = 25.425$, $p < 0.01$) with a 95% confidence interval (0.757–0.884), meaning that it was the highest level of agreement among all the games.

In Game 2, the experts showed 100% agreement in judging originality, elaboration, and dynamic integration. Fleiss' kappa statistic shows considerable and statistically significant agreement among the experts in Game 2 (Kappa = 0.688, $Z = 21.311$, $p < 0.01$) with a 95% confidence interval (0.625–0.751).

In addition, 100% inter-rater agreement was achieved in Game 3 for the measures of originality, elaboration, dynamic integration, and refinement of ideas. The overall agreement reached by the experts in Game 3 was considerable and statistically significant (Kappa = 0.628, $Z = 19.451$, $p < 0.01$) with a 95% confidence interval (0.565–0.691), being the game with the lowest level of agreement of the three games, as was the case in the first phase of the Delphi method.

In the whole phase 2 of the Delphi method, a considerable and statistically significant level of global agreement was obtained (Kappa = 0.723, $Z = 38.824$, $p < 0.01$) with a confidence interval of 95% (0.687–0.76). The percentage agreement of 80% was obtained for each of the indicators of verbal creative thinking, which is considered key for the measurement or not of each of them in the different games. Likewise, Fleiss' kappa statistic showed considerable and almost perfect degrees of agreement in this second phase, significantly increasing the levels of agreement that had occurred in the first phase. Therefore, the Delphi method was stopped in this second phase.

4 Discussion

The results obtained show that the experts consulted consider that the main indicator of verbal creative thinking is originality (Forthmann et al., 2021; Pichot et al., 2022), understanding that the original ideas contributed by the subjects in the proposed tasks are distant in meaning from the task stimuli (Beaty and Johnson, 2021; Dumas et al., 2021).

To originality are added elaboration and flexibility, since their measurement is considered in the three games, appreciating a clear tendency of the experts for the classic indicators of creativity. Also considered, although to a lesser extent since it is only evaluated in three games, is fluency, which is another of the classic indicators on which estimates of the creative thinking of individuals are based (Runco and Acar, 2019; Corbalán, 2022). In fact, most creativity tests usually measure fluency, flexibility, and originality in their verbal tasks (Torrance, 1974; Corbalán et al., 2003; Artola et al., 2004; López-Martínez, et al., 2018). However, the indicator that is not

usually measured in verbal tasks is elaboration, which is usually considered in figurative tasks.

The indicators used to assess verbal creative thinking in a problem-solving task were fluency, flexibility, originality, elaboration, and sensitivity to problems. The indicator that was added to those already described was sensitivity to problems (Guilford, 1968). This indicator is considered to be the starting point of creative thinking, since problem posing, and problem finding are responsible for the emergence of creativity.

In addition, flexibility, originality, elaboration, opacity, and dynamic integration are the key indicators to be measured in a creative idea generation task in the evaluation of the construct. This type of task is usually carried out in creativity tests, although in this case there is the specificity of including opacity, in which non-literal language is sought, and dynamic integration, which focuses on the unity of the elaborated text (Desrosiers, 1978; López-Martínez, et al., 2018). The incorporation of these indicators implies the transition from general creativity to verbal creative thinking.

In Game 3 regarding the improvement of ideas, the measurement of fluency, flexibility, originality, elaboration, dynamic integration, and refinement of ideas is considered crucial. In addition to the indicators described above, the refinement of ideas is a key indicator in a task where the goal is to improve a given product with the aim of making it suitable for solving the task at hand and original compared to the rest of the individuals (OECD, 2020; Matheson et al., 2023). This task is the last step of verbal creative thinking. It should be mentioned that usually only tasks of idea generation are given to the detriment of tasks of problem solving and improvement of ideas.

In conclusion, it should be noted that the detection of verbal creative thinking is key to its development in the school context. The tools used to measure the verbal area of creativity are not sufficient because they do not consider all the indicators identified in this study that make it possible to measure this thinking (Guilford, 1968; Desrosiers, 1978; Kasirer and Mashal, 2018; Acar et al., 2019; Beaty and Johnson, 2021; Forthmann et al., 2021). For this reason, this information is valuable for the development of a tool that assesses verbal creative thinking in an appropriate manner, using texts that have key relevance in this verbal domain.

Measuring it is a step forward in this facet, as creativity is one of the 21st century competencies that allows society to adapt and solve problems (OECD, 2020; Corazza et al., 2022). Teachers play a fundamental role in its improvement, as they oversee the implementation of educational practices that allow its progress through creative intervention programs and the development of a creative curriculum. They are also key to identifying talent in the area of knowledge most closely related to language, writing and reading.

The main limitation of this study was the choice of creativity indicators. This did not allow the experts to consider indicators other than those previously established for measurement in each of the games. However, the selection of indicators was made after a thorough review of the scientific literature. The intention of this selection was that the experts would consider both traditional indicators of creativity, which are widely known, as well as specific indicators of verbal creativity, which have not been considered as much in the evaluation of this thought in the various tests of creativity. In fact, it was the combination of both in the different tasks that made it possible to measure the construct called verbal creative thinking.

Once the indicators of Verbal Creative Thinking have been identified in the present study, the main line of future research is to develop a test to estimate the verbal creative potential, which includes the content validity of the test and the development of a pilot study with the intended participants of the test, individuals in primary education. Also, this test will serve not only to work on aspects of reading comprehension but also to prevent language development disorders.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Comisión de Ética de Investigación – Universidad de Murcia. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

OL: Writing – original draft, Writing – review & editing. AL: Writing – original draft, Writing – review & editing. MV-Y: Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Consciousness and education: contributions by Piaget, Vygotsky and Steiner

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The objective of this study is to gain an understanding of the development of consciousness and its relationship with education based on different theoretical models—namely those by Piaget, Vygotsky and Steiner. All three of them focus on different subcomponents of the educational process and there is hence a need for integrative discussion. Piaget and Vygotsky are fundamental references in the understanding of developmental and learning processes. Steiner was a pioneer in proposing a pedagogy that progresses by integrating feeling and wanting alongside thinking in the educational process. Their theories have important similarities but also differences and these will be essential for broadening the understanding of the construction of consciousness and its relationships with education.

KEYWORDS

consciousness, education, Piaget, Vygotsky, Rudolf Steiner, awareness, development, cognitive development

1 Introduction

The theme of consciousness in Education Sciences has gained increasing prominence. This interest is expressed in research and teaching focused on culturally responsive teaching (Schirmer and Lockman, 2022; Tsevreni, 2022), argumentation between teacher and student focused on civic consciousness (Zhadan et al., 2004; Islam, 2019; Zaiets et al., 2022) and, above all, for the development of critical consciousness (Zorrilla and Tisdell, 2016; Hamamra et al., 2021; Ilten-Gee and Manchanda, 2021; Knipe, 2021; Naidu, 2021; Upadhyay et al., 2021; Gómez and Cammarota, 2022; Hernandez and Harris, 2022; Rauf and Shareef, 2022; Sarigöz, 2023; Seider et al., 2023). The critical consciousness approach, founded by Paulo Freire, aims to develop a deep knowledge of the world, its social and political contradictions, as well as acting against oppressive elements, based on the understanding of their determinants and towards greater equity, considering reflection and action in education. In turn, the civic consciousness approach highlights the close connection of each citizen to society and is based on the idea that the true interests of society are those of its citizens.

As such, the movement around studies on consciousness in Education Sciences is mainly focused on knowledge and emancipation of socio-historical aspects, which impact more on existence permeated by oppression, and less on the study of the process of development of consciousness itself. This aspect is considered just as fundamental in education as investment in critical consciousness and it is in this sense that we have developed this study, which aims to gain understanding of the development of consciousness and its relationship with education based on differing theoretical models.

The perspectives of Piaget, Vygotsky and Rudolf Steiner have been chosen as the theoretical models. Piaget and Vygotsky are among the main theorists influencing school education (Sharkins et al., 2017). Both focus on developing consciousness in education (Zender, 1973; Zhang, 2022). Rudolf Steiner, in turn, presents a different proposal for understanding and developing consciousness based on the integration of human thinking, feeling and wanting (Gidley, 2007, 2008, 2010; Stoltz et al., 2023). In order to overcome the dichotomies between the intellectual and emotion, the material and the spiritual, body and mind, and to increase understanding about how consciousness emerges, the need exists for discussions based on differing theoretical approaches in education.

2 Method

This literature review is a traditional or narrative review. Initially, we chose primary sources from Piaget, Vygotsky and Steiner on consciousness and education. After mapping each author's ideas, we performed a search on the Eric, Scopus and EBSCO databases to collect articles and books that discuss the topic of consciousness and its relationship with education in the work of the authors we researched. The analysis and reflective discussion began with each author's trajectory regarding the topic, considering all the material selected; subsequently, we aimed to establish relationships between the authors.

2.1 Consciousness and education in Piaget

Piaget can be considered to be one of the most influential figures in the field of Education (Zhang, 2022). For Piaget, consciousness plays an essential role in determining behavior (Zender, 1973). Through his Genetic Epistemology he presents the process of knowledge building with effect from its genesis. In this process he considers both in the essence and in the final version of his theory the intra, inter and trans passage and the processes of grasps of consciousness (Piaget and Garcia, 1983, 1987; Stoltz, 2018). The intra, inter and trans triad refers to the process of cognitive construction, starting with intra-object relationships (sensorimotor), moving on to inter-object relationships (pre-operational and concrete operational) and culminating in trans-object relationships (formal operational). Starting from the interaction between subject and object, each stage of knowledge development, which culminates in the construction of structures (sensorimotor, pre-operational, concrete operational and formal operational), involves intra, inter, trans passages and grasps of consciousness (Piaget and Garcia, 1983).

In the final version of his work, Piaget reformulated his logic based on a logic of meanings, giving it a less extensionist character, following the path of a logic that is both intentional and extensional (Piaget and Garcia, 1987). The starting point of this logic are inferences, a proto-logical or natural deduction system, whereby the meaningful implication relationship is the fundamental logical relationship. Starting with inferences means considering intuitions, purposes and representations as underlying cognitive behaviors. Meaningful implication is a relationship between two actions, statements or operations, which have a meaning in common for a person. Attributing meanings to objects, as well as to actions, consists of interpreting them and interpretation is permeated both with complexity and always with inferences. Meaningful implications are related to the process of consciousness in Piaget's theory.

Piaget speaks of the exteriorization or physical-causal movement and the interiorization or logical-mathematical movement in the consciousness grasping process (Piaget, 1974a,b). These two parallel movements, which arise from the observables at the object's periphery and also from the observables at the periphery of actions on objects, move towards the centre both of the object and the subject's actions. Grasp of consciousness is, therefore, the result of the progression of the interaction between the object's observables and the subject's observables (Piaget, 1974b; Stoltz, 2018). All construction of knowledge in Piaget's model is initially the result of the subject's interaction with the physical and social environment and is expressed through grasps of consciousness via reflecting abstractions and considering meaningful implication (Piaget, 1975, 1977a,b; Piaget and Garcia, 1987). Piaget distinguishes between different types of abstraction depending on the starting point from which the subject abstracts. Abstraction through the material properties of reality or empirical abstraction enables knowledge of the properties contained in the object. In turn, reflecting (*réfléchissante*) abstraction derives from coordination of the subject's actions carried out on the object, which are not observable as the subject processes them internally. This type of abstraction involves two moments: a reflective and a reflexive moment. Reflective implies the transition to the level of representation of content contained in the action. Reflexive, on the other hand, implies second-order reflection, thinking about what has been obtained at the previous level, thinking about thinking, leading to a form that can be used in different contents. In the Piagetian model, attention is focussed on the subject and on its constructions, whilst not disregarding social interactions and transmission, which it considers to be a *sine qua non* condition, alongside maturing and experience, these being factors coordinated by the self-regulating process of equilibration which in turn determines the possibility of a new equilibrium arising from a situation of cognitive imbalance (Piaget, 1964, 1975, 1990/1932, 2003/1936, 2009/1945; Kesselring, 1999; Stoltz, 2018). Grasp of consciousness, for Piaget, refers to cognitive functioning, is not explained as overall enlightenment and always refers to specific actions or notions. Grasp of consciousness begins with a *savoir-faire* and moves on to the understanding of what one already knew how to do; or from a practical action, that is an autonomous type of knowledge, to the understanding of that action, which involves conceptualization, and then inverting the order, whereby understanding guides the action (Piaget, 1974a,b; Stoltz, 2018). Piaget's (1926) first studies about language and thought contributed to the formulation of his theory of consciousness (Zhang, 2022).

Criticisms of the Piagetian model are based above all on its non-discussion of culture in the development of knowledge, even though Piaget (Piaget and Inhelder, 2003) always understands social aspects in relation to cultural aspects. The Piagetian model is criticized for understanding egocentric thinking as self-centered, deficit-oriented and needing to be overcome in order to achieve operational thinking and consciousness (Zhang, 2022). In turn, Zender (1973) states that Piaget, like Vygotsky, placed emphasis on what the child presents and not on what it lacks. Some studies have focused on understanding Piaget's concept of consciousness (Morgado, 1998; Ferrari et al., 2001; Ferreiro, 2001; Pons and Harris, 2001; Ferreira and Lautert, 2003; Moro, 2005; Ferrari, 2009; Fávero, 2011; Pons et al., 2012; Pinheiro and Becker, 2014; Stoltz et al., 2014; Dongo-Montoya, 2017; Stoltz, 2018).

However, his concept of consciousness in education, based on its most recent version (Piaget, 1974a,b, 1976), is little known and explored in scientific literature. Its use can be thought of in conjunction with the proposal for developing critical consciousness in education based on Paulo Freire (Becker, 2010, 2017; Alves, 2019).

In short, "the process of constructing grasp of consciousness is explained by meaningful implication, reflecting abstraction and equilibration. The dialectics between body and mind and between causality and implication pervade the discussions on consciousness in Piaget's work" (Stoltz, 2018, p. 01). Reflecting abstraction concerns the knowledge acquired through the coordination of the subject's actions on the object initially and when thinking about such coordination, constituting a second-order abstraction. The concept of equilibration refers to the progressive movement of self-regulation and the search for a new balance or understanding based on a situation of cognitive imbalance, and is a vector of development. There is no consensus in the literature regarding understanding of the concept of consciousness, since over the course of his work Piaget approached it in a slightly different way (Stoltz, 2018). Nevertheless, the final version of the concept (Piaget, 1974a,b, 1976) is the result of an evolutionary process throughout his work, which includes a variety of empirical research and theoretical reflections. In this sense, it can be seen that creative activity based on what is meaningful in one's own existence can trigger reflections that allow the development of consciousness of one's own activity. Such awareness, following the Piagetian model, would be the result of the interaction between the subject's observables and the observables of the creatively produced object. This process would be facilitated by the mediator who guides the subject's attention along two parallel paths: sometimes towards the creatively produced object, sometimes towards the coordination of actions on the object within a logic of meanings (Stoltz, 2018; Stoltz et al., 2023). In the process of developing critical consciousness, this means not only knowledge of socio-historical determinants of action, but also knowledge of how the person is linked to action produced individually or collectively in a social and cultural context. Thus, the Piagetian model of consciousness-raising emphasizes the construction of the process starting from practical action to conceptualized action through the use of semiotic resources (directing thought towards the means used and the results obtained at each moment of the process) in reflecting abstraction and having as a basis a logic of meanings, in a movement of increasing equilibration, which distances it from Cartesian dualism and brings it closer to Vygotsky. It is the educator's role to encourage the student's actions through experiences, studies, questionings, problems and challenges that contribute to the construction of knowledge by the student (Piaget, 1998, 2000, 2003; Stoltz and Parrat-Dayan, 2007; Stoltz, 2018). Intelligence and reality are built through actions and these in turn depend on the energy that unleashes them, the affective factor (Piaget, 1954; Vonèche and Stoltz, 2007). The educator's mediation aimed at facilitating the process of consciousness must start from questioning what has been done in practical action, seeking to achieve consciousness of the physical and mental actions in the transformation process involved in the action.

2.2 Consciousness and education in Vygotsky

The essential role of consciousness in human behavior permeates all of Vygotsky's work (Zender, 1973; Van der Veer, 1984; Liu and Matthews, 2005; Toassa, 2006; Barros et al., 2009; Bozhovich, 2009; Lordelo and Tenório, 2010; Machado et al., 2011; Zavershneva, 2012, 2014; Pedrosa, 2013; Clot, 2014; González Rey, 2016; Dafermos, 2018; Davidov, 2021). However, the concept of consciousness underwent essential changes throughout his scientific career and was never finished (Zavershneva, 2014; Davidov, 2021). Vygotsky's publication Thought and Language is the key to understanding human consciousness from his point of view (Carvalho et al., 2010).

Consciousness as a form of self-regulation and higher mental function always has its origin in a social and cultural process. In the same way as the origin of cognition occurs in a social process, for Vygotsky (1978/1935, 2002/1934; Ratner, 1995; Van Der Veer and Valsiner, 1999) this social process can be modified through the development of consciousness in the dialectic movement between individual and culture. It is in words that we find the objectification of the monistic Vygotskian view, given that the latter adds both socially shared and felt signification, in addition to meaning resulting from the subject's activity with signification. In Vygotsky we find a type of materialist monism, given that all cognitive development is understood based on its material basis; and in the subject this understanding is based on its own brain (Van der Veer and Valsiner, 1994).

The Vygotskian theory of mediation is especially interesting in the discussions about consciousness. Based on the understanding of it as the intervention of an intermediary element in the relationship between mankind and the world, mediation expresses the intervention of culture, its instruments, signs and symbolic systems that enable the ownership and production of knowledge (Leontiev et al., 1991; Moll, 1996; Vygotsky, 2002/1934). As such, Vygotsky presents a prospective vision of learning and development, given that what the subject already knows how to do is not so much a determinant but rather how they make use of mediators to go even further, this being the same as saying how they make the most of the help or support of an expert or someone who has more knowledge (Vygotsky and Luria, 1996). It is the educator's role to intervene in the ZPD – Zone of Proximal Development, which is located between the student's real development zone and their potential development zone. This means intervening between what the student already knows and is able to resolve independently – their real development zone, and what they may come to know – their potential development zone, which is determined by the resolution of problems with the help of someone more capable, whether this be the teacher or another more competent subject (Vygotsky, 1978/1935; Stoltz, 2012; Stoltz et al., 2015; Dafermos, 2018). Brushlinskii (2002) criticized Vygotsky's concept of ZPD because it leads to exacerbated pedagogical optimism, whereby any child can be taught everything provided its ZPD is respected. The gap in the Piagetian model regarding culture being taken into consideration is discussed in Vygotsky as a mediator *par excellence* of the individual's relationships with the world.

According to Zavershneva (2014), an evolution in the understanding of the notion of consciousness can be seen in Vygotsky's work. Starting from an idea of consciousness as a reflection of reflexes (Vygotsky, 1925/2013), in which he proposes a model of consciousness as a transmission mechanism between systems of reflexes, Vygotsky (1930/2013) moves towards the notion of consciousness as a system of secondary connections between higher mental functions, signaling the concept of mediation in the development of higher mental processes. This model gives rise to a

third model (Vygotsky, 1968/2013), which understands consciousness as a dynamic semantic system, although he did not further develop this idea due to his premature death. According to Vygotsky, the level of development of conceptual thinking becomes an indicator of the level of development of consciousness. Thus, Vygotsky (1968/2013) considers semiotic analysis to be the only suitable method for studying the structure of the system and content of consciousness.

In order to understand the evolutionary process of the notion of consciousness in Vygotsky's work, it is necessary to remember that he began with art, prior to developing his cultural-historical psychology (Dafermos, 2018; Davidov, 2021). Art, in its different manifestations, involves emotions and feelings and is understood to enable *catharsis*, involving resolution of conflicts in a playful manner (Vigotski, 1999; Connery et al., 2010; Oliveira and Stoltz, 2010; Stoltz et al., 2015). Art always expresses the social and historic development of a people, as well as the artist's vision of the world, but it is not limited to these functions. It is for this reason that Vygotsky, in his work Educational Psychology (Vygotsky, 1997/1926), highlights the importance of working with imagination and creativity in education. Everything depends in the first place on the teacher's emotion, which is internalized by the student. For Vygotsky, emotions have a physiological basis and, through the development of higher mental functions, can be controlled or self-regulated. It is important to highlight that art, for Vygotsky, whose view involves working with emotions, makes possible the production of individual senses which are the fruit of the subject's negotiation with historically produced social significations.

After 1924 and with the advent of the delimitation of his cultural-historical psychology, which is of a dialectic and Marxist basis and is, therefore, materialist, Vygotsky ceases to concern himself with the question of art and creativity in itself. Later he returns to this issue at the end of his life in the text entitled: *On the problem of the psychology of the actor's creative work*, in his unfinished theory on emotions (González Rey, 2016). According to González Rey (2016), the third moment of Vygotsky's work can be characterized as a return to human spiritual complexity. Zavershneva and Van der Veer (2018) characterize this last period as the theory of dynamic semantic systems and the psychology of perezhivanie, which involves the semantic construction of consciousness, where the emphasis is on the study of meaning and sense as a result of operation mediated by signs.

Dafermos (2018) states that Vygotsky ended up leaving two proposals for the unit of analysis of consciousness: meaning as a unit of analysis and the concept of perezhivanie as an indivisible unit of personality and the social environment, highlighting ambiguity regarding the unit of analysis of consciousness. Cornejo (2012) points to the fact that phenomenologically experienced meaning subordinates objective meaning to subjective meaning and raises problems with the Marxist basis of Vygotsky's work. There is a polyphony of voices in Vygotsky's work (Van der Veer, 1984; Dafermos, 2018), also showing a romanticist Vygotsky, more interested in describing the ever dynamic conscious experience than in imposing abstractions on this experience (Cornejo, 2012, 2015). Cornejo (2015) points to the romantic roots of Vygotsky's holism, especially in his work Thought and Language.

On the other hand, Clot (2014, p. 128) notes that in his final years Vygotsky is inclined to understand consciousness beyond thought, not as a field contemplated by the subject, but rather as a relationship between meaning given by the socio-historical environment (meaning) and meaning recreated in activity (sense). For Vygotsky, consciousness mediates, without ceasing to be mediated (Clot, 2014).

Zavershneva (2012), like Roth (2017), points out that Vygotsky goes beyond classical Marxism, indicating specific determinants of the development of consciousness. Among these determinants is the word, which plays a fundamental role in the structure of the higher mental function, highlighting Vygotsky's program and forming its solid core. The idea of consciousness as a relationship, as a work of connection always subject to disconnection, considers the simultaneous evolution of language, abstraction and consciousness (Clot, 2014; Zavershneva, 2016). "'En el principio fue el acto (y no el acto fue al principio), y al final surge la palabra, y eso es lo más importante' (L.S.). Cual es lo significado de lo que hemos dicho? 'A mi me basta con esta consciencia', es decir, ahora me conformo con que el problema haya sido planteado." (Vygotsky, 1968/2013, p. 130). Mediated action, communication through signs, which involves communication and generalization, becomes central in the discussion of consciousness in the final text specifically focused on this topic (Vygotsky, 1968/2013). For Zavershneva (2014), Vygotsky was successful in describing above all the cognitive sphere of consciousness, considering meaning as the result of operations mediated by signs. However, the concepts of higher emotions, will and personality, and their relationship with consciousness, involved in Vygotsky's (1999) last project, were not completed. According to Zavershneva (2014), between 1933 and 1934, Vygotsky began the transition from meaning to the notion of perezhivanie or experience (*Erlebnis*, in German) in the investigation of the relationships between consciousness and personality. "The more personality is developed, the better the external social world is represented in the inner world of the person. Therefore, the problem of personality eventually is the knot, in which all main threads that originate in the problem of consciousness, such as the role of speech, society, environment, the problem of freedom, and the principles of the systemic and semantic nature of psyche, weave together" (Zavershneva, 2014, p. 92).

Davidov (2021) considers dramatic Vygotsky's attempt to look for the driving force of cognitive development in the emotional sphere of humankind, rather than in the development of its activity, which highlights the inconsistency of Vygotsky's approach in his final years in relation to the fundamental basis of mental development: on the one hand this basis is activity, while on the other hand it is affection. While for Zavershneva (2014), from the perspective of Vygotsky, consciousness exists for as long as there is an interactive theatrical performance, in which the main participant is the personality and the multiple people behind it. In this sense, Vygotsky's vision follows a postmodern perspective of understanding consciousness based on the unity between affective and intellectual processes and could accompany the development of critical consciousness in education.

In summary, Vygotsky moves from the study of higher mental functions to the investigation of the semantic structure and development of consciousness. In this process, the focus changes from the analysis of psychological systems to the semantic analysis of consciousness and from the problem of meanings to the problem of sense, dedicating himself, in his final year of life, to the problem of emotional experience (perezhivanie) in the study of consciousness. In this process, he ends up distancing himself from his Marxist basis and moving closer to a phenomenological approach, which has been gaining ground in education.

2.3 Consciousness and education in Rudolf Steiner

Steiner's proposal is mainly based on Goethe, Schiller, Schelling, Fichte and Hegel (Clement, 2016). For example, in relation to Goethe, Steiner assumes that "The Goetheanistic cosmovision differentiates itself from the materialist cosmovision by the questions it asks; neither of the cosmovisions contradict each other, rather they complement each other. Goethe's ideas provide the basis for the former." (Steiner, 1926, p. 77). The themes of freedom, knowledge and art permeate Steiner's work (Clement, 2016). Despite the recognition of Goethe's influence, recent research has pointed out the link between Steiner's work and ideas from German idealism, which can be seen as the realization of this vision in practical life (Traub, 2011; Clement, 2016; Sparby, 2020).

Steiner's anthropological proposal is measured by mankind itself and the process of its development. It is based on the phenomenological observation that it is necessary for human development in terms of achieving some form of freedom, which is only attained through the development of consciousness (Steiner, 1963, 2005/1904). As in Piaget and Vygotsky, consciousness is understood to be a process. In Steiner this process is seen to be unending and involves both a material and a spiritual basis. In Steiner's view, the cognitive process includes observation and thought. For Steiner (1987), thought goes beyond the rational intellectual, it is a productive and creative activity (Stoltz and Wiehl, 2021; Traub, 2023), which involves both analytical thinking and what he describes as intuitive thinking, that will be discussed later on. Observation leads to perception, just as thought leads to concepts. Perception always represents part of reality. Concepts are the other part of reality, obtained by thinking. Reality therefore has both a material and a conceptual part, which Steiner understands as the gate to the spiritual world. "Only when the language of the outside world is in agreement with our inner self do we achieve total reality" (Steiner, 1926, p. 253). Due to our initial cognitive organization we perceive the external world as separate from us, which has occasionally been characterized by researchers as a dualistic positioning (Clement, 2016). It is, however, just one world, which is made up of ideas and concepts that permeate matter. Human beings have the task of achieving cognition of total reality. The fundamental question in Steiner is the existence of a sense for cognitive development and this in turn is related to the development of consciousness and has to be discovered by the subject itself. This is the mark of its very freedom. This sense emerges with the development of an ethical individualism (Steiner, 1987), whereby the goals of the individual are in agreement with universal goals or whereby the logic of the subject is in agreement with the external logic that surrounds it (Steiner, 2000; Sparby, 2016, 2017; Traub, 2023). This individualism is ethical only because it is in agreement with the essence of things and requires more than rational thinking but rather intuitive thinking. Indifferent observation and contemplation come prior to the process of developing knowledge (Steiner, 1979/1886). Following this, interactive observation and thought enable the development of reason in articulation with feeling and wanting. They therefore go beyond rational logic (Steiner, 1980/1892, 2022). It is important to emphasize that this rational logic is not excluded, but instead of becoming lost in the vacuum of logical abstraction, it is necessarily reencountered in the world and acts in consonance with the choice of a goal, an ideal, that is in agreement with a universal logic that sustains the universe around us (Steiner, 1987; Schiller, 1990). The encounter with a universal logic is related to the capacity of intuitive thinking. As such, the need exists to develop the ability to be intuitive, to grasp contend that are spiritual. Contemplation and meditation are understood to enable the development of intuitive thinking (Steiner, 1996b; Veiga, 2008; Stoltz and Wiehl, 2019, 2021). If the aim of education found in Piaget and Vygotsky, ultimately, is the development of consciousness, in Piaget with the development of intellectual and moral autonomy, and in Vygotsky with the development of the intellect, affection and wanting in personality, in Steiner we see an education capable of making that aim possible effectively integrating wanting and feeling with thinking. Will and love for the object, as well as cultivating thinking about one's contribution in the world, resulting in concrete actions coherent with the sense actively given by the subject in relation to its existence, derive from the development of an ethical individualism (Steiner, 1979/1886, 1987). For Steiner, to know is to maintain a relationship with the world, this being a relationship with meaning, involving theory and practice (Welburn, 2005; Veiga, 2010; Sparby, 2016; Stoltz et al., 2023; Traub, 2023).

Steiner's proposal for education, materialized in his Waldorf Pedagogy, consists in working on wanting, feeling and thinking in an integrated manner (Steiner, 2005; Veiga, 2006, 2010, 2015; Veiga and Stoltz, 2014; Stoltz and Weger, 2015; Schieren, 2020). Acquisition of a sense of human autonomy brought with it a distancing from the world. In this sense, connection and participation in the world are Goetheanistic elements in Waldorf education (Schieren, 2020). In the educational process, the first seven years of life are dedicated above all to the development of wanting through sensory motor activities. Between seven and fourteen years of age greater emphasis is placed on feeling through manual activities and creative and artistic productions. Emphasis on thinking is given principally after the person is fourteen years old, during adolescence. This means that concepts are worked on above all through images and in a practical manner and then worked on later through thinking (Schieren, 2010). The educational process described facilitates the development of an ethical individuality as an expression of intellectual and moral freedom in love, bringing together truth and science and resumed in the reply to the question: what is the use of all this knowledge? (Steiner, 1980/1892).

Rudolf Steiner's theoretical model is aimed at people's development and this is only possible through the development of their consciousness, this being a task that is imposed on today's mankind (Steiner, 1963, 2005/1904, 2013; Stoltz et al., 2017; Sparby, 2020; Traub, 2023). In relation to Piaget and Vygotsky, Steiner advances by definitively integrating science and art in cognitive development, as two means of having access to reality and through his proposal of ethical individualism as the aim of education (Steiner, 1994, 2004; Stoltz and Weger, 2012, 2015; Stoltz et al., 2017). Ethical individualism can be developed through the synthesis between science, art and spirituality in education (Stoltz and Veiga, 2021; Stoltz and Wiehl, 2021). Each subject is unique and is the expression of the possibility of the human being (Veiga, 2010). Another essential aspect for achieving this aim in education is the prolonged work involving the body, emotions and feelings through practical activities prior to emphasis on intellectual activity (Steiner, 1996a, 2003). But even in adolescence and the primacy of the activity of thinking, this is developed through artistic activities and this alone shows itself to be a significant differential in relation to other pedagogies and enables the

development of intuition integrated with thinking (Schneider, 2006; Schleder and Stoltz, 2014).

Steiner proposes a close link between knowledge and consciousness (Sparby, 2020; Traub, 2023). Art, science and spirituality are essential to the development of knowledge and consciousness. This knowledge would assimilate into itself the creative element of the Universe (Steiner, 2014), which is related to the spiritual development of human beings. Taking into account the gradual development of consciousness parallel to the development of knowledge, Steiner recognizes the following levels: material knowledge; imaginative knowledge; inspirational knowledge and intuitive knowledge (Steiner, 1987, 1996a,b, 1998a,b, 2008, 2014; Sparby, 2017, 2020; Traub, 2023). The transition from materialistic knowledge and consciousness to imaginative and subsequent consciousness is due to the development of regular attention concentration exercises (Majorek, 2007), which enable the development of new organs of perception, in addition to physical perception. These exercises, also seen as meditative (Steiner, 1996b, 1998a, 2013), enable the revelation of a new self, different from everyday life, through access to the spiritual world.

The first level of development of consciousness is acquired through material knowledge. This is understood as common or scientific sensory knowledge, which involves: the object, which promotes impressions on the senses; the image that man forms of this object; the concept, from which man arrives at a spiritual understanding of a thing or an event and "self," which arrives at the material and spiritual unity of the object or forms the unity between image and concept. Material consciousness depends on the physical organism, especially the human brain, to manifest itself. This level of development of consciousness can also be observed by Piaget in his theory of grasp of consciousness and by Vygotsky, when describing consciousness as a higher mental function based on mediation and self-regulation. Here Steiner (1987) mentions in particular thinking as a state of exception, which is guided by observation of thinking and thinking about thinking in the sense of passing to the first level of higher knowledge, namely imaginative knowledge.

In imaginative knowledge, as described by Rudolf Steiner, there is no longer an external sensory object, leaving one with image, concept and self. At this level of knowledge and consciousness, images appear that do not originate from the material domain, but rather from the intellectual/affective domain and the spiritual domain. The common senses: touch, smell, taste, sight and hearing remain inactive here. Initially, it is necessary to acquire the ability, through concentration exercises, to form images full of meaning without sensory impressions. Steiner (1996b) proposes a series of exercises that can lead to the development of images coming from a higher plane, without falling into illusions.

At the third level of knowledge and consciousness, images disappear, leaving only concepts and self. Man lives in a purely spiritual world. Inspiration provides impressions and self elaborates the concepts. One can compare these impressions as spiritual and non-sensory sounds. For example, the sounds that accompanied the creation of Beethoven's ninth symphony, even though he was then deaf. The world expresses, in spiritual words, it's being to the soul and only through them does the everyday world become comprehensible.

At the final level of knowledge and consciousness, as described by Steiner, inspiration also ceases. Only the self remains in a state of resonance with the phenomena around him. This level is expressed by the faculty of no longer being outside, but rather inside things through conceptual intuition. "The life of things in the soul is *intuition*" (Steiner, 1996b, pp. 24–25). In his work The Philosophy of Freedom, Steiner (2000, p. 105) states that: "*Intuition* is the conscious experience of a purely spiritual content, which takes place in the purely noumenal sphere. Only through intuition is it possible to understand the essence of thinking." The highest level of consciousness denotes the ability to capture free universal contents through the world of ideas and through conceptual intuition. With effect from this level, there is union between knowledge and practical action. "As soon as I recognize such contents as the basis and starting point of my action, I take action, regardless of whether the concept was already mine before, or whether I became conscious of it at the moment of my action… (Steiner, 2000, p. 109). In ordinary life, man has only one intuition: that of his own self, which can only be experienced intimately. This is how, through intuitive knowledge, we live in all things. Self-knowledge or self-awareness is an example of intuitive knowledge. However, to penetrate things in this way one needs to step outside oneself and look at others based on them. Meditation, attention concentration exercises, contemplation of natural phenomena such as growth and withering, looking back at daily actions, feelings and thoughts in interactions with the world, as well as other paths described by Steiner (1996a), can cause psychic life to temporarily move away from the sensory world and become capable of inner work towards higher levels of consciousness. In this case and according to Steiner (1996b, 2016), moral evolution is absolutely necessary so that man does not become a hostage to elementary forces when developing his consciousness towards higher regions. To this end, he points out: 1. the conscious distinction between ephemeral and eternal, based on the idea that no one knows that which is eternal in things if they do not have deep knowledge of the ephemeral; 2. attach oneself emotionally to things that have value and usefulness and giving them more appreciation than ephemeral and insignificant things; the value of the isolated object must always be considered in its connection with a totality; develop the following abilities in psychic life: control of thoughts, control of actions, equanimity, impartiality, trust in the world around us and inner balance. The transition to higher levels of consciousness requires effort, patience and regularity in carrying out exercises, in addition to developing a moral attitude towards the world and towards oneself. Development of consciousness involves self-knowledge and self-education in a direction that satisfies the human being. Inner calm and an attitude of veneration towards knowledge superior to our own being are prerequisites for going beyond material consciousness and for the development of new, non-physical senses that promote openness to the world of concepts and ideas.

Achieving higher levels of development of consciousness is justified by the gaining of new impulses for society through intuition and which enable, based on their representation, the improvement of the fields of health, education, art, agriculture, architecture, social organizations as seen in different anthroposophical initiatives around the world (Clement, 2016). Academic research into Rudolf Steiner's thought is relatively recent and, despite the development of criticism related to the debatable quality of Steiner's philosophical texts, questions regarding the originality of his ideas and intentions with his work (Traub, 2011; Zander, 2011), has identified Rudolf Steiner as a thinker who combines knowledge and practical achievement with great social impact. Even though contradictions and ambivalences are observed in his work (Wagemann, 2012), it represents a movement beyond the spiritual void of modern science, an investment in aesthetic thinking (Welsch, 2003; Clement, 2016), which allows the development of a "porous self" (Taylor, 2018), capable of opening up to new possibilities of knowledge and consciousness, beyond materialist consciousness (Sparby, 2020; Traub, 2023).

In summary, Rudolf Steiner presents a multifaceted and in-depth overview regarding the development of consciousness based on self-knowledge and self-education. The possibility of consciousness of self presents itself as an indispensable condition for continuing the process of developing material consciousness towards higher levels. For Steiner, all that is being is ultimately consciousness, and consciousness is the ability to access reality that is ultimately spiritual in its origin and material in its realization. Consciousness thus defines, for Steiner, the very level of evolution of the person and humanity. Waldorf Education, founded by Rudolf Steiner, seeks to promote integrated thinking, feeling and wanting through work with art, science and spirituality, preparing people for living in the world and for conscious involvement in its transformation. This proposal for education for consciousness finds support both in studies that aim to develop critical consciousness and civic consciousness, and also in studies on Consciousness-Centred Education (Beauregard, 2020), and Consciousness-Based Education (Lagrosen and Lagrosen, 2020; Fergusson et al., 2022).

3 Final remarks

The objective of this study is to gain understanding of the development of consciousness and its relationship with education based on differing theoretical models: Piaget, Vygotsky and Rudolf Steiner. It can be seen that the theoretical models are in agreement in understanding consciousness as a complex and multifaceted process, bringing inspiring ideas to educational practices. On the other hand, they present different perspectives, highlighting either the intellectual cognitive aspect or the integral aspect. Piaget understands consciousness as reflective abstraction based on the movement between causality and implication within a logic of meanings; Vygotsky understands consciousness as a dynamic semantic system related to emotional experience and the social situation of development; while Steiner understands consciousness as the ability to access reality through observation, rationality and intuition. The three theorists note the need for reflection and self-reflection for the development of consciousness and link it to conceptual thinking. The research of both Piaget and Vygotsky has a materialist basis and highlights intellectual, social, affective and moral integration in the development of consciousness, which is expressed in practice. Rudolf Steiner presents research with a materialistic and spiritual basis through access to the world of ideas or the spiritual world, accessible to anyone through regular exercises of concentration of attention and meditation. This opens up a new field of research, which is broad and challenging, aimed at the development of the person and humanity through the development of their consciousness.

A more profound notion of development is illustrated through the discussion in this paper. As Valsiner pointed out, developmental changes involve novelty and irreversibility time (Valsiner, 2000). The three scholars stress a notion of development that encompasses these two main qualities of development. In the same vein, the romantic roots of Steiner and Vygotskian work are connected with Goethe's work about the metamorphosis of plants. In this work, an interesting theoretical proposal about the notion of change and conservation of the whole is carefully described (Cornejo, 2015). Romanticism laid the basis for understanding core phenomena like human development, guided in a holistic sense. This understanding is followed by Steiner and by Vygotsky.

The three scholars described in the paper put emphasis, in different ways, on the active role of the person inside their social context, each of them with slightly different notions and points of emphasis, more individual-object-oriented, social-context-oriented, or aesthetics-oriented. The activity performed by every person constitutes a central aspect of their development. The concept of self-education in Steiner goes in this direction and some authors propose that consciousness in Vygotsky always possesses a personal and subjective dimension (Valsiner and Van der Veer, 2014). In Piaget, the child also plays an active role in his or her environment.

In view of the challenges of the current world, there is a need to expand the vision of science beyond materialistic science and to consider different theoretical-practical models in order to gain a better approach to the phenomenon of consciousness, as well as the possibility of developing it through introspection or through the first person, contributing to a more human and sensitive education. In this sense, research focused on different methods of developing consciousness in teacher training becomes fundamental and is a challenge for future research.

Author contributions

TS: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. UW: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing, Funding acquisition. MDV: Funding acquisition, Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Parental involvement and student creativity: a three-level meta-analysis

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Introduction: The Ecological Systems Model of Creativity Development (ESMCD) proposes that parental involvement positively impacts student creativity. However, prior empirical studies present mixed results, including positive, negative, and no correlations between these variables.

Methods: To synthesize these inconsistent primary studies, the current study conducted a systematic meta-analysis synthesizing 30 primary studies involving 37 independent samples with 70 effect sizes and a total $N = 20{,}906$ participants.

Results: The results demonstrated: (1) an overall significant small, positive correlation ($r = 0.101$) between parental involvement and student creativity; (2) significant small, positive correlations between specific involvement types (autonomy support $r = 0.144$; behavioral control $r = 0.133$; content support $r = 0.131$) and creativity, alongside a significant small, negative correlation between psychological control and creativity ($r = -0.117$); (3) no statistically significant moderating effects of student grade level, parental gender, region, or publication type.

Discussion: This systematic meta-analytic review consolidates empirical evidence indicating that parental involvement positively predicts students' creativity, while highlighting the detrimental impact of psychological control on creative outcomes. Further research elucidating the mechanisms underlying these relations is critical for informing parenting approaches and education policies seeking to foster creativity development among students.

KEYWORDS

parental involvement, creativity, students, meta-analysis, three-level modeling

1 Introduction

Creativity, defined as the capacity to generate products that are novel, socially valuable, and appropriate (Zhang and Sternberg, 2001; Runco and Jaeger, 2012; Sternberg et al., 2024), constitutes a pivotal engine of societal advancement.

Parental involvement is defined as the active participation of parents in all aspects of their children's social, emotional, and academic development (Castro et al., 2015), which has a multifaceted and multidimensional inner structure (Epstein, 1990, 1995; Jeynes, 2007; Pomerantz et al., 2007).

Studies probing the link between parental involvement and learning outcomes can be traced back to 50 years ago (e.g., Coleman, 1966, 1968; Epstein, 1990, 1995; Fiskerstrand, 2022; Kim, 2022). However, the existent empirical findings leave some issues still unsolved. Firstly, the results about the relationship between parental involvement and creativity were inconsistent which could be divided into three categories, some suggested a positive correlation, others reported a negative correlation, and still

others suggested no correlation. Secondly, some empirical findings were inconsistent with the prediction deduced from existent theory. The Ecological Systems Model of Creativity Development (ESMCD) argued that parental involvement was conducive to fostering creativity. The negative, or insignificant correlations were not consistent with the theoretical prediction. ESMCD postulated that parents could provide guidance when children were in the process of problem-solving, parents could also provide encourage independence and autonomy, supporting their children's decision-making with the parent-child relationships which played a key role in promoting creative development (Yeh, 2004).

The present paper provides a synthesis about the existent inconsistent results using a three level meta analysis, clarify the link between empirical evidence and theoretical research, and identify some issues need to be studied in the future.

1.1 The importance of creativity

The cultivation of creativity among students holds profound significance for both individual development and national prosperity (Pang and Plucker, 2012).

First, creativity is vital to individual development. The OECD (2020) conducted a study to identify the key factors for personal success in the 21st century, and found that creativity is a key factor (Collard and Looney, 2014). A meta-analysis showed that creativity is associated with individual success outcome indicators such as problem solving procedures, prestige of honors or academic awards, working environments, class climate, openness to new experiences, affective sensibility and leadership (Ma, 2009).

Second, creativity is closely related to national prosperity. Creativity is the source of innovation which is a driving force of economic and social progress. As for delivering sustainable economic growth and social development, creativity have a greater effect than the traditional inputs such as labour or capital (Bobirca and Draghici, 2011). Consequently, the ability of any state to attract, retain and develop creative human capital and to exploit creative capabilities tends to become, to a significant extent, the key to global competitiveness.

1.2 Research on parental involvement

1.2.1 The construct of parental involvement

There are two categories defining parental involvement: the static structure view and the dynamic process view.

The static structure view suggested that parental involvement was divided into several specific types. Epstein (1995) presented there are six types of parental involvement including parenting, communication, volunteering, learning at home, decision making, and collaborating with the community.

Similarly, Xu et al. (2024) reviewed about 30 primary studies, and found that parental involvement in the homework field can be divided into five types, including autonomy support, content support, parental control, frequency, and mixed. Autonomy support mean parents attend to students' ideas and support their homework initiatives. Content support mean parents provide direct support on the content of assignments. Parental control mean when parents function to monitor, control, and interfere with homework assignments. Parental involvement was coded as "frequency" when it focused on the frequency or amount of its involvement. A study was coded as "mixed" when it included more than one dimension of involvement.

The dynamic process view holds that parental involvement as a whole is a dynamic process (Fiskerstrand, 2022). Fiskerstrand (2022) classified parental involvement into 12 categories, including competence, belief, motivation, emotion, presence, framing, parenting, activity, talking, helping, choosing, and outing. From the perspective of being, doing, and thinking, these 12 categories can be grouped into four classes. They are the parental thinking (including competence, belief, motivation, emotion), the parental being (including presence, framing, parenting), and the parental doing (including activity, talking, helping, choosing, outing) (Fiskerstrand, 2022).

Considering the primary studies included, the present project adopted the Xu et al. (2024) framework to classify parental involvement. Then the parental involvement were divided into four subtypes: autonomy support (AS), parental control (PC), behavior control (BC) and content support (CS).

1.2.2 Relevant studies on the outcomes of parental involvement

Previous studies mainly focused on parental involvement and academic achievement, schooling and children's adjustment (including truancy control, STEM learning, reading, computational thinking), student engagement (including home-based digital learning), and resilience.

Some studies have explored the relationship between parental involvement and academic achievement, and found that parental involvement can promote academic achievement. Wilder (2014) synthesized the results of nine meta-analyses and the results indicated that the relationship between parental involvement and academic achievement was positive, regardless of a definition of parental involvement or measure of achievement. Similarly, Kim (2022) has conducted a second-order meta-analysis of parental involvement and achievement research over the past 50 years (including 1,177 primary studies in 23 meta-analyses), the results show that there is a positive association between parental involvement and achievement. For the impact of specific types of parental involvement, Kim (2022) and Wilder (2014) had consistent results, pointing to the strongest effect for parent expectations and aspirations and mixed results for homework help. The meta-analysis results of Jiang et al. (2023) shows an overall positive link between supportive parent homework involvement and students' mathematics achievement and a negative link between intrusive parent homework involvement and students' mathematics achievement. Xu et al. (2024) used three-level meta-analysis to explore the relationship between parental homework involvement and students' achievement. The results revealed an overall weak negative relationship between parental homework involvement and students' achievement. Within specific categories of parental involvement, students' achievement was positively related to autonomy support, but largely unrelated to content support, parental control, frequency, and mixed.

Some studies have studied the relationship between parental involvement and schooling and children's adjustment (including truancy control, STEM learning, reading, computational thinking) and revealed positive association between parents' involvement in children's schooling and children's adjustment. The meta-analysis by

Barger et al. (2019) revealed small positive associations ($r = 0.13$ to 0.23) between parents' naturally-occurring involvement in children's schooling and children's academic adjustment (i.e., achievement, engagement, and motivation) that were maintained over time. Parents' involvement was also positively related to children's social ($r = 0.12$) and emotional adjustment ($r = 0.17$) and negatively related to their delinquency ($r = -0.15$), concurrently. Kanungo et al. (2024) conducted a scoping review analysis (including 17 articles) of the forms of parental involvement for truancy control, the findings indicated that volunteering and communication are adequate indicators of truancy control and both indicators can significantly impact truancy prevention programmes. The review of Thomas et al. (2020) about parent involvement and its influence on children's STEM learning found that parent involvement positively affects children's quantitative skills and problem-solving skills in the terms of the specific skills in STEM content areas.

In addition, some studies have found that parental involvement also promotes students' reading (Çaliskan and Ulas, 2022) and computational thinking (Cai and Wong, 2023). Çaliskan and Ulas (2022) employed a pretest-posttest quasi-experimental design with a paired control group, data were collected from a total of 100 fourth graders studying in two different primary schools. The findings showed that there were significant differences between the experimental group and the control group, meaning that the parent-involved reading activities developed by the researchers had a positive effect on the students' reading comprehension, reading motivation, and attitudes towards reading. Cai and Wong (2023) conducted a systematic review about parental involvement in computational thinking education found that three ways in which parents were involved (including affective, behavioral, and cognitive participation) all play an active role in students' computational thinking education.

Some studies have tapped the relationship between parental involvement and student engagement and revealed there was a positive correlation between parental involvement and student engagement (home-based digital learning belongs to its subcategory). Erol and Turhan (2018) investigated 1,488 students and used the Parental Involvement Scale and Engagement to School Scale to measure parental involvement and student engagement. The results showed a significant positive correlation between parental involvement and student engagement. Increasing and encouraging parental participation in the educational process can enhance students' engagement with the school. A review of Yang et al. (2023) revealed that parental involvement was the most crucial aspects of social support for students' school engagement. The results also found that student engagement was reflected via ABC dimensions (i.e., affective, behavioural, and cognitive). Qualter (2024) conducted a narrative literature review about shaping the role of parental involvement in home-based digital learning found that parental involvement plays the most central role in home-based digital learning. The enhancement of parents' self-efficacy and motivation in home-based digital learning is conducive to the development and education of children's digital technologies.

Some studies have discussed the relationship between parental involvement and resilience and revealed parental involvement has a positive impact on student engagement. Kovács et al. (2022) conducted a systematic literature review about resilience of parental involvement found that whether the goal is to build upon resilience as a personality trait or target its development as a consequence, strong collaboration between the parents, teachers and professionals concerned in the process can significantly contribute to the child's psychological, emotional and academic development. Olaseni (2020) conducted an empirical study with a sample of 347 adolescents in Nigeria and found that parental involvement significantly predicted academic resilience in such a way that high parental involvement is linked with high academic resilience. Cui et al. (2024) studied 105,641 Chinese students using latent profile analyses (LPAs) and multivariate analysis of covariance (MANCOVA) and found that parents' more frequent involvement in students' everyday lives, coupled with less frequent involvement in their study matters, may effectively foster academic success and enhance the development of resilient traits.

1.3 The relationship between parental involvement and creativity

Three perspectives have been proposed by previous empirical research on the relationship between parental involvement and student creativity: the facilitating view, the hindering view, and the non-correlation view.

The facilitating view proposes parental involvement promotes creative development, reflected by significant positive correlations. Niu (2007) conducted a study on Chinese high school students, and found autonomy-supportive parenting positively predicted creativity. Likewise, Pugsley and Acar (2020) surveyed 1,324 parents, in which the assessment of children's creativity was reported by parents, identified creative home environments and values were associated with higher children's creativity.

Conversely, the hindering view argues parental involvement impedes creativity, with significant negative correlations. Jankowska and Karwowski (2019) surveyed 75 elementary school students and found a negative correlation between parental performance-orientation and creative thinking in elementary students. Similarly, Krumm et al. (2013) found disciplinary and overinvolved parenting related to lower creativity.

Finally, the non-correlation view shows no direct link between parental involvement and student creativity. Oh et al. (2014) surveyed 137 primary school students and found maternal involvement unrelated to primary students' creativity score based on the science creativity test (SCT) scale. Likewise, Guo et al. (2021) surveyed 559 students and evidenced personality traits (openness and darkness) fully mediated the relationship between parental involvement and creativity, and the correlation between parental involvement and creativity was close to zero.

1.4 The research questions and hypotheses of the present study

Despite emerging attention to the parental involvement-creativity link since the 1990s, empirical findings and theoretical predictions remain inconsistent. To integrate these contradictory results, the present study employs a three-level meta-analytic model (Assink and Wibbelink, 2016; Cheung, 2014) synthesizing the literature. The research objective is to examine the association between parental involvement and student creativity alongside moderating factors impacting this association. Specifically, this meta-analysis addresses the two-fold research questions coming as follows:

(1) What is the relationship between parental involvement and student creativity (positive, negative or no correlations)?
(2) Do the following variables moderate this relationship: involvement type (autonomy support, psychological control, behavioral control, content support), grade level, parental gender, region, and publication status?

1.4.1 The relationship between parental involvement and creative relationships

Previous findings have yielded three perspectives: the facilitating view, hindering view, and non-correlation view. Bronfenbrenner's early theory (Bronfenbrenner, 1977; Bronfenbrenner and Morris, 2007; Woolfolk, 2013) broadly proposed environmental influences on development without specifying directionality. Yeh (1999, 2004) delineated four positive parental involvement types promoting creativity through "appropriate family climate," "creative activity experience," "creative skill guidance" and "appropriate parenting styles." However, additional involvement styles exist, including psychological control and detachment. When examined holistically using omnibus measurements, the cumulative role of parental involvement should demonstrate a blended influence across facilitating, hindering and null effects. Therefore, we propose the following opening hypothesis:

> *Hypothesis 1*. Parental involvement and creativity will demonstrate a significant but small correlation of less than 0.200.

1.4.2 Potential moderators

The relationship between parental involvement and student creativity in the following studies may have been moderated by several variables: parental involvement type, grade, parental gender, region, and publication type.

1.4.3 Parental involvement type

Parental involvement can be described using different models. From the measure perspective, concerning, parental involvement can be divided into four subtypes: autonomy support (AS), parental control (PC), behavior control (BC) and content support (CS) (Xu et al., 2024).

AS refers to respecting children's perspectives, encouraging independent problem-solving, providing choices (Grolnick and Ryan, 1989; Ryan et al., 2006). Tang et al. (2022) surveyed on 5,523 students and evidenced AS positively predicted elementary/middle schoolers' creativity ($r = 0.100$). Chen et al. (2021) investigated a sample of 258 7th graders and revealed a significant correlation between parental autonomy support and creative thinking ($r = 0.200$).

Alternatively, PC entails coercive, psychologically intrusive tactics inducing compliance via love withdrawal or guilt, it often divided into psychological control (PyC) and behavioral control (BC). PyC encompasses parental intrusion into the child's inner world, aiming to align the child's thoughts, behaviors, and feelings with parental demands through strategies such as withdrawal of love and guilt induction, whereas BC regulates behavior through monitoring and discipline to social norms (Barber, 1996; Barber and Harmon, 2002; Silk et al., 2003). Chen et al. (2021) found that BC dimensions positively ($r = 0.270$, 0.320 and 0.200), and PC dimensions negatively ($r = -0.080$, -0.070 and -0.060) correlated with the three dimension of creative thinking (fluency, flexibility, and originality). Ren et al. (2017) found that BC dimensions positively ($r = 0.110$, 0.110 and 0.100), and PC dimensions negatively ($r = -0.100$, -0.100 and -0.040) correlated with the three dimension of creative thinking.

Finally, CS represents direct academic involvement like guidance and home-school communication (Cho and Lin, 2011; Oh et al., 2014; Zheng et al., 2020) linked CS to heightened creativity ($r = 0.290$) on the creative problem solving in math/science scale among 733 elementary/middle schoolers (Cho and Lin, 2011).

These differential effects align with self-determination theory positing autonomy, relatedness, and competence as undergirding motivation and creativity (Ryan and Deci, 2019, 2020). In contrast, parental psychological control, such as "love recycling" and "guilt triggering," thwarts intrinsic motivation, narrowing exploratory behavior and hampering creativity. Accordingly, we propose the Hypothesis 2.

> *Hypothesis 2*. The moderating effect of parental involvement subtype will be significant.

1.4.4 Grade

The parental involvement-creativity link may vary by children's grade level. As grade level increases, opportunities for involvement in creative development may diminish for several reasons: increasing academic difficulty and specialization exceeding parental expertise, long times of school life and study limiting parent-child engagement, and children's advancing cognitive skills (Said-Metwaly et al., 2021).

Empirically, moderating effects of grade have been demonstrated. Cho and Lin (2011) surveyed 733 elementary and middle school pupils and found positive family processes more strongly correlated with creative problem-solving in elementary than middle or high schoolers. Liang et al. (2021) also showed grade level differences in the involvement-creativity relationship for both mini-c and little-c creativity among 526 students. Collectively, these results indicate parental involvement exerts greater impact at elementary relative to secondary levels as academic contexts shift. Therefore, we propose Hypothesis 3.

> *Hypothesis 3*. The moderating effect of grade level on the parental involvement-creativity relationship will be significant.

1.4.5 Parental gender

Theoretically, both paternal and maternal involvement could encompass autonomy support, psychological control, behavior control and content support. However, differential links with creativity have been proposed. For instance, among 65 5th graders, Wallinga and Crase (1979) evidenced significant positive father-creativity but not mother-creativity correlations. Yet with 550 Chinese high schoolers, Liu et al. (2013) found maternal involvement more strongly favored creative thinking development. Due to the inconsistency among various research, we propose Hypothesis 4:

> *Hypothesis 4*. The moderating effect of parental gender on the parental involvement-creativity relationship will not reach statistical significance.

1.4.6 Region

The influence of region on the interplay between parental involvement and student creativity warrants examination. Regions are often distinguished as Eastern (e.g., Chinese, Korean, and Japan), associated with psychological control and content support, and Western (e.g., European countries such as England and France and their former colonies) emphasizing autonomy support and behavioral monitoring (Niu and Sternberg, 2003; Ofole and Ezeokoli, 2014; Oh et al., 2014; Man et al., 2015; Fanchini et al., 2018; Zhang, 2023).

Eastern culture may have a dampening influence on creativity. Niu and Sternberg (2001), through the experimental study of students from two different cultures in China and the United States, showed that the artistic creativity of Chinese students was more likely to be reduced as a function of restrictive task constraints or of the absence of explicit instructions to be creative.

Western culture may have a stimulating influence on creativity. Niu and Sternberg (2001) showed that an independent self-oriented culture (western culture) is more encouraging of the development of artistic creativity than is an interdependent self-oriented culture (eastern culture). Shao et al. (2019) found that individuals from different cultures, particularly those from individualist and collectivist cultures, show differences in preferred creative processes and creative processing modes. To be specific, usefulness seems more important than novelty in the East, whereas novelty seems equally important as usefulness, if not more so, in the West when they are engaged in creative endeavors.

These varying socialization patterns cultivate differing levels of creativity across cultures (Niu and Sternberg, 2001). Overarching cultural orientation effects also emerge empirically. For example, in a cross-cultural study across eight countries, Zhang et al. (2021) found the involvement-creativity link varied significantly, with nonsignificant correlations in most Eastern countries (China, Kosovo, Russia, Saudi Arabia) in contrast to a significant negative correlation in the Western country of Chile. Therefore, we hypothesize:

> *Hypothesis 5*. The moderating effect of region on the parental involvement-creativity relationship will be significant.

1.4.7 Publication type

According to previous research (Card, 2012), publication type may also be a potential moderating variable. During journal review processes, core publications preferentially select significant findings over nonsignificant results published in peripheral outlets like dissertations or conference papers (Borenstein et al., 2009; Card, 2012). Our literature review observed such patterns; for example, Yin (2019) found a nonsignificant parental involvement-creativity association in a master thesis. By contrast, among studies published in core educational psychology journals, like Man et al. (2015) in a journal found that parental behavioral control and psychological control and social creativity were significantly correlated with correlation coefficients of 0.090 and −0.210. This expected effect of publication bias leads to our final hypothesis:

> *Hypothesis 6*. The moderating influence of publication type on the parental involvement-creativity relationship will be statistically significant.

All research hypotheses are organized as a diagram as shown in Figure 1.

2 Methods

2.1 Literature search

2.1.1 Scope and modalities of the search

A systematic search was conducted across major Chinese (Chinese National Knowledge Infrastructure (CNKI), Wanfang Data Knowledge Service Platform, VIP Chinese Journal Service Platform) and English (SAGE, Wiley, Springer, Taylor and Francis, ScienceDirect, ProQuest, JSTOR, Web of Science) databases combining parental related terms ("parental," "paternal," "maternal") with involvement terms ("involvement," "assistance") and creativity terms ("creativity," "creative thinking") in title, abstract and keyword fields. To minimize publication bias, additional searches utilized public search engines and reference lists, including relevant reviews (e.g., van der Zanden et al., 2020). The final search date was November 6, 2023 resulting in an initial pool of 3,777 records. Figure 2 diagrams the systematic search and selection process.

2.1.2 Inclusion and exclusion criteria

Studies that met the following criteria were included in the meta-analysis: (1) reported correlation coefficients between the total score or dimensions of parental involvement and student creativity and its sub-dimensions, or other statistics that could be transformed into correlation coefficients, such as *F*-values or *beta* values. Multiple regressions were excluded due to difficulty in recovery. (2) The study population consisted of students from kindergarten through undergraduate level. Primary means K-6, middle school and high school mean 7–12. (3) Sample sizes for independent samples are reported. (4) Measurement instruments for and parental involvement and creativity were reported.

Studies that met the following criteria were excluded in the meta-analysis:

(1) Creative self-efficacy and creativity are not the same concept, and related literature is not included in this meta-analysis.
(2) Since parenting style and parental involvement are not the same concept, related literature is also excluded.

2.1.3 Search results

More than 40 studies were initially retrieved, and a total of 30 studies met the above criteria (see Table 1), containing 37 independent samples, with a total participation of 20,906, including 7 Chinese-language studies, 23 English-language studies, 24 journal articles, and 6 dissertations. The publication years span from 1991 to 2022.

2.1.4 Coding of original study characteristics

Each study was coded according to the characteristics (see Table 1). It is important to note that effect sizes were calculated in terms of independent samples and were coded separately if more than one independent sample was reported in a single study at the same time.

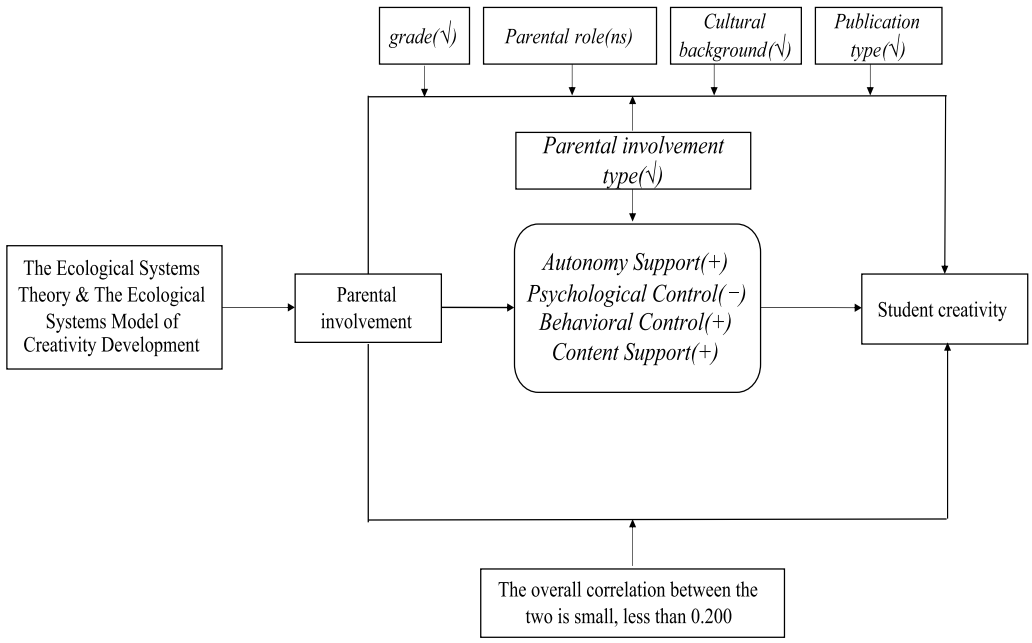

FIGURE 1
Research hypothesis of the present study. "+" indicates a positive effect, "−" indicates a negative effect, "√" indicates a significant moderating effect, "ns" indicates a non-significant moderating effect.

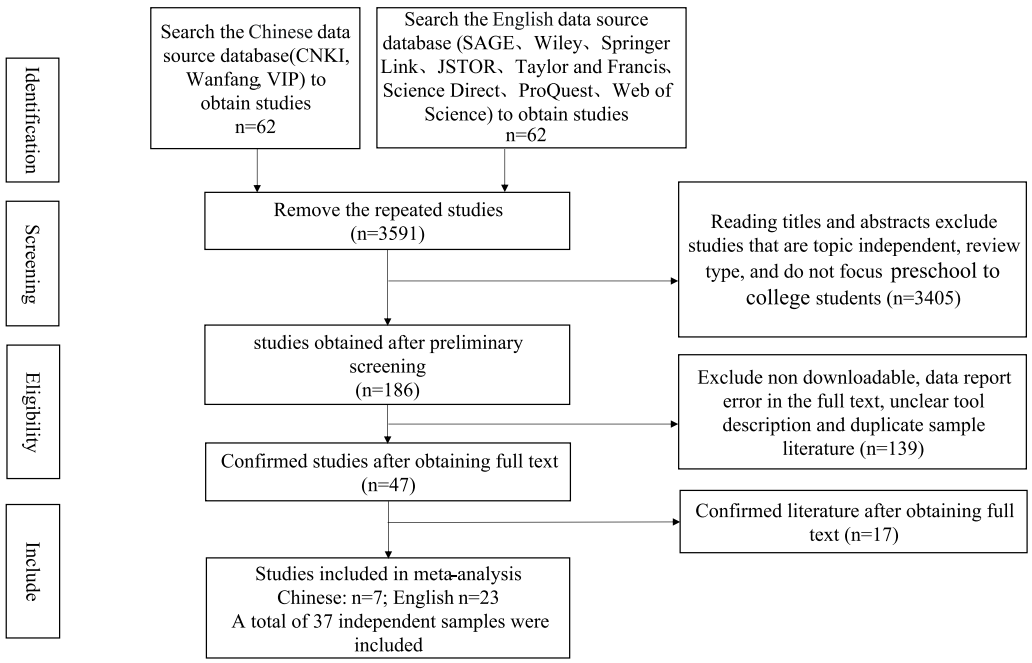

FIGURE 2
The search process and search results of the present study.

2.2 Extraction of potential moderator variables

The basic characteristics of potential moderating variables extracted from primary studies is listed in Table 2.

2.3 Coding process and coding confidence

The primary studies were coded by the first author and subsequently screened by the third author, demonstrating a Kappa coefficient of 0.965, with a high consistency (Card, 2012). Any

disagreement in coding were addressed through discussion and subsequently revised.

2.4 Statistical calculations

2.4.1 Calculation of effect sizes

The effect size used for this research is the correlation coefficient r (zero-order r) (Borenstein et al., 2009). In the calculation process, each r value was first converted to the corresponding Fisher's Z score with the formula $Z = 0.5 \times \text{In}\ (\frac{1+r}{1\ \ r})$. The Fisher's Z values were then converted to calculate the zero-order correlation coefficient r with $r = \frac{e^{2z}+1}{e^{2z}-1}$ (Borenstein et al., 2009). Where the variance of Z is $V_Z = \frac{1}{n-3}$, n denotes the sample size, and the standard error of Z is SEz = $\sqrt{V_Z}$. Krumm et al. (2015) reported the F-value. Fanchini et al. (2018) reported the β-value. $r = \sqrt{\frac{F}{F+dfe}}$ (Card, 2012), $r = \beta$ (simple linear regression) (Kim, 2011) which was transformed into an r-value to be included in the calculation.

2.4.2 Model selection

The current study employed a three-level random effects meta-analytic model (Assink and Wibbelink, 2016; Harrer et al., 2021) that assumes error at the sample (level 1, participations), outcome (level 2, effect sizes), and study levels (level 3). This approach estimates intra-cluster shared effect sizes through a random effects model, while permitting the same cluster share a same effect.

2.4.3 Homogeneity test

In this study, I^2 and Tau^2 were used to represent the between-study variance. It is suggested that 25, 50, and 75% of I^2could be used as thresholds for low, moderate, and high heterogeneity (Borenstein et al., 2009). When a three-level model is used, the Tau^2 value is equal to the sum of two components, Tau^2 (level 2) and Tau^2 (level 3) (Assink and Wibbelink, 2016).

2.4.4 Publication bias

Publication bias refers to the phenomenon that studies with significant results are more likely to be published (Borenstein et al., 2009). Rosenthal's Fail safe N (Nfs), Funnel plot, trim and fill method, Egger's regression are commonly used to detect publication bias (Borenstein et al., 2009).

2.4.5 Assessment of quality

The Basic Quality Assessment of Primary Study, BQAPS (Xu et al., 2024 press) was used as a quality assessment tool to assess the quality of studies included in the meta-analysis. Based on the scoring criteria, score of 0–6 categorized as low-quality, 7–12 categorized as low-medium level, 13–18 were categorized as medium-high level, and 19–24 were categorized as high quality.

2.4.6 Statistical calculation tools

All statistical calculations were conducted in R (R Core Team, 2022). The metafor package was used for the calculation of the three-level model (Viechtbauer, 2010; Harrer et al., 2021). The meta package was used for the creation of the funnel plots (Assink and Wibbelink, 2016; Balduzzi et al., 2019; Harrer et al., 2021).

3 Results

3.1 Characteristics of the original literature included

A total of 30 primary studies with 37 independent samples were included (see Tables 1, 2) in the analysis. The main study characteristics extracted and their frequency distributions are shown in Table 2.

3.2 Homogeneity test

The Q-test indicated significant heterogeneity among the effect sizes ($Q = 639.949$, $p < 0.001$). The total $I^2 = 90.843\%$, which is greater than the critical value of 75%, indicates heterogeneity in the preliminary study, as shown in Table 3. Therefore, further analysis of moderating variables is required to find the possible reasons for the differences in the results of the primary study.

3.3 Publication bias test

The trim and fill method showed a total effect of $r = 0.089$ [95% CI (0.053; 0.126)] across all primary studies after the addition of the 3-effects data, which did not differ significantly from the overall correlation coefficient of the previous pooled effect size of $r = 0.101$ [95% CI (0.061; 0.140)] before and after the trim and fill.

The funnel plot analysis presented that the distribution of effect values is basically symmetric (see Figure 3). The Egger regression with Intercept = 0.085, $SE = 0.035$, $t = 0.350$, $p = 0.726$ indicates that the funnel plot is symmetric. The insecurity coefficient, $Nfs = 7{,}386$, is greater than $5K1 + 10 = 160$. In summary, the effect of publication bias in this paper is negligible.

3.4 Moderating effects of literature quality

A meta-regression analysis was conducted with quality score as the independent variable and the effect size value as the dependent variable. The obtained results indicated $F_{(1,68)} = 1.007$; Intercept = −0.067; $SE = 0.169$; $p = 0.693$; $\beta = 0.010$; $SE = 0.010$; $t = 1.004$; $p = 0.319$. These findings suggest that there is no significant correlation between literature quality scores and effect size values.

3.5 Main effects

The correlation between parental involvement and student creativity is $r = 0.101$ [95% CI (0.061; 0.140)], $t = 5.070$, $p < 0.001$ (see Table 3). Following Ellis's (2010) criteria, the observed relationship between parental involvement and student creativity fell within the category of a low degree of positive correlation.

TABLE 1 Basic information of the primary studies included in this meta-analysis.

Author, year[a]	Effect size number	Sample size	Parental involvement type[b]	Female ratio	Grade	Country	Measurement tools of creativity[d]	Parental role	Publication type[e]	Quality assessment
Chagas, 2009	1	28	CS	0.5	Primary and middle	Portugal	TCT-DP	Parents	J	15
Chen, 2021	3	258	AS/PyC/BC	0.48	Middle	China	rCAB	Parents	J	18
Cho and Lin, 2011	1	733	CS	NA[c]	Primary and middle	Korea	CPSMS	Parents	J	20
Cho and Lin, 2011	1	236	CS	NA	Primary	Korea	CPSMS	Parents	J	20
Cho and Lin, 2011	1	328	CS	NA	Middle	Korea	CPSMS	Parents	J	20
Cho and Lin, 2011	1	169	CS	NA	Middle	Korea	CPSMS	Parents	J	20
Cho and Lin, 2011	1	24	CS	NA	Primary	Korea	CPSMS	Parents	J	20
Cho and Lin, 2011	1	22	CS	NA	Middle	Korea	CPSMS	Parents	J	20
Diarra, 2017	2	262	AS/BC	0.62	Primary	Mali	SCMQ	Parents	J	13
Fanchini, 2018	1	855	CS	0.48	Primary	France	Self-report	Parents	J	15
Gralewski, 2020	2	552	AS/PyC	0.59	Middle	Poland	TCT-DP	Mother	J	17
Guo, 2021	2	559	AS/BC	0.68	College	China	AUT, ICAA	Parents	J	16
Jankowska, 2019	2	75	CS	0.55	Primary	Poland	TCT-DP	Parents	J	17
Kim, 2020	2	333	CS	0.51	Primary and middle	Korea	TTCT	Parents	J	15
Kong, 2019	1	417	AS	0.51	Preschool	China	CPTC	Parents	D	20
Krumm, 2015	1	359	CS	0.54	Primary and middle	Argentina	TTCT	Parents	J	14
Li, 2021	2	776	AS/PyC	0.49	Middle	China	MDCBQ	Parents	D	20
Liang et al., 2021	3	80	AS/PyC/CS	0.48	Middle	China	TTCT, CAT, CDQ-R	Parents	J	15
Liang et al., 2021	5	526	AS/PyC/CS	NA	Primary and middle	China	Absi, CDQ—R, CSE	Father/mother/parents	J	17
Liu, 2013	4	550	AS/CS	0.55	Middle	China	TTCT	Father/mother	J	16
Man, 2015	2	540	PyC/BC	0.5	Primary	China	SCT[1]	Father	J	14
Michel, 1991	1	30	CS	0.5	Primary	Britain	TTCT	Mother	J	14
Ofole, 2014	1	677	CS	0.42	Middle	Nigeria	SPB	Parents	J	17
Oh et al., 2014	2	39	CS	0.33	Primary	Korea	SCT[2]	Father/mother	J	15
Oh et al., 2014	2	98	CS	0.56	Primary	Korea	SCT[2]	Father/mother	J	15
Pérez-fuentes,2019	4	742	AS/PyC/BC/CS	0.53	Primary and middle	Spain	CBQD	Parents	J	15
Pugsley,2020	3	962	AS/CS	NA	Na	36 countries[f]	TICC	Parents	J	16
Ren, 2017	2	503	PyC/BC	0.49	Middle	China	rCAB	Parents	J	14
Szechter, 2004	1	15	CS	0.67	Preschool	NA	SGM	Parents	J	15
Tang, 2022	1	5,523	AS	0.48	Primary and middle	China	CIB	Parents	J	18

(Continued)

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TABLE 1 (Continued)

Author, year[a]	Effect size number	Sample size	Parental involvement type[b]	Female ratio	Grade	Country	Measurement tools of creativity[d]	Parental role	Publication type[e]	Quality assessment
Wang, 2011	4	651	AS/CS	0.55	Middle	China	TTCT	Father/mother	D	20
Wang, 2018	2	800	CS	0.51	Middle	China	rCAB	Father/mother	D	19
Wang, 2019	2	82	AS/CS	0.61	Preschool	China	TCAM	Mother	J	15
Wang, 2023	2	680	AS/PyC	0.44	Middle	China	TTCT-Verbal	Parents	J	17
Yin, 2019	2	1,440	CS	0.49	Primary and middle	China	rCAB	Father/mother	D	18
Zhang, 2022	1	584	AS	0.72	College	China	BICB	Parents	J	18
Zhao, 2012	1	398	AS	0.45	Primary	China	WCS	Parents	D	17

[a]To reduce space, most list only the first author; u1–u6 indicates a study with multiple independent samples.
[b]AS, parental autonomy support; PyC, parental psychological control; BC, parental behavioral control; CS, content support.
[c]NA indicates that the paper does not provide the appropriate information.
[d]TCT-DP, Test for Creative Thinking-Drawing Production; rCAB, Runco creativity assessment battery; CPSMS, Creative Problem Solving in Mathematics and Science Scale; SCMQ, Social Creativity Measure Questionnaire; AUT, Alternative Uses Test; ICAA, Inventory of Creative Activities and Achievements; TTCT, Torrance Tests of Creative Thinking; CPTC, Teacher evaluation questionnaire for creative personality tendency of children; MDCBQ, Middle school students daily creative behavior questionnaire; CAT, Consensus Assessment Technique; CDQ-R, Creativity Domain Questionnaire; Absi, Aurora battery of successful intelligence; CSE, Creative self-efficacy; SCT[1], Social creativity test; SPB, Success Potential Battery; SCT[2], Scientific Creativity Test; CBQD, Creative Behavior Questionnaire: Digital; SGM, Spatial-Graphic Measures; CIB, Runco Ideational Behavior Scale; TCAM, Thinking creatively in action and movement; BICB, Biographical Inventory of Creative Behaviors; WCS, Williams Creativity Scale.
[e]J, Journal; D, Dissertation.
[f]Including US, Australia, Canada, UK, New Zealand and other countries.

TABLE 2 Basic statistics of potential moderators included in the current study.

Moderator variable	Category	Independent sample		Effect size	
		*K*1	%	*K*2	%
Parental involvement Type	Autonomy support (AS)	17	29.82	21	30.00
	Psychological control (PyC)	9	15.79	9	12.86
	Behavioral control (BC)	6	10.53	6	8.57
	Content Support (CS)	25	43.86	34	48.57
Grade	Preschool	2	5.56	4	6.15
	Primary	10	27.78	15	23.08
	Middle	10	27.78	26	40.00
	Primary and middle	12	33.33	17	26.15
	College	2	5.56	3	4.62
Parental gender	Father involvement	8	17.78	9	12.86
	Mother involvement	10	22.22	14	20.00
	Parental involvement	27	60.00	47	67.14
Region	East	26	74.29	51	77.27
	West	9	25.71	15	22.73
Publication type	Journal	24	80.00	58	82.86
	Dissertation	6	20.00	12	17.14
Literature quality	Medium	27	72.97	55	78.57
	High	10	27.03	15	21.43

*K*1, number of independent samples; *K*2, number of effect sizes.

TABLE 3 Main effects of the relationship between parental involvement and student creativity.

*K*2	Fisher's *Z*/*SE*	Zero-order *r* (95% CI)	*t*	*Tau*²/percentage in total variance	
				Level 2	Level 3
70	0.101/0.020	0.101 [(0.061; 0.140)]	5.070	0.016/ 77.263	0.002/ 13.580

*K*2 = number of validity values. Variance in level 2 = within-study variation; Variance in level 3 = between-study variation; SE = standard error.

3.6 Moderating effects test

3.6.1 Parental involvement type

The parental involvement type had a significant moderating effect ($F_{(3,66)} = 17.591$, $p < 0.001$) (see Table 4). Autonomy support was positively associated with student creativity with an *r*-value of 0.144 [95% CI (0.092, 0.194)]. The content support group had an *r*-value of 0.131 [95% CI (0.084, 0.179)]. The *r*-value for the psychological control group was −0.117 [95% CI (−0.189, −0.045)]. The *r*-value for the behavioral control group was 0.133 [95% CI (0.045, 0.218)].

3.6.2 Grade

The moderating effect of grade was not significant ($F_{(4,60)} = 0.900$, $p = 0.552$). The *r*-values were 0.150 [95% CI (−0.029, 0.319)], 0.119 [95% CI (0.035, 0.203)], 0.081 [95% CI (0.023, 0.137)], 0.087 [95% CI

(0.018, 0.156)], and 0.106 [95% CI (−0.056, 0.263)] for pre-school, elementary, middle school, elementary and secondary, and university, respectively. There were no significant differences between the *r*-values for the subgroups of grade.

3.6.3 Parental gender

The moderating effect of parental gender was not significant ($F_{(2,67)} = 0.300$, $p = 0.742$). The *r*-values for maternal involvement and parental involvement were 0.096 [95% CI (0.011, 0.180)], and 0.108 [95% CI (0.061, 0.154)], respectively. The *r*-value for father involvement was 0.065 [95% CI (−0.037, 0.165)]. The *r*-values for the three subgroups of parental gender were not significantly different.

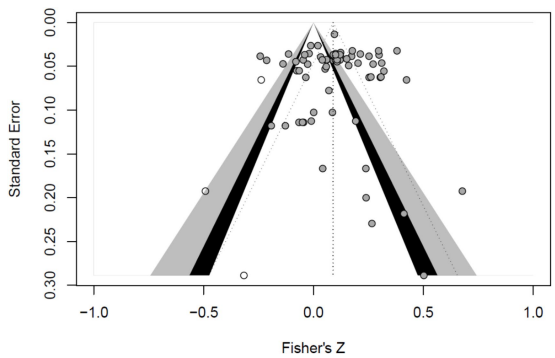

FIGURE 3
Funnel plot of the distribution of effect values in the present study.

3.6.4 Region

The moderating effect of region was not significant ($F_{(1,64)} = 0.098$, $p = 0.756$). The *r*-values were 0.085 [95% CI (0.044, 0.125)] and 0.098 [95% CI (0.021, 0.174)] for the Eastern and Western culture groups, respectively.

3.6.5 Publication type

The moderating effect of publication type was not significant ($F_{(1,68)} = 0.934$, $p = 0.337$). The *r*-values was 0.111 [95% CI (0.066, 0.154)] and 0.062 [95% CI (−0.029, 0.151)] for the journal group and master's thesis group, respectively.

4 Discussion

4.1 Main effect of parental involvement and students' creativity

The present meta analysis integrated the contradictory findings from 37 independent primary studies uncovering a statistically significant positive correlation ($r = 0.101$) between parental involvement and students' creativity scores. This result thereby affirms Hypothesis 1 which suggests that while previous empirical studies may exhibit variations, they still align with the predictions of EST (Bronfenbrenner and Morris, 2007; Woolfolk, 2013) and ESMCD (Yeh, 2004).

EST proposed that individual development is impacted by four interconnected systems—macrosystems, exosystems, mesosystems, and microsystems. Specifically, it suggests that within the microsystem,

TABLE 4 Test results of moderating effect.

Moderator variable	Subgroup[a]	*K*2	Intercept/Fisher's *Z* (95% CI)	*r*[b] (95% CI)	*F*	*Tau*² Level 2 variance	*Tau*² Level3 variance
Parental involvement type	AS	21	0.145 (0.092, 0.197)	0.144 (0.092, 0.194)	17.591***	0.005	0.007
	PyC	9	−0.118 (−0.191, −0.045)	−0.117 (−0.189, −0.045)			
	BC	6	0.134 (0.045, 0.222)	0.133 (0.045, 0.218)			
	CS	34	0.132 (0.084, 0.181)	0.131 (0.084, 0.179)			
Grade	Preschool	4	0.151 (−0.029, 0.331)	0.150 (−0.029, 0.319)	0.263	0.018	0.000
	Primary	15	0.120 (0.035, 0.206)	0.119 (0.035, 0.203)			
	Middle	26	0.081 (0.023, 0.138)	0.081 (0.023, 0.137)			
	Primary and middle	17	0.087 (0.018, 0.157)	0.087 (0.018, 0.156)			
	College	3	0.106 (−0.056, 0.269)	0.106 (−0.056, 0.263)			
Parental gender	Father	9	0.065 (−0.037, 0.167)	0.065 (−0.037, 0.165)	0.3	0.017	0.002
	Mother	14	0.096 (0.011, 0.182)	0.096 (0.011, 0.180)			
	Parental	47	0.108 (0.061, 0.155)	0.108 (0.061, 0.154)			
Region	East	51	0.085 (0.044, 0.126)	0.085 (0.044, 0.125)	0.098	0.017	0.000
	West	15	0.098 (0.021, 0.176)	0.098 (0.021, 0.174)			
Publication type	Journal	58	0.111 (0.066, 0.155)	0.111 (0.066, 0.154)	0.934	0.016	0.003
	Dissertation	12	0.062 (−0.029, 0.152)	0.062 (−0.029, 0.151)			

[a]The true Fisher's *Z* value for each subgroup was obtained separately by using each subgroup as the reference group in turn in the three-level model.
[b]*r* values were transformed by Fisher's *Z* value. *** $p < 0.001$.

the family microenvironment may wield influence over children's development (Bronfenbrenner, 1977; Bronfenbrenner and Morris, 2007; Woolfolk, 2013). The EST did not explicitly state that microsystem foster creativity, however, the creativity is an inner part of individual's development. Therefore, it is reasonable to deduce that microsystem may affect the individual's creativity.

This inference is supported by the ESMCD which states that the home environment established by parents within an intermediate system positively impacting creativity via three pathways: fostering independence, providing creative activity engagement, and directly encouraging participation in such activities (Yeh, 1999, 2004). Independence development can foster a child's ability and character of braveness to try out, which is conducive to the creative development of adventure. Providing creative activity engagement can enable children to receive more love and encouragement, which is conducive to creating a constructive family atmosphere. This family atmosphere includes flexibility in family structure, caring for family members, mutual trust and support, opportunities to express emotions, and a high emphasis on cultural and intellectual activities, which contribute to the development of creative potential. Directly enveloping participation helps cultivate children's problem solving ability and adaptive cognition skills, which play a key role in the creative development process. Through these influences, parents have a significant influence on shaping individual characteristics, and these creative personality traits later have a significant influence on creativity. Parents who adopt these influences also build a supportive home environment that contributes to daily creativity.

Furthermore, a recent empirical study presented some evidence supporting this claim. Jankowska and Gralewski (2022) found that a constructive parenting style (autonomy granting) was positively related to three of four factors of the climate for creativity in the parent–child relationships, i.e., encouragement to experience novelty and variety ($r = 0.330$), support of perseverance in creative efforts ($r = 0.390$), and encouragement to fantasize ($r = 0.280$).

4.2 Moderating effects of parental involvement type

This study discovered that parental involvement type significantly moderated the relationship between parental involvement and student creativity, supporting Hypothesis 2.

Parental autonomy support was significantly and positively correlated with student creativity ($r = 0.144$), a result that further explains the main effect and suggests that parental autonomy support is conducive to fostering student creativity. This is consistent with the facilitation perspective and is supported by similar studies (Kim, 2012; Moltafet et al., 2018).

The above result is also supported by SDT-related research. SDT suggests that parental autonomy support creates a home environment that develops children's intrinsic resources (e.g., generates intrinsic motivation), which in turn influences children's creative development (Deci and Ryan, 2012; Ryan and Deci, 2019, 2020).

Content support and students' creativity scores were significantly positively correlated ($r = 0.131$), and the r value of this result was higher than the main effect, indicating that content support is more conducive to the promotion of students' creativity. This is consistent with the facilitation view, and this result is also supported by a line of related studies (e.g., Cho and Lin, 2011; Oh et al., 2014). In other words, parents actively providing study guidance for their children may contribute to the fostering of students' creativity.

Behavioral control was significantly correlated with students' creativity scores ($r = 0.133$), indicating that behavioral control may promote the development of creativity in students. This is consistent with the facilitation view. This result is also consistent with the results of previous studies (Man et al., 2015; Ren et al., 2017; Chen et al., 2021). Through the strategy of behavioral control, parents may establish rules for their children's daily activities and behaviors, fostering effective problem-solving skills and playing a protective role in adolescent development.

Psychological control was significantly negatively correlated with students' creativity scores ($r = -0.117$), contrary to the results of the main effect, suggesting that psychological control may hinder the development of creativity in students. This is consistent with the results of the hindrance view (e.g., Liang et al., 2021) which says that psychological control leads to psychological harm that negatively affects creativity. This result suggests that not all parental involvement has a positive impact on creativity, and that psychological control, a parental involvement type, can weaken students' intrinsic motivation and thus negatively affect their creative development.

4.3 Moderating effects of other variables

The present meta-analysis showed that the moderating effect of grade on the relationship between parental involvement and student creativity was not significant and did not support Hypothesis 3. This is inconsistent with the findings of previous studies (Barbot et al., 2016; Liang et al., 2021). There may be two reasons for this. Firstly, in the process of parental involvement in school, parental involvement is more likely to be achievement-oriented involvement than creative development-oriented involvement. Research suggests that excessive concern for academic performance may affect student creativity (Yi et al., 2013). Second, the level of parental involvement in schooling programs varies little across stages (Jeynes, 2012).

The present study demonstrated that the moderating effect of parental gender on the relationship between parental involvement and student creativity was not significant, supporting Hypothesis 4. This is inconsistent with the results of previous studies (Wang, 2018; Oh et al., 2014). The possible reasons for this came as following. First, the samples included in the present study is too small to tap the real differences. Second, although more involvement of mothers has been reported, parental involvement also needs to pass through other variables, such as student autonomy motivation, in order to have an impact on children's creativity (Ryan and Deci, 2019, 2020).

The present study presented that the moderating effect of region on the relationship between parental involvement and student creativity was not significant and did not support Hypothesis 5. This is inconsistent with previous findings (Niu and Sternberg, 2001, 2002, 2003). A possible reason leading to this result may be that differences in the subtypes themselves in different regions lead to different results in different regions. For example, Yamamoto et al. (2022) observed the significant difference between Chinese and Japanese parental involvement suggesting that the East group should be divided into more subgroups. Dotterer (2022) noted that the variations in parental

participation existed at the racial/ethnic level and the longitudinal effects of parental involvement on academic achievement which showed the significant differences could be observed among Asian Americans and other races, such as African Americans, European Americans, and Hispanics. Further research is needed to identify the reasons.

This study did not detect the moderating effect of publication type and did not support Hypothesis 6. This is inconsistent with the previous findings on the detection of publication bias (Card, 2012; Borenstein et al., 2009). The result indicated that the differences in publication type and publication bias in this study were negligible, which further enhances the credibility of the results of this study.

4.4 Theoretical and practical implications

The present study has theoretical significance:

(1) This is the first meta-analysis concerning on the relationship between parental involvement and creativity in the last 30 years. It integrates conflicting original studies which presented more reliable results.
(2) The results of this study reduces the gap between the empirical results about parental involvement and creativity and the theoretical predictions of ESMCD (Yeh, 1999, 2004).
(3) The results of this study revealed new problems deserving further investigation. That is, parental involvement needs to be systematically classified to clarify its connotation.

There are some implications for practice.

Firstly, an environment of independent support is conducive to the enhancement of the individual's creativity. Therefore, in practice, parents provide autonomous support when raising their children by allowing them to make independent decisions on certain issues, or by listening to their children's opinions and expressing their own opinions, which can promote children's creativity. Moreover, parents avoid psychologically controlled participation in order to avoid harming their children's creativity.

Secondly, it is very important to cultivate and protect internal factors of individuals. As emphasized by the ecosystem model of creativity, family and school experiences can only have positive effects without individual factors. The results show that from the SDT perspective, parental autonomy support and behavioral control can have a positive impact on creativity. Therefore, in practice, attention should be paid to protect students' internal motivation, or promote the internalization of external motivation, to enhance their belief in creativity.

4.5 Research limitations and future prospects

By conducting a meta-analysis of the primary studies, the results of the current paper reaffirm the link between the empirical evidence and the predictions derived from EST (Bronfenbrenner and Morris, 2007) and ESM of creativity development (Yeh, 2004). At the same time, it reveals that not all parts of parental involvement are positively correlated with student creativity (i.e., negative effect of psychological control).

However, there are some limitations in this study. Firstly, the number of primary studies in some subgroup analyses is small. The small number of primary studies may make some subgroup analyses impossible (see Tables 2, 4).

Secondly, it failed to analyze the moderator effect of creativity measuring tools. These tools included (see Table 1) measured different aspects of creativity including creative thinking, creative problem solution, creative drawing production, domain creativity, scientific creativity, spatial-graphic creativity, creative activities, creative behaviors. Because of this diversity, the current meta-analysis did not provide analysis of the moderator effect of measures.

Thirdly, the interaction between parental involvement and other factors and their impact on student creativity deserve to be studied carefully. Given the modest correlation between these two variables, it suggests the potential influence of additional factors including individual factors (e.g., internal motivation, openness to experience, etc.), educational factors (e.g., parents' expectations of their children's creativity, balance between free exploration and necessary guidance, encouragement of students' creativity, provision of rich learning resources, etc.), school factors (communication between parents, schools, and teachers), and societal factors (national policies to enhance students' creativity, socio-cultural environment that emphasizes creativity). To explore the interaction between parental involvement and these factors, researchers can choose a specific factor, such as internal motivation, and build a mediation model of parental involvement, internal motivation and students' creativity. Furthermore, it is also possible to select several factors to build more complex chain mediation models, mediation models with moderation, and so on.

Several issues should be further studied in the future.

First, much more primary studies are urgently needed. Some new primary studies should put emphasis on the parental control types, western cultures and high quality literature. The reason for the conflicting findings of the original literature included in this meta-analysis may be that the sample of the original study is not representative enough. When the samples of the original studies are merged together through meta-analytic methods, The sample size has been expanded, and the larger the sample size, the greater the reliability of our conclusion generalization (Card, 2012).

Second, future study should pay more attention to measurement of creativity. These measurement tools that focus on the product, press, processes of creativity is recommended in the future studies. Some studies using different measurements of creativity are needed when further exploring the relationship between parental involvement and individual creativity.

Third, future research should explore why the correlation between parental involvement and creativity is not high. In addition to parental involvement as a factor influencing creativity, other factors (e.g., individual factors) also have an impact on students' creativity (van der Zanden et al., 2020). Bronfenbrenner (1977) and Yeh (2004) agreed that parental involvement is a meso-system in the overall ecological system and interacts dynamically with the micro-system and the macro-system. And a deduction can be made that their interaction could contribute to the development of individual's creativity. However, the specific mechanism of this interaction has not been tested carefully in previous research.

Fourth, parental involvement may have an impact on student creativity through other variables. For example, Cho and Lin (2011) found that internal motivation and intellectual beliefs partially mediated the effects of positive parental involvement on creative problem solving in math and science. This implies that parental involvement should collaborate with other factors, such as internal motivation, in shaping creativity during its developmental process. That means that the creative children may elicit a different kind of parental involvement from their parents.

5 Conclusion

Based on this meta-analysis of 37 independent primary studies, a positive yet weak correlation is observed between parental involvement and student creativity. Also, parental autonomy support, content support, and certain types of parental behavioral control positively impact student creativity, whereas parental psychological control exhibits a negative association with student creativity. Furthermore, the correlation between parental involvement and student creativity appears to be minimally influenced by factors such as grade, parental gender, and region.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

HF: Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review & editing. YF: Data curation, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. YZ: Data curation, Resources, Writing – original draft.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1407279/full#supplementary-material

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Factors associated with the permanence of doctoral students. A scoping review

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The permanence of students in doctoral programs is a multi-causal phenomenon, which makes it difficult to address and leads to an isolated investigation of its causes, being necessary a joint understanding. The aim is to investigate, through a scoping review of quantitative studies published between 2015 and 2021, the influence of individual, academic, socioeconomic and institutional factors on retention, attrition and dropout. The 32 included studies evidenced a predominance of research focused on individual factors versus few that combined all possibly relevant factors. The present study provides evidence for the emergence of several subfactors: female students, self-efficacy and motivation (individual); the relationship with the supervisor (academic); support for psychological needs (institutional); and migratory status (socioeconomic). This article highlights the need for research that understands this problem with a multifactor approach and an impact on permanence.

KEYWORDS

doctoral attrition, doctoral persistence, doctoral dropout, student affairs, doctoral education, higher education

Introduction

The study of the permanence of students in their doctoral programs is relevant, not only because doctoral training is considered the most demanding process of teaching and learning and the culminating point of educational achievement (Jairam and Kahl, 2012), but also because it affects the university institutions (Skopek et al., 2022), as well as the generation of knowledge and the development of innovation in society. In this respect, the dropout of doctoral students implies high costs at the personal, institutional and societal levels.

Permanence is considered a multifaceted condition and has been defined from different perspectives. For example, Swail (2004) defined permanence as the ability of a student to remain in a university, whereas Berger and Lyon (2005), cited in Demetriou and Schmitz-Sciborski (2011), conceptualized permanence as "the desire and action of a student to stay within the system of higher education from beginning year through degree completion" (p. 12).

These two attempts to offer a definition of permanence reveal the effort made by authors to differentiate between the concepts of permanence and retention of students. In this respect, Serra (2010) states that permanence is oriented to the variables associated with the student, while retention is directly related to institutional capacities or variables, to guarantee the permanence and graduation of its students. On the other hand, Gómez Mendoza and Alzate Piedrahíta (2018) concluded that most of the studies analyzed refer to the permanence of students as the

situation in which they finish and obtain their degree, and emphasized that the student who persists at the doctoral level is the one who does not interrupt his or her study plan. Furthermore, Tinto (1993) understands the permanence of the doctoral student as the sustained personal and intellectual interactions that occur within and between students and teachers and the various communities that make up the academic and social systems of the institution. Tinto's definition encompasses both academic integration, defined as the relationships between students and faculty within a given academic field, and social integration, which encompasses the relationships between students and faculty outside the academic context.

Moreover, different models have been proposed to account for the factors that influence the permanence/dropout of university students. A first model proposes how conditions outside the university, such as psychological variables like sense of usefulness, satisfaction and stress, influence the decision to abandon a university degree (Bean and Metzner, 1996), whereas the model proposed by Spady (1970) considers that dropout is directly related to the student's integration into the university environment.

A third conceptual model on the permanence/dropout of university students incorporates the theoretical developments of the student permanence model proposed by Tinto (1987) and the academic integration model of Bean and Metzner (1996). This third theoretical framework explains how student dropout is also a consequence of the student's economic conditions. Finally, a fourth model, more focused on permanence, proposes that, in order to persist, students need to be part of formal academic systems and commit to the academic demands of their institutions. In addition, they need to participate in informal academic systems (relationships with faculty and administrative staff) and integrate into formal social systems by participating in the institutional activities outside their program of study that occur in the relationship with their peers (Tinto, 1993). This model of academic integration and social integration (Tinto, 1975, 1993) has been considered the most tested, cited, and respected approach to integration and retention (Simpson, 2003), and it will the one employed as the guiding framework for the present scoping review.

Individual factors

In order to understand the determinants of dropout, Castaño et al. (2004) propose a classification based on four determinants. The first group presents the following descriptors: students' age, gender and marital status, their family context, possible calamities and health problems, their social integration, time incompatibility with extracurricular activities, and unmet expectations. Authors such as Spady (1970), Tinto (1975), or Giovagnoli (2002) are associated with this first group of dropout determinants.

Academic factors

The second group includes academic determinants, associated with the postulates of Spady (1970) and Tinto (1975), which include professional orientation, type of school, academic performance, program quality, study methods, student's results in the entrance exam, their dissatisfaction with the program or other academic factors, and the number of subjects they have to take in their programs.

Institutional factors

The third classification groups the institutional factors described mainly by Porto and Di Gresia (2000). These include academic normality, availability of scholarships and forms of financing, university resources, law enforcement, political environment, and the level of personal integration with teachers and students.

Socioeconomic factors

The fourth and last category refers to socioeconomic determinants, studied in the research carried out by Tinto (1975) or Porto and Di Gresia (2000), among others. These include factors such as the socioeconomic stratum from which the student comes, his or her employment situation, economic dependence, whether they have dependents, their parents' level of education, their parents' employment status and income, and the macroeconomic environment.

Results of previous reviews

Recent studies referring to individual aspects of doctoral students have found that these individuals show high levels of stress (Vekkaila et al., 2018), mental health problems such as depression (Byrom et al., 2022), or a deterioration in their physical health (Juniper et al., 2012). Despite the fact that these students have such negative perceptions about their physical or mental health, such difficulties have been commonly addressed and accepted as inherent to the training process (Byrom et al., 2022).

It has also been highlighted how individual and contextual attributes of the student influence their experience (Bard et al., 2000). Some studies highlight the importance of social interactions for the maintenance of motivation, e.g., modeling and teacher support, as determinants for the training of researchers (Pyhältö et al., 2020).

Other studies highlight the importance of formal and informal encounters that favor peer and faculty relationships (Hanson et al., 2020). Previous research has concluded that training in doctoral programs does not always provide a suitable environment to foster students' motivation or well-being (Levecque et al., 2017).

High doctoral attrition rates can pose a financial and reputational challenge for universities, as a consequence of the direct relationship between research output and the work of doctoral students (Horta et al., 2018), in addition to the ordinary costs that doctoral programs have for institutions (Bair and Haworth, 2004). In this regard, authors such as Jaksztat et al. (2021) state that a high attrition rate implies an inefficient use of university facilities, which can jeopardize the success of the research carried out in such institutions.

Research question

Following the recommendations of previous studies on the need to explore the relationships of factors associated with dropout as a whole rather than independently (Sverdlik et al., 2018), the present scoping review poses the following research question: What individual, socioeconomic, academic and institutional factors (phenomenon of interest) influence the permanence, attrition and

dropout of doctoral students according to peer-reviewed investigations published between 2015 and 2021 in journals registered in SCOPUS AND Web of Science?

Methods

The present scoping review was developed in accordance with the recommendations contained in the PRISMA Extension for Scoping Reviews (PRISMA – DcR): Checklist and Explanation (PRISMA; Tricco et al., 2018) and the description offered by Grant and Booth (2009; p. 101) as a type of review that provides "preliminary assessment of potential size and scope of available research literature."

Eligibility criteria

In the present review, the following publications were eligible: (1) refereed; (2) registered between January 2015 and September 2021; (3) in English or Spanish; (4) with keywords in title and/or abstract; and (5) indexed in both Scopus and Web of Science.

For the selection of the time window in which the articles were published, we took as reference the SCOPUS report downloaded in October 2021, which showed that the highest concentration of articles published on doctoral students was between January 2015 and September 2021, with a total of 4,440 different publications. Likewise, English and Spanish were chosen as the two publication languages of the articles to be included in the present investigation, as they were the two most used languages, accounting for more than 96% of the total (4,249 articles in English and 43 in Spanish).

To be included in the analyses, studies had to report on students in academic doctoral programs, employ the classification of the determinants associated with dropout described by Castaño et al. (2004), and have included individual variables such as age, support network, motivation, psychological needs, physical or mental health, gender, race, family, disability, or marital status. Furthermore, the present investigation included studies that had investigated academic variables such as academic trajectory, type of program, academic performance, learning strategies, admission processes, or academic load. With respect to the institutional studies were included when they had investigated variable such as academic normality, scholarships and forms of financing, university resources, integration with teachers and students, supervisors, or online programs. Studies were also selected for further analyses if they had focused on socioeconomic variables such as income, employment, or dependents (Intervention). Finally, studies that discussed doctoral student permanence, attrition, or dropout (Outcome) were also included in the sample.

Studies that reported on students in academic programs other than doctoral programs (high school, undergraduate, master's, postdoctoral), or that had as their main focus supervisors, program directors, or administrative personnel (P) were excluded. As for intervention (I), studies were excluded from further analyses when they were related to curricular and efficiency models in education, internship and research policies, marketing strategies, the quality of academic programs, curricula for training in writing for research, or the use of information and communication technologies (ICTs). Furthermore, with regard to the results of the studies, those that did not report on the permanence, attrition or desertion of doctoral students were excluded. Finally, all studies with qualitative and mixed designs were excluded because of the objectives and expected results in the present study aim at collecting the available quantitative evidence so studies with such designs might not contribute to the strength of the evidence in a relevant way. Table 1 shows both the inclusion and exclusion criteria used in the present investigation.

Sources of information

The search was conducted in the meta-search engines UNIKA (Library at the University of Navarra) and EUREKA (Library at the University of La Sabana), and in the databases of Scopus and Web of Science. The references of the relevant articles retrieved were also examined to find additional studies using the snowball methodology (Berndt, 2020).

Search strategy

In accordance with the use of the SPIDER methodology (Sánchez-Martín et al., 2023), from which the research question guiding this

TABLE 1 Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
1. Studies that include individual variables: age, support network, motivation, psychological needs, physical and mental health, gender, race, family, disability and marital status. 2. Studies that include academic variables: academic trajectory, type of program, academic performance, learning strategies, admissions processes, academic load. 3. Studies that include institutional variables: academic normality, scholarships and forms of financing, university resources, integration with professors, students and supervisors. Online programs. 4. Studies that include socioeconomic variables: income, employment, or dependents. Studies that assess retention, attrition or dropout of doctoral students. 5. Studies published in English and Spanish 6. Studies published between 2015 and 2021	1. Studies with student populations in academic programs other than doctoral programs (high school, undergraduate, master's, postdoctoral). 2. Studies that have as their main target supervisors, program directors, or administrative personnel. Studies related to curricular and educational efficiency models, internship and research policies, marketing strategies, the quality of academic programs, curricula for research writing training, or the use of information and communication technologies (ICTs). 3. Studies that did not report on the retention, attrition or dropout of doctoral students. 4. In terms of research methodology, all studies with qualitative and mixed designs were excluded.

TABLE 2 Elements employed with the SPIDER methodology.

SPIDER	Elements
I. Sample (S)	Students in doctoral programs
II. Phenomenon of interest (PI)	Studies that assess personal, academic, socioeconomic and institutional factors in relation to permanence, desertion and doctoral attrition, as described by Castaño et al. (2004).
III. Design (D)	Literature published in scientific journals, from quantitative studies
IV. Evaluation	Doctoral attrition, Doctoral persistence, Doctoral dropout, Desgaste doctoral, Persistencia doctoral, Deserción doctoral
V. Research type	Peer-reviewed quantitative studies published in journals indexed in SCOPUS and Web of Science databases January 2015 to December 2021.

TABLE 3 Keywords and Boolean terms employed in the search.

Keywords	Boolean	Keywords	Boolean	Keywords	Boolean
PhD students	AND	Self determination theory	AND	Doctoral attrition	OR
PhD students	AND	Perceived competence	AND	Doctoral persistence	OR
PhD students	AND	Academic motivation	AND	Doctoral dropout	
PhD students	AND	Making decisions			
PhD students	AND	Mental Health			
PhD students	AND	Student affairs			
Estudiantes de doctorado	AND	Teoría de la autodeterminación	AND	Desgaste doctoral	OR
Estudiantes de doctorado	AND	Competencia percibida	AND	Persistencia doctoral	OR
Estudiantes de doctorado	AND	Motivación académica	AND	Deserción doctoral	
Estudiantes de doctorado	YAND	Toma de decisiones			
Estudiantes de doctorado	YAND	Salud mental			
Estudiantes de doctorado	AND	Asuntos estudiantiles			

scoping review was formulated, the choice and organization of keywords for the search of the studies was made. Table 2 shows the elements employed within the SPIDER methodology, a strategy that allows the researcher to explore and synthetize information in such a broad topic as this.

Table 3 shows the keywords and Boolean terms used in the search.

Selection of studies

For the selection of the studies, the procedure defined by the PRISMA methodology was used. For the first identification stage, after 44 searches derived from keywords and Boolean terms, 899 studies were retrieved, distributed as follows: 286 in EUREKA, 328 in UNIKA, 67 in Scopus, and 218 in Web of Science. These searches and their corresponding results were coded and systematized in matrices. These matrices were entered into a spreadsheet to facilitate the organization of the information of each of the studies, by disaggregating into columns all the aspects that would later be analyzed in the different phases of the screening.

Next, a careful review was made of: (1) title, (2) year of publication, and (3) abstract, to determine if the initially selected studies meet the inclusion criteria or had to be dismissed because of the exclusion criteria. For those articles whose abstract did not present sufficient evidence to be placed in one of the inclusion or exclusion categories, a third grouping called "undefined" was created with the aim of classifying them, at a later stage, based on a complete reading and on a more in-depth review of each of these studies. Additionally, the quality of the articles was assessed using the EACSH (López-López et al., 2019), a scale to determine the quality of scientific articles in social and human sciences, and 96% of the studies showed ratings between a very high and medium-high level.

Data extraction

After this preliminary classification of the studies, the researchers created a data extraction matrix that included the following elements: (1) APA-type citation, (2) first author, (3) country of publication, (4) country in which the study was conducted, (5) type of study, (6) type of data collection (cross-sectional or longitudinal), (7) type of sampling, (8) participant definition, (9) sample size of participants, (10) mean age, (11) standard deviation of age, (12) percentage of female participation, (13) social status, (14) race, (15) purpose of the study, (16) dependent variables, (17) independent variables, (18) research question, (19) research instruments, and (20) results oriented to the description and relationship of the factors associated with the permanence, attrition and dropout of students in doctoral programs.

Two of the investigators independently read and evaluated each of the studies included in the sample. The entire team then analyzed the overlaps as well as the divergences in the extractions made by those two investigators. If there was a divergence on any category of analysis, the two initial investigators discussed the cause: if the cause was an error in the analysis, it was corrected; when the divergence was

due to a difference in the origin of the data supporting the finding, it was decided whether or not to include that information.

Data analysis

After analyzing the data with a quantitative description of the characteristics of the studies collected in the extraction matrix, a qualitative analysis was initiated using the web version of the ATLAS.ti software (Version 3.15.0–2022-03-09). In this analysis, a thematic exploration was carried out based on the elaboration of a codebook, built on the following deductive categories of analysis (Castaño et al., 2004): (1) Individual factors: age, gender, marital status, family context, calamity and health problems, social integration, time incompatibility with extracurricular activities, unmet expectations; (2) Academic factors: professional orientation, type of institution, academic performance, quality of the program, study methods, entrance exam results, dissatisfaction with the program and other academic factors, number of subjects; (3) Institutional factors: academic normality, scholarships and forms of financing, university resources, law enforcement, political environment, level of personal interaction with teachers and students; and (4) Socioeconomic factors: socioeconomic stratum, employment status, parents' employment status and income, economic dependence, dependents, parents' educational level, macroeconomic context of the country. Additionally, inductive (emergent) categories of analysis were extracted, and the codes of attrition, permanence and dropout were included, according to the evaluation guidelines in the SPIDER tool (Methley et al., 2014). This way of proceeding resulted in the configuration of a deductive approach whereby, by looking at the frequency of the codes in the studies, an analysis of the relationship between them and of co-occurrences was made, based on the central model stated in the codebook. In a final stage, the thematic networks were constructed on the basis of the central model, and then entered into the analysis of co-occurrences.

Results

Selection of studies

From an initial selection of 899 articles, after eliminating duplicate studies and applying the exclusion criteria, the sample consisted of 32 studies (Figure 1).

Descriptive analysis of the studies included in the final analysis

Half of the studies analyzed in the present investigation (16) had been conducted at universities located in the United States, while studies from Canada ($n = 3$) and Belgium ($n = 3$) each accounted for 9.4% of the analyzed sample (18.75% in total). Regarding the year of publication of the studies, a progressive increase in the number of studies published is evident, from one study in 2015 to 5 studies in 2021. The highest number of studies is recorded in 2020 with 9 studies.

With respect to the information about the population that some of the studies reported, it was observed that their sample sizes ranged from 18 to 3,004 doctoral students (average $N = 914$), where 62% of the participants were women. Likewise, the mean age of the participants was 32.2 years, ranging from 18 to 80 years. Detailed information about the populations in the studies included in this investigation is presented in Supplementary Table S1.

According to the type of methodology employed in these studies, most were cross-sectional (78.1%), with either an observational (42%) or descriptive (58%) approach, i.e., none of the 32 investigations included in our analysis used an experimental approach. With respect to the manner in which their samples were selected, the vast majority of the studies (90.6%) used non-probability convenience sampling.

On the other hand, the analysis of the measurement instruments reported in these studies enabled a first classification of information by factors associated with permanence or dropout. Of the 58 instruments used, 65.5% measured individual factors, 12.1% academic factors, 15.5% institutional factors, and 6.9% socioeconomic factors.

As for the limitations reported by the studies themselves, 50% of these studies mention the characteristics of their sample and their implications for the results of the study (De Clercq et al., 2021; Holmes and Rockinson-Szapkiw, 2020; Sverdlik and Hall, 2020). A second limitation was the inherent restriction in analyzing such educational processes because they are limited to studies in a given country, an issue already mentioned by Gruzdev et al. (2020). Furthermore, the studies carried out by Hands (2020) admit that the inclusion of samples of students from a single discipline limits the generalization of their findings. A summary of the main findings in each of these investigations, including the scoping review results can be found in Supplementary Table S2.

Content analysis of the studies

For the analysis process, a codebook was developed containing both the factors associated with dropout (Castaño et al., 2004) and the previously mentioned subfactors. Once the codebook was defined, the thematic networks for each of the factors were constructed. For this analysis within the ATLAS.ti software, groundedness is equivalent to the number of citations in the studies to which a code or category is related (Justicia, 2005).

The thematic network of the individual factor is the one with the highest number in its groundedness (233). Within this network the following subfactors were found, organized in descending order according to the frequency of groundedness: family context, calamity and health problems, unmet expectations, social integration, age, gender, marital status, time incompatibility with extracurricular activities and satisfaction – success. The emerging categories presented a total of 6 subfactors, according to their frequency: motivation, self-determination, well-being, self-efficacy, women and exhaustion.

The next factor analyzed in relation to its thematic network was the academic one. The following subfactors, according to their groundedness, emerged here: type of educational institution or university, professional orientation, program quality, academic performance, results in the entrance exam, study methods, number of subjects, and dissatisfaction with the program and other academic factors. With respect to the academic factor, four subfactors also emerged that had not been detected in the analyses carried out by previous research: supervisor, appropriation of the research project,

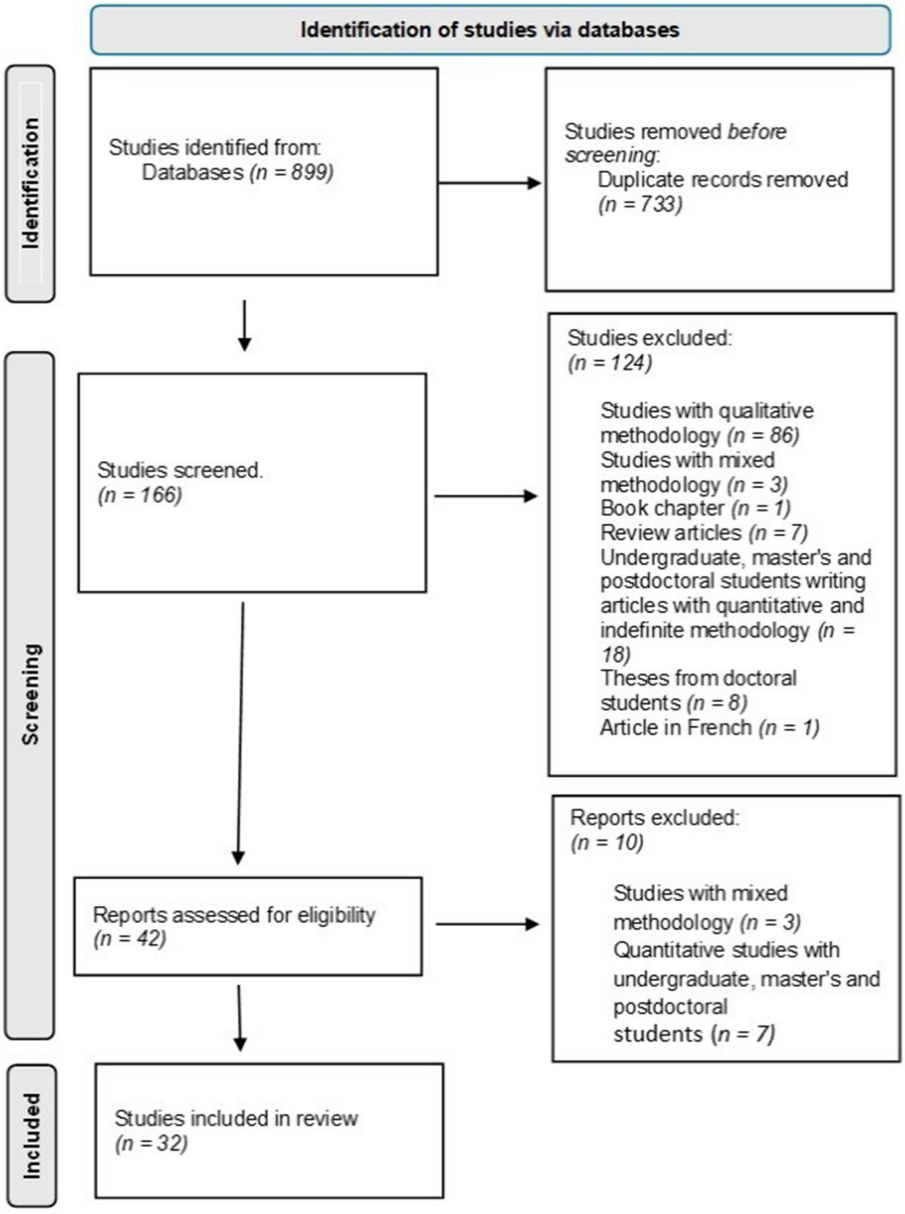

FIGURE 1
Flow diagram of the procedure followed in the selection of studies according to the PRISMA methodology.

perceived progress, and online learning (in descending order of frequency).

The thematic network of the institutional factor and its groundedness consisted of the following subfactors: level of personal interaction with teachers and students, university resources, and scholarships and forms of financing. However, the subfactors of the political environment, academic normality and law enforcement did not show any groundedness. Within the analysis of the institutional factor, however, the institutional support for psychological needs was recorded as an emerging category.

Finally, the analysis of the socioeconomic factor detected the following subfactors: employment situation, parents' educational level, dependents, economic dependence, and socioeconomic stratum. The macroeconomic context and the parents' employment status and income did not show any groundedness, but within the socioeconomic factor, the analyses found two emerging subfactors: immigration status and professional network support (Figure 2).

Once the data were analyzed independently, according to each of the four factors associated with dropout, they were related to their subfactors (Castaño et al., 2004). In addition, the categories emerging from this analysis were studied in relation to the following categories: dropout, attrition, completion and intent to drop out. Of the four thematic networks the individual factor, 233 quotations (groundedness) were found, with a higher number (66) for family context. In the studies analyzed in the present investigation, the groundedness for the academic factors was 120, with 43 quotations referring to the emergent supervisor subfactor. Institutional factors, in turn, presented 55 quotations, while socioeconomic factors

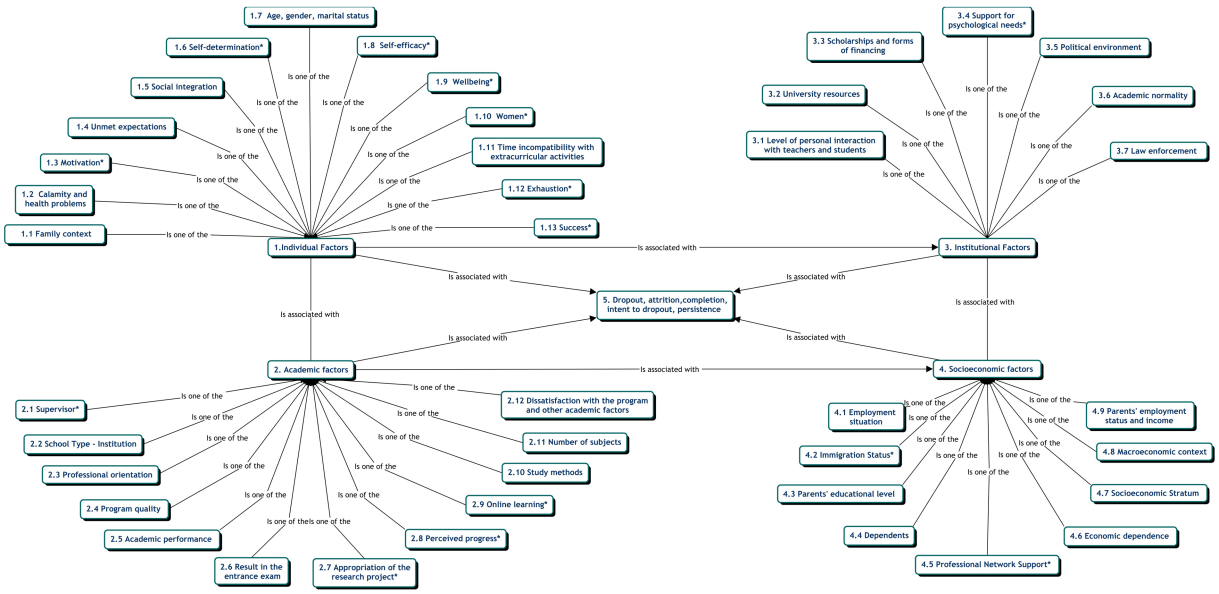

FIGURE 2
Thematic network of factors associated with dropout and emerging categories.

showed a smaller groundedness with only 24 quotations. Both institutional and socioeconomic factors included an emergent subfactor: support for psychological needs and professional network support, respectively. It should be clarified that, in the same publication, researchers may have addressed one or more factors and subfactors.

To broaden the understanding of the influence of individual, academic, institutional and socioeconomic factors associated with student dropout in their doctoral programs, based on the construction of the thematic networks (factors, deductive and emergent subfactors), it was found that the presence of a factor or subfactor in each study did not exclude the rest, but on the contrary, all authors measured more than one factor or subfactor in their research.

Co-occurrence analysis between factors

A co-occurrence analysis, i.e., a record of all related factors in the same study, was used to study those cases in which the researchers studied more than one factor or more than one subfactor. In this regard, the relationship between individual and academic factors presented the highest number of co-occurrences (22). Furthermore, the studies tended to relate academic factors such as professional orientation, supervisor, type of institution, academic performance and program quality, with the following individual factors: age, gender and marital status, self-efficacy, well-being, satisfaction – success, calamity and health problems, social integration, unmet expectations, motivation, exhaustion, self-determination and family context. The second highest frequency of co-occurrences was found between individual and institutional factors (11), with 5 co-occurrences between the level of social integration (individual) and the level of personal integration of teachers and students (institutional).

Within the co-occurrences between the individual and institutional factors, a relationship was also found between the individual subfactor of family context and the institutional subfactors of scholarships and forms of financing, level of personal interaction with teachers and students, and support for psychological needs. In addition, the subfactors of the individual factor social integration, motivation and family context were found to present co-occurrences with the institutional subfactor support for psychological needs. On the other hand, the institutional subfactor university resources presented co-occurrences with the individual subfactor well-being, a finding that is consistent with the frequency with which the word support appears in the studies.

Three co-occurrence analyses were performed: (1) between the individual factors and the academic factors and subfactors, (2) between the institutional factors and the socioeconomic factors and subfactors, and (3) between each of the subfactors that appeared within each factor. Regarding the relationships between the individual factors (well-being, calamity and health problems, social integration, motivation, women, and family context) and the socioeconomic factors (socioeconomic stratum, parents' employment status and income, economic dependence, dependents, parents' educational level, macroeconomic context of the country, immigration status, and professional network support), a decrease was observed in terms of frequency in the co-occurrences when compared to the results obtained in the co-occurrences of the individual factors with the academic and institutional factors. This decrease was even greater in the number of co-occurrences between the academic and institutional factors and subfactors.

On the other hand, in the relationships between the institutional and socioeconomic factors, co-occurrences were found between the institutional subfactor level of personal interaction with teachers and students and the socioeconomic subfactor work situation. Finally, between the academic and socioeconomic factors no relationship value was found, either at the global level or between the subfactors.

Co-occurrence analysis with the categories: dropout, attrition, completion, intent to drop out and permanence

The presence in the studies of the analysis categories of dropout, attrition, completion, intent to drop out and permanence was also coded, as were the co-occurrences among them and with each of the factors at the general level. In this way, relationships could be established not only between the factors associated with dropout (Castaño et al., 2004), but also within the categories themselves, as well as between them and the aforementioned factors. These categories were included in the analysis because they were already part of the search words and appeared with a greater number of frequencies in the analysis of the 32 studies in the word cloud that was generated by the software ATLAS.ti, typical of this type of analysis.

The studies show the highest relationship between the factors associated with the dropout category, with a frequency of 44 co-occurrences, followed by permanence (34 co-occurrences), attrition (19 co-occurrences), intent to drop out (13 co-occurrences), and completion (12 co-occurrences). In this set of frequencies, the relationship is based on data taken either directly from students who are pursuing their doctoral studies, or from the academic records of students who pursued it at the time, but subsequently dropped out of the program (Table 4).

As in previous analyses, the highest number of co-occurrences is found in the relationships between individual factors and the categories analyzed, except in the category of completion, where academic factors co-occur more frequently.

COVID-19 update

With the aim of considering in the present study a historically relevant event such as the COVID-19 pandemic, an additional search process was conducted in April 2024, with the same criteria employed as in 2022. Although it yielded a total of 43 articles, only 13 investigations matched those eligibility criteria and were subsequently analyzed in depth. The main conclusion to be drawn from such analysis is that the variables associated with the permanence of doctoral students most studied were the individual ones in terms of mental health and the institutional ones in terms of admission processes and the need for institutional support by the universities.

In particular, Paucsik et al. (2022) highlight an increase in depression, anxiety and stress, which implies a decrease in well-being. Similarly, Aristeidou and Aristidou (2023) also reported that three out of four doctoral students experienced depression mainly associated with the care of children living with them and the lack of funding.

On the other hand, Tu et al. (2023) concludes that experiencing a negative impact due to the pandemic and reflecting on such adverse event correlates with higher PTG (Post Traumatic Growth). Furthermore, they also evidence the need for institutional policies to manage risks and build resilience in academic communities. Likewise, Smith et al. (2024) underscore the relevance of having psychological structural supports in the institutions.

The research teams in those 13 studies show their concern for the mental health of doctoral students during the COVID-19 pandemic. However, only one of the articles explored the academic quality in relation to the increase in the admission of students to doctoral programs, during this time, with non-academic motivation and absence of academic skills, which questions the graduation of these students (Maloshonok et al., 2023).

As can be seen the studies published from September 2021 to May 2024 report variables that have already been assessed in the initial sample, which corroborates the reliability of the results obtained in the analysis of the studies in the initial sample of the present review.

Discussion

This scoping review aimed to identify, from the literature published between 2015 and 2021, how individual, academic, institutional and socioeconomic factors (Castaño et al., 2004; Tinto, 1975), are related to doctoral student permanence, attrition and dropout. To the best of our knowledge, the present research constitutes the first review that attempts to identify the relationship between the aforementioned factors and the permanence of doctoral students.

This scoping review has shown the diverse attention that researchers have paid to the different factors: individual factors have the highest frequency (19%), followed by institutional (13%), socioeconomic (10%), and academic (9%). An interesting finding is the existence of studies that integrated the four factors (9%) and also of studies that focused on the combination of individual and academic factors (28%), individual and institutional (6%), individual and socioeconomic (3%) and academic and institutional factors (3%). In this regard, authors such as Jackman et al. (2022) point out how inadequate the study of factors in isolation can be and highlight the need to incorporate all of them in order to understand the doctoral experience holistically, in addition to helping to structure intervention plans that are better adjusted to the reality of doctoral students.

In this sense, there is a consensus on the need for research that encompasses the entire reality of the doctoral student and his or her different contexts, which can be reflected in the model of authors such as Tinto (1975, 1993), who proposes the need to study formal and informal academic systems, as well as the integration of people in social systems.

The results show the majority of studies focus on individual factors. This contrasts with the lower percentage (9%) of studies that combine

TABLE 4 Co-occurrence of factors in the categories of dropout, attrition, completion, intent to dropout, and persistence.

Factors	Dropout	Attrition	Completion	Intent to drop out	Persistence
Individual	18	5	4	8	16
Academic	16	8	5	2	9
Institutional	5	3	2	1	5
Socioeconomic	5	3	2	1	4

all factors. These findings agree with Skopek et al.'s (2022) point of view (2022), who state that research on dropout at the doctoral level and on the time elapsed to obtain the corresponding degree has focused on the sociodemographic and individual characteristics of the students, so its scope is limited when it comes to addressing the complexity inherent in the doctoral training of students. Furthermore, the most recent studies analyzed (2022–2024), conducted in the midst of the COVID-19 pandemic, evidence the researchers' concern for students' mental health. This fact contributes to the increase in the number of studies that focus solely on individual factors leaving aside other factors such as academics, which may also affect student retention (Maloshonok et al., 2023).

Doctoral permanence is a multifactorial issue

The exploration of the factors studied in the different research studies through the systematization of the information in the semantic networks used for this review enriched the factors proposed in both Tinto's (1993) and Castaño et al.'s (2004) models, since, by means of this analysis, particular subfactors emerged as determinants of student retention.

Individual factors

In the case of individual factors, of the six emerging subfactors reported in the results section, the emerging factor women has been a finding that evidences interest on the part of researchers. This is likely because of the increased participation of women in doctoral programs (Volkert et al., 2018). Another possible explanation is reported by authors such as Epstein and Fischer (2017) when drawing attention to the high dropout rates of female science students compared to males, finding in self-efficacy (another emerging subfactor) an opportunity for intervention to increase the levels of permanence in doctoral programs. Furthermore, Epstein and Fischer (2017), concluded that women may postpone motherhood due to their doctoral work or even discard their future academic careers. Unfortunately, this study is the only one of all those analyzed that addresses this issue, so it might be interesting to conduct further research on this, including the impact that motherhood may have on the success of doctoral students.

Likewise, the emerging factor motivation is one of the most studied by researchers, since it is found in about 70% of the analyzed research, so we can observe a consensus among researchers on the relationship and the impact that the motivational profiles of students have on the permanence and completion of their doctoral studies (De Clercq et al., 2021; Sverdlik and Hall, 2020).

Academic factors

Within the academic factors, the three subfactors reported by the present study are characteristic of the doctoral training environment, as is evident from the studies analyzed in the present investigation. One aspect noted as important by several of the studies analyzed was the relationship with the supervisor. Authors such as Gruzdev et al. (2020) found among students a higher level of both satisfaction and compliance with regulatory deadlines (enrollment times, delivery of reports, estimated time for the degree), when they had supervisors with high levels of involvement in the doctoral work, and who were concerned about how their doctoral students adapted to the academic world. Litalien and Guay (2015) corroborate this by stating that the support of the supervisor, teachers and other academic staff improves the perceived competence of the student, which in turn generates a lower risk of dropping out of the program. In this relationship between individual factors and academic factors, it stands out that the perceived competence and the supervisor appear as emerging subfactors within the individual and academic factors, respectively.

Institutional factors

The only emerging subfactor within the institutional factors is support for psychological needs. In this regard Schwoerer et al. (2021) highlight the importance for doctoral students of sources of social, emotional, mentor (supervisor) and professional peer support. In fact, institutional support is considered as a determinant for the promotion of health (physical and mental) of doctoral students (Volkert et al., 2018). In addition, several studies show that greater support reduces stress levels, which influences the student's perception of balance between their work and personal life (Ribau and Alves, 2018).

Socioeconomic factors

Another result of the present study was the relationship between the emerging socioeconomic subfactor migration status and the type of program (academic subfactor). This relationship is reflected in the lower success rate of non-European students, specifically, in social sciences (De Clercq et al., 2021). Similarly, this study identified that switching university frequently predicts higher dropout rates among European doctoral students.

Wollast et al. (2018) conducted an interesting analysis of individual, academic, institutional, and socioeconomic factors. These authors concluded that students who are single, with low master's degree grades, without scholarship, belonging to the fields of social sciences and humanities and aged over 26 are 50% more likely to drop out of their doctoral program. Therefore, it is essential to recognize those factors or socioeconomic profiles of risk of dropout in this type of population, so that, in this way, institutions can facilitate actions to reduce their potential negative impact.

Permanence vs. dropout of doctoral students

The present review has identified a marked interest of researchers to study the permanence of doctoral students. The vast majority of the studies included in the present analysis (87%) have focused on investigating the permanence rather than on attrition or dropout from doctoral programs. This may be due either to the availability of the target population, or to an interest of researchers and institutions to have information that helps to prevent situations that may lead to dropout in doctoral studies, and thus increase success rates in these programs (Gómez Mendoza and Alzate Piedrahíta, 2018), as opposed to those studies focused on dropout, where the possibility of some type of intervention with students is lost. However, it is necessary to clarify that the concept of permanence is based on the definitions of dropout and its rates reported by other researchers or by the institutional measurements performed.

In this regard, Rockinson-Szapkiw et al. (2016) analyzed institutional (financial support, program, curriculum, and support services) and integration (academic, social, economic, and family) variables with the objective of distinguishing those affecting

permanence or dropout. The results showed that support services, program quality, curriculum, and academic integration (with faculty and family) were factors that helped to explain permanence.

Relationships between factors to work on the permanence of doctoral students

The relationship between different individual, academic, institutional and socioeconomic factors has been addressed by authors such as Wollast et al. (2018), who studied the following variables: nationality, marital status, master's degree, age at enrollment, field of research, permanence at the same university, and funding. In their research they found that the marital status (individual subfactor) is a predictor of the study completion (success) rate, since there is a higher relative percentage of married doctoral students who complete their doctoral programs. On the other hand, in relation to institutional factors, they identified that students with a research grant in health sciences have better permanence rates compared to students without a grant in humanities and social sciences programs, who show higher dropout rates.

Regarding the mental well-being and stress of doctoral students, Miller and Orsillo (2020) showed that both the acceptance of experiences and valued living act as protectors against depression, anxiety and stress. Along the same vein, Byrom et al. (2022) observed that the supervisor's support (academic subfactor) and the perceived self-confidence (individual subfactor) decrease stress levels. Likewise, these authors found that self-confidence predicts the mental well-being of doctoral students, that family support correlates positively with achievement orientation, and that general health and hours of sleep decrease predicted stress levels and increase mental well-being. Schwoerer et al. (2021), in turn, showed that doctoral students who perceive greater support from their supervisor report less stress and fewer work-life conflicts. However, these same authors found that, when evaluating only the mediating role of academic support from the supervisor, this role does not have an effect on the decrease in the stress that the doctoral student perceives.

One aspect that the studies analyzed consider keeping in mind in terms of the perception of well-being is the experience of the impostor syndrome (Clance, 1985) that doctoral students might experience. In this regard, authors such as Sverdlik et al. (2020) concluded that doctoral students' perceptions of their belonging to the academic community are positively related to lower levels of such syndrome. Tao and Gloria (2019) studied the moderating effect of gender (women) on the relationship between the impostor syndrome and the beliefs on academic permanence in STEM (Science – Technology – Engineering – Mathematics) programs, and highlighted that this relationship is stronger in programs in which there is a higher number of women, which was evidenced by low perceptions of academic self-efficacy and negative perceptions regarding the research and training environment.

Lee et al. (2020) concluded that the strongest positive predictor for permanence is the student-faculty relationship, above technological factors, knowledge, skills, self-efficacy, or intentions to persist. Other studies, such as the one conducted by Estrada et al. (2019), concluded that for historically underrepresented students, the student's scientific identity significantly influences permanence by valuing it as a mediating variable between social support and the intention to persist. These results demonstrate the value of doctoral student integration and relate to the emerging subfactors of well-being (individual factors), supervisor (academic), psychological needs support (institutional), and professional network support (socioeconomic), which in turn supports the concept of integration put forth by Tinto (1993).

Limitations

The present scoping review has only analyzed studies focused on the student, so in future research it would be valuable to integrate the information reported by either the universities or the supervisors themselves, in order to provide a more complete perspective that can account for various processes of mental health support at both individual and academic levels. Among others, this could include supervision, academic processes and scholarship systems, as well as the processes of employment linkage as employers.

Another limitation of the present study was the exclusion of studies that did not present a quantitative methodology. Future research should incorporate studies with mixed and qualitative methodology into the analysis, providing evidence on the perceptions of all the individuals involved in the development of a doctoral thesis.

Finally, only five longitudinal studies were found (16% of the total), which prevents us from having findings that allow a complete understanding of the student's trajectory. Most of the researchers made cross-sectional measurements with the participation of students enrolled in doctoral programs, which prevents them from knowing the relationships of these students with dropout and focuses the results only on the characteristics associated with the permanence and retention of doctoral students at university.

Conclusion

This literature review identified a wide range of relationships among individual, academic, institutional, and socioeconomic factors with respect to doctoral student permanence, attrition, and dropout.

The in-depth study of 32 publications, after a rigorous search and corresponding screening, enabled a two-level analysis. The first, descriptive, allowed us to evidence a growing interest in the topic of study, as reflected in the increase in publications since 2018, a greater number of studies reported in North America (50%), a high prevalence of cross-sectional studies (78%), and a greater number of studies focusing on the permanence of doctoral students (47%). Likewise, in order to understand each of the factors associated with the permanence of doctoral students, the identification of the 58 instruments used by researchers to measure these factors was of great importance.

The second analysis, carried out with the help of the software ATLAS.ti, made it possible to investigate the frequency and type of relationships between factors and subfactors that Castaño et al. (2004) had previously mentioned. Taking these categories as a starting point, an inductive analysis was performed, later complemented by a deductive analysis that provided 13 emerging categories specific to the population under study, thus enriching the initial approach of these authors. The report of the frequencies of the codes in terms of their groundedness made it possible to answer the question about the factors that researchers had studied the most (i.e., the individual ones).

Likewise, the co-occurrence analyses enabled the study of the relationship between the different factors, also in terms of frequency, showing that the most studied relationship had been the one between individual and academic factors, while the least studied is the relationship between institutional and socioeconomic factors (Skopek et al., 2022).

The integration of the four factors associated with permanence in a single study is fundamental, as permanence is a multifactorial issue. However, according to our findings, only 9% of the studies assessed in this scoping review reported a broad integration of factors. This supports the need to continue working on developing research studies that integrate as many factors as possible. Likewise, the association of factors around student retention is relevant, as measuring and intervening with students during their academic trajectory could lead to better graduation rates and to a decrease in the number of doctoral students who drop out of their programs. In turn, this integration could also favor the participation of the different actors that play a direct or indirect role in the training process (supervisor, professors, colleagues, family, friends, administrative staff, etc.), allowing a comprehensive attention to the permanence of students.

According to the findings reported in the different studies, it can be concluded that both the prevention of desertion and the promotion of permanence are the result of comprehensive attention to the doctoral student. Isolated actions may not have the desired effects if it is not the university institution itself that offers a comprehensive solution that addresses the characteristics of each student. This solution should include fundamental aspects for academic training such as the relationship with the supervisor, the presence of help centers to assist the student population with respect to their migratory status or their need to access scholarships or financial aid, as well as strategies for the well-being of these students that include formal and informal support networks at different levels, from colleagues to friends and family.

This scoping review provides integrative results by going beyond a descriptive analysis of the studies. Furthermore, it offers in-depth findings on the factors that previous research has identified as having an impact on the permanence and dropout of doctoral students. These findings also encourage the need for future research that contributes to the comprehensive understanding of the process and to the timely accompaniment through the interaction of the different factors.

Finally, it is noteworthy that the studies analyzed within the additional literature review to include the possible influence of COVID-19 pandemic (January 2022–May 2024) show a primary interest in the study of the mental health of doctoral students. Although this is an individual subfactor that had been frequently addressed prior to the pandemic, most recent studies have added to this subfactor the pandemic-specific implications of situations such as confinement.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

EH: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing. ER: Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. MA: Formal analysis, Writing – original draft, Writing – review & editing. SQ: Writing – original draft, Writing – review & editing. EL: Conceptualization, Formal analysis, Investigation, Methodology, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Giftedness identification and cognitive, physiological and psychological characteristics of gifted children: a systematic review

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Despite the extensive history of investigation, characterization and diagnostics of giftedness is still a point of debate. The lack of understanding of the phenomenon affects the identification process of gifted children, development of targeted educational programs and state of research in the field of gifted education. In the current systematic review, we seek to delineate the specific aspects in which gifted children differ from their typically developing peers in cognitive abilities, psychophysiology and psychological characteristics. Secondly, we aim to document the prevalence and criteria of intelligence tests used to assess gifted children and adolescents. We reviewed 104 articles from more than 25 countries that examined a total of 77,705 children ages 5–18 years. Results reveal a discernible trend toward adopting more culturally appropriate measures for assessing giftedness in children. Findings highlight that gifted children generally outperform their peers in several cognitive domains such as verbal working memory, inhibition, geometric problem solving, attention-switching and elemental information processing, showcasing an accuracy-reaction time trade-off. Psychophysiological assessments demonstrate heightened and accelerated brain activity during complex effortful cognitive processes. Psychological and behavioral measures reveal that gifted children score higher on tests measuring intrinsic motivation, self-efficacy, and openness to experience; as well as achieving higher grades in school and employing better problem-solving strategies. Our systematic review can be beneficial in educational and research contexts, giving directions in assessment of giftedness and designing future research.

KEYWORDS

giftedness, intelligence, children, intelligence tests, cognitive abilities

Introduction

Superior cognitive abilities or 'giftedness' have attracted the interest of philosophers (Comte, 1844; Saint-Simon, 1813), educators (Gardner, 2004; Harris, 1867), psychologists, psychiatrists (Galton, 1870; Lombroso, 1895; Renzulli, 1978), economists (Bui et al., 2011) and neuroscientists (Geake, 2008; Geschwind and Galaburda, 1985) for a long time. Despite the extensive history of investigation, characterization and diagnostics of giftedness is still a point of debate: components of giftedness and criteria for outstanding abilities lack operationalization

and precision (Robinson et al., 2000; Sternberg and Davidson, 2005; Subotnik et al., 2011). While traditional views linked giftedness closely with high IQ scores, contemporary theories understand it as a multifaceted phenomenon influenced by both cognitive and non-cognitive factors. Renzulli's Three-Ring Conception (Renzulli, 2011) suggests that giftedness arises from the interaction of above-average ability, creativity, and task commitment. Gagné's Differentiated Model of Giftedness and Talent (Gagné, 2004) distinguishes between innate natural abilities (gifts) and systematically developed skills (talents), emphasizing the influence of environmental and personal factors in transforming gifts into talents. Sternberg's Triarchic Theory (Sternberg, 1985) proposes that giftedness involves a balance of analytical, creative, and practical intelligences, indicating that traditional intelligence tests may not fully capture an individual's capabilities. Nevertheless, till now intelligence tests serve as a major giftedness detection tool used by researchers and educators (Hodges et al., 2018), especially when selecting for educational programs. Besides not considering more comprehensive approach to giftedness, overall intelligence tests criteria and thresholds are not well-determined. Such practices differ among countries, states, and even educational institutions (e.g., Bélanger and Gagné, 2006; Mcclain and Pfeiffer, 2012). Cutoff criteria are typically based on either a percentage of children (e.g., the top 5% or 1%) or specific test scores (e.g., an IQ of 130 on classic IQ tests). This variability in selecting gifted children makes it challenging to compare and compile research data, thereby impacting the state of the art in the field. Gifted education is one of the areas that is closely connected with intelligence testing. Thus, lack of consistency in testing criteria affects the identification process of gifted children and the development of educational programs to accommodate the specific needs of gifted children (Silverman and Gilman, 2020; Subotnik et al., 2011).

Furthermore, understanding of giftedness imply uncovering its manifestations in cognitive abilities, motivation, personal traits, and other areas (Berg and McDonald, 2018; Topçu and Leana-Taşcılar, 2018). Nevertheless, it is still unclear whether some characteristics contribute more to the concept of giftedness and what underlying factors are responsible for them. The literature on the traits distinguishing gifted children from those with average abilities is rife with ambiguity. For example, Arffa (2007) suggested superior levels of inhibition in gifted children, while other studies do not support these findings (Duan et al., 2010; Rocha et al., 2020). Vogl and Preckel (2013) demonstrated that higher cognitive ability was correlated with increased social self-concept of assertiveness, whereas Kroesbergen et al. (2015) found no difference in social acceptance and self-concept between gifted and typically developing children. Additionally, Casino-García et al. (2021) revealed even lower scores on family, social, and physical self-concept in gifted children. The literature on mathematical skills (Giofrè et al., 2014; Paz-Baruch et al., 2022) and wellbeing (Košir et al., 2016; Kroesbergen et al., 2015; Vogl and Preckel, 2013) in gifted and mainstream children also contains significant ambiguity.

In the current systematic review we aim to provide greater clarity on what constitutes intellectual giftedness. We seek to delineate the specific aspects in which gifted children differ from their typically developing peers. Secondly, we aim to investigate which tests are most commonly used and what criteria are employed to differentiate between gifted children and their control peers to clarify the trend for practitioners and researchers.

To answer these questions in our systematic review we set the following goals:

a) to document the prevalence of intelligence tests used as selection tool for gifted and control groups in children and adolescents younger than 18 years;
b) to discuss comparisons between gifted and control children focusing on cognitive functions, psychophysiology, and psychological characteristics;
c) to highlight existing methodological, conceptual, and reporting gaps in current research for gifted children.

This synthesized knowledge can be beneficial in educational and research contexts, giving directions in assessment and understanding of giftedness and designing future research.

Methods

Review design and eligibility criteria

The objectives of this review was to synthesize current evidence on the cognitive domains, psychophysiological patterns, and psychological traits that distinguish gifted children and adolescents; and to document the prevalence and criteria of intelligence tests used in assessing giftedness among children and adolescents. The relevancy of this systematic review comes from ongoing debate surrounding the lack of a unified understanding of giftedness and gaps in identification processes. By systematically analyzing existing studies, we aim to inform educational practices and highlight areas necessitating further investigation.

A systematic review was prepared in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Moher et al., 2009; Page et al., 2021) and the checklist (Hutton et al., 2015). Studies included in the final set of eligible articles adhered to the following criteria: (a) written in English; (b) participants were children and adolescents younger than 18 years; (c) participants had no pre-existing medical or psychological disorders; (d) giftedness was determined using well-established intelligence tests discussed in peer-reviewed journals; (e) the intellectual giftedness was main focus of the study; (f) publications were empirical studies such as experimental studies, observational studies, and psychometric evaluations.

Including non-English articles was not feasible without compromising the quality and accuracy of the translations. By focusing on English-language articles, we ensured that the studies included in our review are accessible to a broad international audience. Second, medical and psychological disorders can significantly influence cognitive functioning, physiological responses, and psychological wellbeing (McCutcheon et al., 2023; Snyder, 2013; Webb et al., 2016). Excluding participants with pre-existing conditions reduces variability unrelated to giftedness, enhancing the internal validity of our review and allowing for more consistent comparisons across studies. Third, we considered "well-established intelligence tests" to be standardized assessments that demonstrate strong reliability and validity (e.g., internal consistency, test–retest reliability above 0.80) in measuring intelligence or cognitive abilities, supported by extensive psychometric research. This includes evidence from test manuals (e.g., Wechsler, 2014), independent peer-reviewed studies,

academic textbooks and handbooks (Flanagan and Harrison, 2022), and reviews in authoritative sources like the Mental Measurements Yearbook (Buros Center for Testing, n.d.). Eligible intelligence tests were standardized on a large, representative sample, providing normative data for accurate comparison across diverse populations. These test were commonly used in the identification and assessment of gifted children in both research and applied settings and widely discussed and critiqued in peer-reviewed academic journals, indicating acceptance within the scientific and educational communities (e.g., Watkins and Canivez, 2016). Examples of such tests are the Wechsler Intelligence Scale for Children (WISC-V), Stanford-Binet Intelligence Scales (SB5), Kaufman Assessment Battery for Children (KABC-II), Raven's Progressive Matrices, and Woodcock-Johnson Tests of Cognitive Abilities. Forth, primary outcomes included differences in cognitive domains (e.g., working memory, inhibition, geometric problem-solving), psychophysiological assessments (e.g., ERPs, oscillatory power, BOLD signal, gray and white matter volumes), and psychological measures (e.g., motivation and self-efficacy). We did not deem eligible papers where giftedness was measured only by high performance or talent in a particular subject area studied at school. Lastly, we did not include theoretical papers or conceptual analyses, literature reviews and meta-analyses, editorials, commentaries and opinion pieces, case studies, qualitative studies without empirical data, unpublished work, book and book chapters, non-peer-reviewed articles. We did not impose any restrictions on the publication date; all studies published up to the date of our search were considered for inclusion.

Search strategy and information sources

The literature search was conducted using Web of Science,[1] covering literature up to February 4, 2022. Additional sources included gray literature identified through reference lists of relevant articles. The search strategy included a combination of keywords 'cognitive', 'gifted', 'intelligence', and 'talent' in title and abstract. Boolean operators "AND" and "OR" were used to refine the search. The finalized keyword string was as follows:

> (cognitive[Abstract] AND gifted[Abstract]) OR
> (intelligence[Abstract] AND gifted[Abstract]) OR
> (intelligence[Abstract] AND talent[Abstract]) OR
> (cognitive[Abstract] AND talent[Abstract]),

and included a filter on English-language articles. We did not consult with a librarian, as coauthor MA has extensive experience in conducting systematic reviews and played a key role in developing and refining the search strategy.

Study selection and data extraction

This search yielded a total of 1,214 articles, which underwent a series of selection criteria. After duplicates were removed, studies were first screened based on their title and abstract by three authors (AL, EK, NZh). To increase the inter-rater reliability (IRR), a third of papers was independently assessed by three reviews (Al, EK and NZh). After comparing the assessment results, the IRR was high (>80%). The rest of the papers were split between those reviewers. Reviewers were free to leave the papers uncategorized due to some doubts concerning inclusion criteria. At the end of the screening uncategorized papers were examine by all three reviewers and consensus was reached by discussion. Full-text articles were retrieved for further assessment. A total of 104 articles survived criteria and were included in the review. One of the main reasons for exclusion was the choice of the test to measure giftedness or the absence of it ($n = 117$). We only deemed eligible standardized intelligence tests, which have been discussed in peer-reviewed journals. No method of selection was mentioned in 81 articles. In some articles, authors recruited children that were already identified as gifted; in that case we included the paper only if the identification measure was indicated and met our criteria. The second most common exclusion reason was the type of giftedness ($n = 40$). We rejected articles which focused solely on outstanding achievements or giftedness in other areas rather than intellect (e.g., sports, art, or a particular subject at school).

A PRISMA flow chart illustrates the steps taken the study selection process, detailing the number of records identified, screened, assessed for eligibility, and included in the review (Figure 1).

Data were extracted using a standardized form capturing details on author(s), publication year, country where the study was conducted, age and gender of participants, sample size, what tests were used to select intellectually gifted children for each study, criterion of giftedness. The combined total number of participants across all relevant studies included a substantial sample of 77,705 individuals. In our systematic review we aimed to provide a comprehensive synthesis of the existing literature. To achieve this, we included studies both with and without control groups. Studies without control groups were studied to address our methodological research question concerning the intelligence tests used in identifying giftedness. Our main results regarding the characteristics of giftedness were based on studies including both gifted and control groups as it allows direct comparisons between gifted children and their non-gifted peers. Thus, if the study contained a control group we proceeded with evaluation of further methods and results, including experimental method, the target variable of analysis, the task/questionnaire chosen, and statistical differences reported between the gifted and control groups. We ensured that the control groups were demographically and contextually similar to the gifted groups in terms of age, gender, socioeconomic status, and ethnic background. This approach aimed to attribute observed differences specifically to giftedness. The combined total number of participants in articles with a control group included 27,309 individuals. To ensure accuracy, all three reviewers cross-checked the extracted data and all the terms were taken as they were used in the original articles.

Quality assessment and data synthesis

We conducted an informal quality assessment by critically reviewing each included study's methodology, sample characteristics, data analysis methods and reported findings. Data from the included studies were synthesized by creating a comprehensive summary

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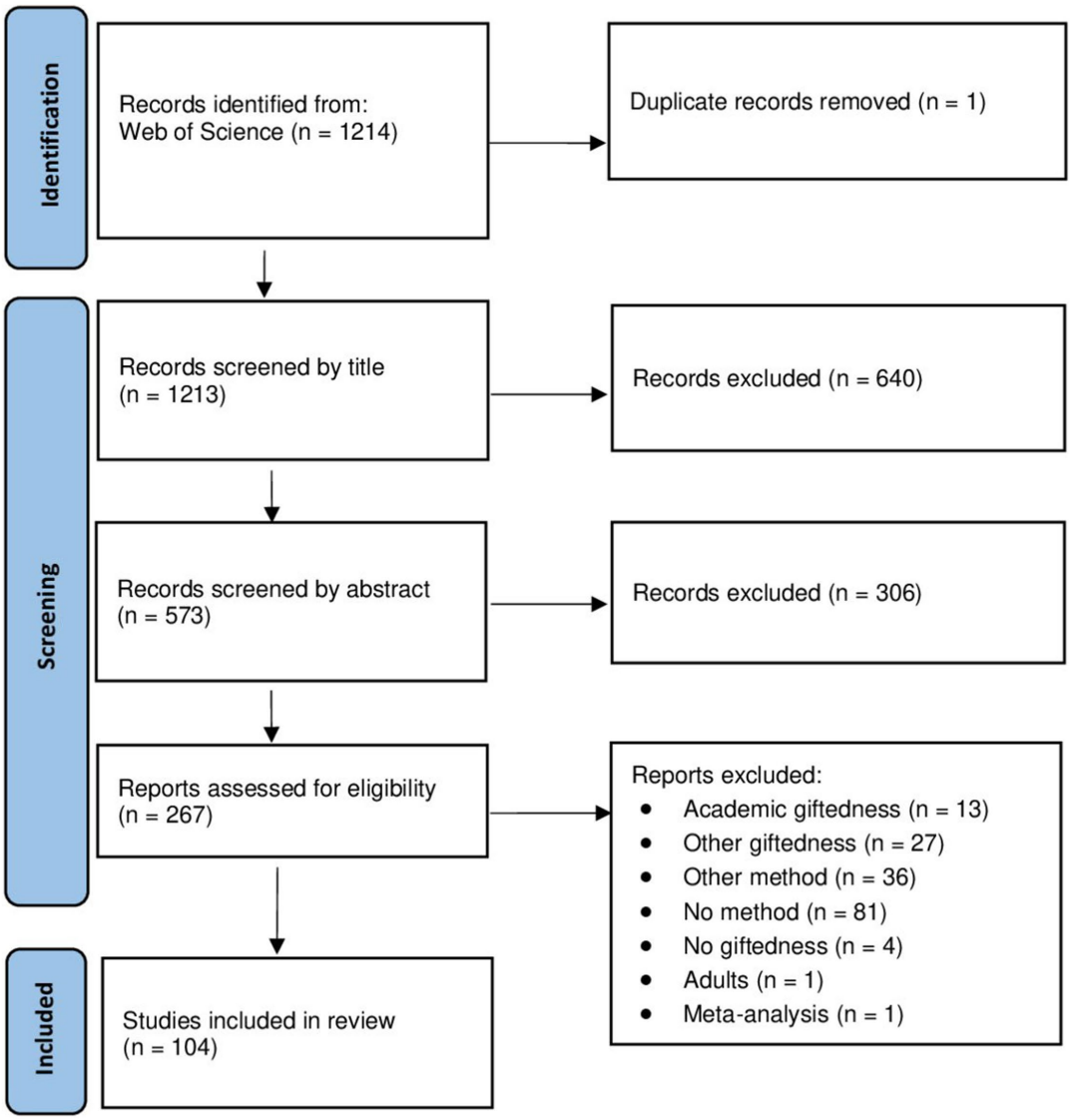

FIGURE 1
PRISMA flow diagram illustrating the study selection process for the systematic review.

(Supplementary Table 1S), which summarizes demographic, methodological choices and research findings reported by article. We organized articles in blocks based on the topic of interest: cognitive functions, psychophysiology, psychological characteristics, and other. By organizing the data in this manner, we facilitated a systematic comparison of studies, enabling us to identify patterns, similarities, and differences across various research contexts. The summary table served as the foundation for a narrative synthesis, as the heterogeneity of study designs and outcome measures precluded a quantitative meta-analysis.

Results

Giftedness assessments

Supplementary Table 1S summarizes information for 104 articles, including author, year of publication, topic of interest, country, number of participants, age group, measurement of giftedness, criteria of giftedness, experimental method, target of analysis, dependent variable/s and significant differences between gifted and control children. Articles were published between 1930 and 2022. Main topics of interest were: Cognitive abilities ($n = 42$), Psychophysiological data ($n = 16$), Psychological characteristics ($n = 20$), and Other ($n = 54$). Some of the articles considered more than one topic of interest. In most articles that reported participant gender, the proportion of boys and girls in the sample was comparable ($n = 62$), girls outnumbered boys in five articles, and boys outnumbered girls in 26 articles. Most of the articles were published in the USA ($n = 38$), followed by China ($n = 12$), Israel ($n = 9$), Spain ($n = 5$), Germany ($n = 5$), South Korea ($n = 5$), Canada ($n = 4$), Denmark ($n = 4$), France ($n = 4$), Australia ($n = 2$), Iran ($n = 3$), Turkey ($n = 2$), Sweden ($n = 2$), and Netherlands ($n = 2$). Other countries produced one eligible article.

For 59 out of 104 studies the target group was primary school children (from 6 to 11 y.o.), for 45 studies—younger adolescents (from

12 to 14 y.o.), for 32—older adolescents (15–18 y.o.), for 22—younger children (<6 y.o.). Some articles considered children from more than one age group.

Figure 2 illustrates the distributions of different tests used to select gifted and control groups in eligible articles. The Wechsler Intelligence Scale was the most popular test used ($n = 51$). Subscales of the Wechsler Intelligence Scale Test were specified, where possible. Second most popular test among eligible papers was the Raven's Matrices Test ($n = 25$). Stanford-Binet was used 16 times, Cattell's Culture Fair Test—five, CogAT—four and Naglieri Nonverbal Ability Test—three. Other tests ($n = 27$) were used in less than three articles and composed the category "Other tests."

Within the category of the Wechsler scales the most frequently used test was the Wechsler Intelligence Scale for Children (WISC). The classical version of WISC was used in seven studies, the revised WISC version—in 18 studies, WISC-III—in five studies, WISC-IV—in five studies, and WISC-V in one study. The criteria of giftedness for most of the studies stayed in range from 120 to 130 (see Supplementary Table 1S, column "Criterion of giftedness"). One study set the criteria to 160 and two studies selected the top 5% and top 1% of the participants who took part in the test. The scale was used with all age groups. Another type of scale was the Wechsler Preschool and Primary Scale of Intelligence (WPPSI) which was given to younger children, primary school children, and younger adolescents in seven studies. Two papers used Wechsler Adult Intelligence Scale and administered it to older adolescents. Four papers did not specify the type of scale.

The three versions of Raven's Progressive Matrices were used in the final sample of the review. The Advanced Progressive Matrices (RAMP; $n = 13$) were given mainly to older adolescents with the criteria of scoring higher than 26–33. The Standard Progressive Matrices (RSPM, $n = 5$) tested abilities of younger adolescents and primary school children by indicating the criteria of giftedness as top 5% or top 10% of children participated in the test. Four papers did not provide information on the criterion. The criteria for the Colored Progressive Matrices ($n = 3$) were the top 2% and standardized score more than 110 and 130. The test was given to primary school children and younger children. The other four papers did not specify the version of the Raven's Progressive Matrices.

The criteria for the Stanford-Binet Intelligence Test ($n = 16$) mostly fell within the scores 120–135. One study set the criteria to top 5% and one study—to 150. Children from all the age groups took this test.

Cognitive abilities

Of the 104 eligible articles, 42 examined cognitive abilities, 27 of which involved a control group. Of the 27 articles with a control group, samples of 15 studies were gender balanced, five included more males, three were exclusively male, one had more females, and three did not provide this information. One study focused on younger children, 13 studies on primary school children, 14 on younger adolescents, and nine studies evaluated older adolescents.

Working memory

Out of six articles that used tasks related to working memory, five of them found significant differences between gifted and control children (Table 1). Significant differences in accuracy were found in forward and backward parts of the Digit span task (Fard et al., 2016; Leikin et al., 2013), as well as in the working memory task where children had to remember words (Coyle et al., 1998) and the last item of a series (Calero et al., 2007; Zhang et al., 2017). Gifted group did not perform better than the control group in the working memory task with digits and letters and both parts of the Corsi task (Leikin et al., 2013; Paz-Baruch et al., 2016).

Attention

Three articles found differences in various types of attention (Table 2). Gifted children performed significantly better on the d2

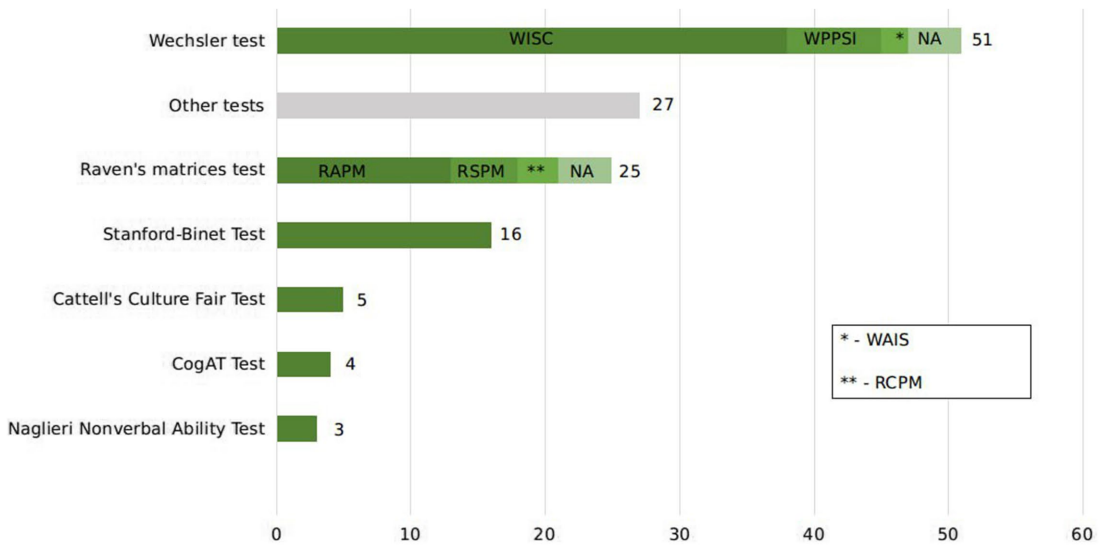

FIGURE 2
Commonly used intelligence tests for giftedness identification. CogAT Test, Cognitive Abilities Test; WAIS, Wechsler Adult Intelligence Scale; RCPM, Raven's Colored Progressive Matrices.

TABLE 1 Working memory: comparisons between gifted children and control children.

First author, year	Age group	Criterion of giftedness	Task/questionnaire	Significant differences
Fard et al. (2016)	Younger adolescents	Wechsler test, score > 110	Digit span task (forward, backward)	Accuracy higher in gifted
Calero et al. (2007)	Primary school	The Kaufman Brief Intelligence Test > 136	Last item recalling	Accuracy higher in gifted
Zhang et al. (2017)	Younger adolescents	Stanford-Binet Test, WPPSI-R, RSPM Score in top 5%	Recall task	Accuracy higher in gifted
Coyle et al. (1998)	Primary school	WISC-R, Short-form WISC-III, Score > 130	Multitrial recall task	Accuracy higher in gifted
Leikin et al. (2013)	Older adolescents	RAPM > 27	Digit span task (forward, backward)	Accuracy higher in gifted
			Letters and digits	No differences in accuracy
			Spatial Corsi test (forward, backward)	No differences in accuracy
Paz-Baruch et al. (2016)	Older adolescents	RAPM > 27	Spatial Corsi test (forward, backward)	No differences in accuracy

WPPSI, Wechsler Preschool and Primary Scale of Intelligence; RSPM, Raven's Standard Progressive Matrices; WISC, Wechsler Intelligence Scale for Children; RAPM, Raven's Advanced Progressive Matrices.

test of selective attention (Paz-Baruch et al., 2016). Higher scores in accuracy for gifted primary school children were found for sustained, supervisory, and divided attention, but not in focused, alertness, spatial, and switching attention (Zhang et al., 2016). At the same time gifted children were faster on attentional switching, alertness, spatial and divided attention tasks but not on focused, sustained and supervisory attention tasks (Zhang et al., 2016). In another study, both groups performed at a high level in terms of accuracy on attentional switching task, and gifted children demonstrated shorter reaction time in comparison with controls (Duan and Shi, 2014).

Inhibition

Three articles out of four found differences on inhibition between the groups (Table 3). Johnson et al. (2003) found differences in processing speed between groups with high and average levels of intelligence on the Spatial location task, the Stroop task, and Trail making test where gifted children were faster in giving their responses. Gifted primary school children made less errors in the ignored repetition condition and the Stroop condition in the Stroop task. Significant differences in reaction time but not in accuracy were observed between the groups in effortful inhibition measured by the Trail making test and automatic inhibition measured by the spatial location task. Montoya-Arenas et al. (2018) research did not find significant differences in accuracy on the Stroop task, no reaction time scores were reported. Younger adolescents scored higher and reacted faster in cognitive control and conflict control tasks (Liu et al., 2011a, 2011b).

Abstract reasoning and planning

Both groups of primary school children showed comparable time and numbers of moves in solving the Tower of Hanoi/London (Montoya-Arenas et al., 2018; Vogelaar et al., 2019; Table 4). In the mental rotation task gifted younger and older adolescents showed higher accuracy, whereas there was no significant difference in reaction time between the groups (Anomal et al., 2020). Results for the Wisconsin Card-Sorting Test that covers a set of executive functions demonstrate the controversy: significant differences between gifted children and control children were found in one article (Tanabe et al., 2014) but not another (Montoya-Arenas et al., 2018). Researchers found higher accuracy of the gifted group in geometry problem solving (Vogelaar et al., 2017; Waisman et al., 2016), and inductive reasoning task (Zhang et al., 2015).

Elementary cognitive processes

Elementary cognitive tasks are often basic tasks that pose limited requirements on cognitive processes that are not commonly considered as working memory, attention, and inhibition tasks. In elementary processing tasks (Table 5), the gifted groups showed better results in cross-out of numbers that measured the speed of processing (Paz-Baruch et al., 2014) as well as in choice reaction time task (Duan et al., 2013) but not in other speed of processing tasks such as the visual matching test, the digit-symbol test, and the symbol search test (Paz-Baruch et al., 2014, 2016). Investigating speed and efficiency of elemental information processing, Kranzler et al. (1994) detected an advantage of gifted younger adolescents in reaction time in the simple reaction time and odd-man paradigm tasks but not in the choice reaction time task. Notably, the authors also analyzed movement time, the interval between releasing the home button and depressing the push button, which resulted in showing differences between the groups in all three tasks. In line with this study, Duan et al. (2013) reported differences in the speed of information processing between gifted and control primary school children using perceptual and processing tasks. They used several measures such as the inspection time task (deciding which stimulus line is longer), the choice reaction time task (judging whether the sample stimulus appeared in the line of other stimuli), and the abstract matching task (choosing appropriate patterns based on the sample one). For all three measures, gifted children were quicker than those in the control group.

Other

Examining self-control abilities using facial expressions, Urben et al. (2018) revealed shorter reaction times of average ability children for neutral and happy faces but no difference for sad faces. Higher accuracy for gifted children in the tasks related to memory and learning was found in auditory verbal learning (Fard et al., 2016), the learning potential test (Calero et al., 2011), and metacognitive competences (Tibken et al., 2022). Researchers also revealed higher skills of the gifted group in reading comprehension (Vogelaar et al., 2017), verbal fluency (Montoya-Arenas et al., 2018), fluid intelligence measured by RSPM (Li et al., 2020),

TABLE 2 Attention: differences between gifted children and their control children.

First author, year	Age group	Criterion of giftedness	Task/questionnaire	Significant differences
Paz-Baruch et al. (2016)	Older adolescents	RAPM > 27	d2 test of selective attention	Higher accuracy in gifted
Zhang et al. (2016)	Primary school	RAPM > Level 1, Cattell's Culture-Fair Test (for verification)	Focused attention identification task	No differences in accuracy No differences in reaction time
			Sustained attention number task	Accuracy higher in gifted No differences in reaction time
			Supervisory attention star counting test	Accuracy higher in gifted No differences in reaction time
			Alertness task	No differences in accuracy Shorter reaction time in gifted
			Spatial location detecting task	No differences in accuracy Shorter reaction time in gifted
			Divided attention dual visual and acoustic task	Accuracy higher in gifted Shorter reaction time in gifted
			Switching location detection task	No differences in accuracy Shorter reaction time in gifted
Duan and Shi (2014)	Younger adolescents	RSPM	Switching task	No differences in accuracy Shorter reaction time in gifted

RAPM, Raven's Advanced Progressive Matrices; RSPM, Raven's Standard Progressive Matrices.

TABLE 3 Inhibition: differences between gifted children and their control children.

First Author, year	Age group	Criterion of giftedness	Task/questionnaire	Significant differences
Johnson et al. (2003)	Primary school	WISC-III (Grades 1–3) > top 1%, WISC-III (Grades 4–5) > top 3%, CCAT, Canadian Achievement Test-2	Automatic inhibition spatial location task	No differences in accuracy Shorter reaction time in gifted
			Effortful inhibition trail making test	No differences in accuracy Shorter reaction time in gifted
			Stroop task	Higher accuracy in gifted Shorter reaction time in gifted
Montoya-Arenas et al. (2018)	Primary school	WISC-III > 130	Stroop task	No differences in accuracy
Liu et al. (2011b)	Younger adolescents	WPPSI, Stanford–Binet Test	Eriksen flanker task	Higher accuracy in gifted Shorter reaction time in gifted
Liu et al. (2011a)	Younger adolescents	WPPSI	Go-nogo task	Higher accuracy in gifted No differences in reaction time

WISC, Wechsler Intelligence Scale for Children; WPPSI, Wechsler Preschool and Primary Scale of Intelligence.

concrete and formal operations (Carter and Ormrod, 1982) and strategic thinking (Coyle et al., 1998; Yun et al., 2011) in comparison with their peers. Higher accuracy in gifted children was observed in mental-attention capacity (Johnson et al., 2003), pattern recognition task (Paz-Baruch et al., 2016), self-regulation and concentration (Calero et al., 2007), and simple arithmetic exercises that measured the speed of processing (Paz-Baruch et al., 2014).

Psychophysiological data

Sixteen articles examined psychophysiological data, 14 of them focused on differences between gifted and control groups.

Event related potentials (ERP) studies

There were eight articles investigating event-related potentials (ERPs) related to cognitive functions (Table 6). Six of them demonstrated significant differences between gifted and control children in at least one ERP component.

One out of two articles analyzing the P1 component of ERPs (peaks ~100 ms after stimulus onset) found a significant difference between the gifted and the control group. Amplitude of the parietal P1 was higher in gifted adolescent boys when solving geometric problems (Waisman et al., 2016). Gifted children also experienced the peak of P1 later than the control group, in other words, the latency of P1 in this study was higher in gifted children (Waisman et al., 2016). Another paper, a facial expression identification study, revealed no difference in P1 response between gifted and control groups of younger adolescent boys during the early visual processing stage (Liu et al., 2015).

Both articles investigating the N2 component of ERP (~200–350 ms post-stimulus) found a significant difference between the gifted and the control groups. The N2 component had larger amplitude

TABLE 4 Abstract reasoning and planning: differences between gifted children and control children.

First author, year	Age group	Criterion of giftedness	Task/questionnaire	Significant differences
Anomal et al. (2020)	Younger adolescents Older adolescents	WISC, WAIS Score > 120	Shepard-Metzler mental rotation task	Accuracy higher in gifted No differences in reaction time
Vogelaar et al. (2019)	Primary school	RSPM in top 5%	Tower of London	No differences in number of moves
Montoya-Arenas et al. (2018)	Primary school	WISC-III > 130	Tower of Hanoi	No differences in number of moves
			Wisconsin Card-Sorting Test	No differences in number of categories achieved
Tanabe et al. (2014)	Younger children Primary school Younger adolescents Older adolescents	WISC-IV > 130	Wisconsin Card-Sorting Test	More conceptual-level responses in gifted
Zhang et al. (2015)	Older adolescents	RAPM > 32	Reasoning task	Accuracy higher in gifted
Vogelaar et al. (2017)	Primary school	RSPM in top 10%	Geometric analogy problem solving	Accuracy higher in gifted
Waisman et al. (2016)	Older adolescents	RAPM > 26	Geometry problem solving	Accuracy higher in gifted

WISC, Wechsler Intelligence Scale for Children; WAIS, Wechsler Adult Intelligence Scale; RSPM, Raven's Standard Progressive Matrices; RAPM, Raven's Advanced Progressive Matrices.

TABLE 5 Elementary cognitive processing: differences between gifted children and control children.

First author, year	Age group	Criterion of giftedness	Task/questionnaire	Significant differences
Paz-Baruch et al. (2014)	Older adolescents	RAPM > 26	Cross-out of numbers	Accuracy higher in gifted
			Visual-matching	No differences in accuracy
			Digit-symbol test	No differences in accuracy
			Symbol-search	No differences in accuracy
Paz-Baruch et al. (2016)	Older adolescents	RAPM > 26	Visual-matching	No differences in accuracy
			Digit-symbol test	No differences in accuracy
			Symbol-search	No differences in accuracy
Duan et al. (2013)	Primary school Younger adolescents	Cattell's Culture Fair Test in top 5%	Inspection time task	Shorted reaction time in gifted
			Choice reaction time task	Higher accuracy in gifted Shorted reaction time in gifted
			Abstract matching (shape discrimination) task	Higher accuracy in gifted Shorted reaction time in gifted
Kranzler et al. (1994)	Younger adolescents	RAPM	Simple reaction time task	Shorted reaction time in gifted Shorter movement time in gifted
			Choice reaction time task	No differences in reaction time Shorter movement time in gifted
			Odd discrimination paradigm	Shorter reaction time in gifted Shorter movement time in gifted

RAPM, Raven's Advanced Progressive Matrices; SAT, Scholastic Aptitude Test.

in gifted children for both classic conflict imposed by the Eriksen flanker task (Liu et al., 2011b) and emotional conflict by face-word Stroop task (Liu et al., 2011b) and by emotional Simon task (Li et al., 2020). The emotional Simon task also revealed lower N2 latency in gifted children (Li et al., 2020).

Three out of six articles investigating ERPs analyzed the P3 component (roughly 250–500 ms after stimulus onset). Two articles revealed increased P3 amplitude in gifted children, both in primary school students and younger adolescents, both in response to a stimulus and in response to a cue providing information about future stimulus (Liu et al., 2011b, Liu et al., 2011a; Zhang et al., 2006). One out of these three articles showed that gifted children demonstrate shorter latency of the P3 component (Liu et al., 2011b; Zhang et al., 2006). However, no difference was found neither in P3 amplitude nor in latency in the study of Duan and Shi (2014) who investigated attentional switching performance in younger adolescents. One article focused on the P3a (~250–280 ms after stimulus onset, mostly associated with the processing of novelty) and the mismatch negativity components (200–400 ms). For both components, a larger amplitude in gifted primary school students and younger adolescents was observed (Liu et al., 2007). One study investigated mental rotation-related negativity (~400 ms post-stimulus onset) and the late discriminative negativity (400–700 ms; Anomal et al., 2020; Liu et al., 2007). For both components greater amplitudes in gifted primary

TABLE 6 ERPs: comparisons between gifted children and control children.

First author, year	Age group	Criterion of giftedness	Event-related potentials (task)	Significant differences
Liu et al. (2015)	Younger adolescents	Cattell's Culture Fair Test	P1 (facial expression identification)	No differences in amplitude
Waisman et al. (2016)	Older adolescents	RAPM >26	P1 (geometric problems solving)	Higher amplitude in gifted Longer latency in gifted
Liu et al. (2011b)	Younger adolescents	WPPSI, Stanford–Binet Test	N2 (Eriksen flanker task)	Higher amplitude in gifted
			N2 (emotional face-word Stroop task)	Higher amplitude in gifted
			P3 (Eriksen flanker task)	Higher amplitude in gifted Shorter latency in gifted
Li et al. (2020)	Primary school	RSPM	N2 (Emotional Simon task)	Higher amplitude in gifted Shorter latency in gifted
Liu et al. (2011a)	Younger adolescents	WPPSI	P3 (GoNogo task)	Higher amplitude in gifted
			Cue-P3 (GoNogo task)	Higher amplitude in gifted
Duan and Shi (2014)	Younger adolescents	RSPM	P3 (attention switching task)	No differences in amplitude No differences in latency
Liu et al. (2007)	Primary school Younger adolescents	Stanford–Binet Test (revised), WPPSI-R	P3a (Involuntary attention switching task)	Higher amplitude in gifted
			MMN (Stimulus discrimination task)	Higher amplitude in gifted
			Late discrimination negativity (Stimulus discrimination task)	Higher amplitude in gifted
Anomal et al. (2020)	Younger adolescents Older adolescents	WISC, WAIS Score > 120	Rotation-related negativity (Shepard-Metzler mental rotation task)	Higher amplitude in gifted (right hemisphere)

WPPSI, Wechsler Preschool & Primary Scale of Intelligence; RAPM, Raven's Advanced Progressive Matrices; RSPM, Raven's Standard Progressive Matrices; WISC, Wechsler Intelligence Scale For Children; WAIS, Wechsler Adult Intelligence Scale.

school students and younger adolescents was observed. Overall, gifted children tend to show greater ERP amplitudes during problem solving.

Electroencephalography (EEG) oscillations studies

Two articles examined brain oscillations using EEG. Both articles investigating EEG oscillations related to cognitive functions show significant differences between gifted and control children in gamma frequency band.

When performing easy tasks for reasoning, gamma rhythm power (30–45 Hz) was lower in gifted older adolescents, whereas when performing difficult tasks, gifted children exhibited significantly increased gamma power compared with a control group (Zhang et al., 2015). Only the gifted group showed a significant increase in gamma power with task difficulty (Zhang et al., 2015). Zhang et al. (2014) analyzed temporal binding of the gamma-band (30–60 Hz) synchronization between frontal and parietal cortices in adolescents with exceptional mathematical ability. Compared with the average-ability participants, the math-gifted adolescents showed a highly integrated fronto-parietal network due to distant gamma phase-locking oscillations. Gifted adolescents also demonstrated more stable frontal–parietal gamma phase dynamics (Zhang et al., 2014).

Other physiological methods

One article examined functional Magnetic Resonance Imaging metrics with the aim to investigate the neural bases for intellectual giftedness in adolescents. The authors showed that the blood-oxygen-level-dependent (BOLD) signal in the posterior parietal cortex was significantly stronger in gifted older adolescents than in their control peers (Lee et al., 2006). Two articles investigated Diffusion Tensor Imaging (DTI) indicators. Such topological characteristics of the brain network as levels of global and local efficiency were higher in gifted older adolescents (Ma et al., 2017). Axial diffusivity, reflecting white matter integrity, was higher in gifted primary school students and young adolescents (Nusbaum et al., 2017). Another article focused on skin conductance in response to an orientation reflex, which was increased in gifted primary school students (Kimmel and Deboskey, 1978).

Psychological characteristics

Twenty articles examined psychological characteristics, 12 of which focused on differences between gifted and control children (Table 7). Four articles were devoted to motivation characteristics of gifted children. Three of them showed higher scores of intrinsic motivation in the gifted group (Bergold et al., 2020; Gottfried and Gottfried, 1996; Guez et al., 2018). One article investigated achievement motivation in older adolescence and found it to be enhanced in the gifted group (Wirthwein et al., 2019). One article focused on extrinsic motivation and demonstrated significantly higher scores in gifted younger adolescents (Guez et al., 2018).

Three articles investigated psychological characteristics related to self-efficacy (Table 8). Academic self-efficacy (Guez et al., 2018), math ability self-concept (Bergold et al., 2020), self-esteem intelligence scores (Wirthwein et al., 2019) and self-regulatory efficacy (Guez et al., 2018) were higher in gifted children in comparison with control children. However, there was no difference in social self-efficacy between the groups (Guez et al., 2018). One article also did not obtain

TABLE 7 Motivation: comparisons of gifted children and control children.

First author, year	Age group	Criterion of giftedness	Questionnaire	Significant differences
Bergold et al. (2020)	Older adolescents	Short version of the revised Culture Fair Intelligence Test Scale 2 > 130	Investigative vocational interests (General Structure of Interests Tests)	Higher in gifted
			Intrinsic motivation in math (The intrinsic value subscale of the Scale for the Assessment of Subjective School Related Task Values)	Higher in gifted
Gottfried and Gottfried (1996)	Primary school Younger adolescents	WISC-R > 130	Intrinsic motivation (Children's Academic Intrinsic Motivation Inventory [CAIMI])	Higher in gifted
Wirthwein et al. (2019)	Older adolescents	Intelligence-Structure-Test +2,000 R > 120	Achievement motivation (Achievement Motives Scale [German version])	Higher in gifted
Guez et al. (2018)	Younger adolescents	Chartier's Reasoning Test on Playing Cards >130	Intrinsic motivation (Academic Self-Regulation Questionnaire)	Higher in gifted
			Extrinsic motivation (Academic Self-Regulation Questionnaire)	Higher in gifted

WISC-R, Wechsler Intelligence Scale for Children Revised.

TABLE 8 Self-efficacy: comparisons between gifted children and control children.

First author, year	Age group	Criterion of giftedness	Questionnaire	Significant differences
Bergold et al. (2020)	Older adolescents	Short version of the revised Culture Fair Intelligence Test Scale 2 > 130	Math ability self-concept (Four modified items from the Scales for the Assessment of Academic Self-Concept)	Higher in gifted
Wirthwein et al. (2019)	Older adolescents	Intelligence-Structure-Test +2,000 R > 120	Self-esteem intelligence (7-point Likert scale)	Higher in gifted
Guez et al. (2018)	Younger adolescents	Chartier's Reasoning Test on Playing Cards > 130	Academic self-efficacy (Children's Perceived Self-Efficacy scales)	Higher in gifted
			Self-regulation score (Children's Perceived Self-Efficacy scales)	Higher in gifted
			Social self-efficacy score (Children's Perceived Self-Efficacy scales)	No differences

a significant difference in social adaptation in children of different ages (López and Sotillo, 2009).

Two studies analyzed the Big 5 personality factors. Both of them found that gifted adolescents were significantly more open to experience and did not differ from ordinary peers in Extraversion, Agreeableness and Conscientiousness (Limont et al., 2014; Wirthwein et al., 2019). One article investigated the relationship between giftedness and perfectionism (Lavrijsen et al., 2021). Gifted younger adolescents had significantly higher scores on the multidimensional perfectionism scale, and, at the same time, lower concern over mistakes.

The level of life satisfaction did not differ between gifted adolescents and the control group (Bergold et al., 2015, 2020). One article focused on different characteristics of overexcitability (Limont et al., 2014). The authors found that gifted adolescents did not differ from their peers in emotional overexcitability, however gifted adolescents surpassed control children in other types of overexcitability (Sensual, Intellectual, Psychomotor, Imaginational).

According to four studies focusing on strategic behavior, gifted children come up with a better strategy when playing games (Chung et al., 2011; Yun et al., 2011) and solving tasks (Coyle et al., 1998; Zhang et al., 2017) than their control peers. Also gifted children tend to cooperate more, be less sensitive to loss (Chung et al., 2011) and stick to one particular strategy (Coyle et al., 1998). The monetary acceptance rate and earnings in the Ultimatum game conducted by Yun et al. (2011) was lower for gifted than control children (Table 9).

Creativity was measured in four studies, with only one evaluating differences between gifted and control children (Kershner and Ledger, 1985). Kershner and Ledger (1985) used the Torrance Tests of Creative Thinking to measure verbal and figural originality, fluency and flexibility. Authors found significant differences between gifted children and controls only in the verbal originality dimension.

Other categories

Besides three main groups of studies listed above, there were four other categories we identified. Seven studies examined participants' achievements, both during the school years and later in adult life. Four of them focused on differences between gifted and control children. According to results, gifted children have higher grades at school (Li et al., 2020; Wirthwein et al., 2019) and on important examinations (Guez et al., 2018). The probability to get a Master's degree is also higher among gifted children in comparison with controls (Bergman et al., 2014). However, differences in future income level are noticeable only when

TABLE 9 Strategies: comparisons between gifted children and control children.

First author, year	Age group	Criterion of giftedness	Strategy	Significant differences
Chung et al. (2011)	Younger adolescents	WISC > 130	Cooperation	Higher in gifted
			Sensitivity to loss	Lower in gifted
Yun et al. (2011)	Younger adolescents	WISC-III	Strategic decisions ratio	Higher in gifted
			Monetary offers for unfair condition	No differences
			Monetary acceptance rate	Lower in gifted
			Earnings in the game	Lower in gifted
			Distributions of offers	No differences
Coyle et al. (1998)	Primary school	WISC-R and Short-form WISC-III > 130	Stability in memorizing strategy	Higher in gifted
Zhang et al. (2017)	Younger adolescents	Stanford-Binet, WPPSI-R and RSPM, top 5%	Clustering memorizing strategy	Higher in gifted

comparing gifted and control boys, with gifted boys earning more (Table 10).

Five studies investigated aspects related to family environment, three of them focused on differences between gifted and control children. According to Weissler and Landau (1993) parents of gifted children are less authoritarian and tend to expose their children to a wider variety of things (toys, books, works of art, traveling) and different sources of information. In general, they pay more attention to the child's development and cultivation of intelligence. Landau and Weissler (1993) conducted the similar research in the same year and confirmed that at least fathers of gifted children are more educated and liberal, while at the same time the level of parents' assertiveness was higher in families with gifted students. No differences were found in such dimensions as socioeconomic status, atmosphere at home, cognitive interaction between parents and children, diversity of parents' interests and parents' level of stress. In the third study comparing the environment in families with and without gifted children no differences were found at any of the dimensions, including democratic/authoritarian family style, achievement orientation, intellectual-cultural orientation, communication and organization (Schilling et al., 2006).

Fifteen studies focus on methodology of assessing gifted children, reporting significant correlations between different intelligence tests, and comparing consistency of results among them. None of these studies compared gifted and control group performance as such.

The last category combined studies ($n = 27$) which topics could not be included in one of the above–listed categories. There were various studies looking for an association between IQ and breakfast consumption (Hisam et al., 2015), TV comprehension (Abelman, 1995), height (Hollingworth, 1930), handedness (Aliotti, 1981), sleep behavior (Demirhan et al., 2018; Piro et al., 2021). Some of the studies revealed unexpected significant differences in gifted and intellectually average children, for example in height (Hollingworth, 1930) and TV comprehension (Abelman, 1995), while in other fields gifted children did not differ much from their intellectually average peers, e.g., in breakfast consumption (Hisam et al., 2015) and sleep behaviors (Piro et al., 2021).

Discussion

The objective of this study was to enhance the understanding of giftedness identification, along with the cognitive, physiological, and psychological characteristics associated with gifted children. We systematically reviewed the literature to document the prevalent tests used to identify intellectual giftedness in children and synthesized data from studies comparing gifted and control children in cognitive, physiological and psychological domains. In accordance with the three questions outlined in the Introduction, we synthesize the key findings as follows: (a) although the Wechsler Intelligence Scale Test remains the most popular choice for identifying giftedness in children, there is a discernible trend, particularly from the 1990s onwards, favoring culturally independent inclusive tests with visual or non-verbal stimuli such as Raven's Matrices; (b) Results indicate that gifted children outperform their peers in cognitive tasks related to verbal working memory, inhibition, attentional switching, geometric problem solving, and elemental information processing, while physiological studies reveal differences in brain activity and structure, showing increased activity in late components of evoked potentials and during complex problem-solving processes; furthermore, gifted individuals exhibit higher intrinsic motivation, self-efficacy, openness to experience, and better school achievements and problem-solving strategies; (c) Significant methodological, conceptual, and reporting gaps exist in current research on gifted children, including variability in measurement approaches, lack of standardization in assessment methods, controversial binary group divisions, inconsistent terminology for cognitive functions and inconsistencies in reporting styles that hinder reliable comparisons and synthesis of findings. The ensuing discussion maps assessments and attributes of children with outstanding intellectual abilities compared to their same age peers in control groups in cognitive functions, psychophysiology, psychological and behavioral characteristics. Concluding, we point to limitations in methodological practices and considerations for future research.

Giftedness assessments

In our systematic review we demonstrate that classic intelligence tests have been used for many decades and remain popular in evaluation of superior intelligence. About 39% of studies used a version of the Wechsler Intelligence Scale test for assessing intellectual giftedness in children. We also reveal a trend for visual–spatial assessments that has become prominent in the last 30 years. The Raven's Matrices Test is the second most popular assessment method in our systematic review: it evaluates visual–spatial abilities and minimizes cultural, and verbal confounds. It is often used to

TABLE 10 Achievements: comparisons between gifted children and control children.

First author, year	Age group	Criterion of giftedness	Achievements measure	Significant differences
Li et al. (2020)	Primary school	RSPM	School grades	Higher in gifted
Wirthwein et al. (2019)	Older adolescents	Intelligence-Structure-Test >120	School grades	Higher in gifted
Guez et al. (2018)	Younger adolescents	Chartier's Reasoning Test on Playing Cards >130	Grade on national examination	Higher in gifted
Bergman et al. (2014)	Primary school Younger adolescents Older adolescents	Swedish WIT III and DBA intelligence tests, top 10%	Master's degree probability	Higher in gifted

collect data in non-English speaking countries such as China, Spain, Israel, and Iran. This is consistent with reports that demonstrate an advantage of nonverbal tasks for screening and identifying gifted children from White, Hispanic and African American backgrounds (Lewis, 2001). The third most popular test is the Stanford-Binet, which was the one of the first tests to determine intellectual capacity in children and had a major influence on the future development of intelligence testing (Boake, 2002; Pichot, 1948). These findings highlight the importance of adopting more inclusive methods for identifying giftedness, as traditional approaches may inadvertently overlook the diverse talents of children from various cultural backgrounds. By prioritizing assessments that reduce verbal and cultural biases, we might begin to foster a more equitable framework for recognizing and nurturing gifted potential across all demographics. Such an approach not only broadens the definition of giftedness but also could lead to educational practices and policies that are more attuned to the needs of a diverse student population.

Notably, different studies employed varying threshold scores to define high intelligence. Most studies included the top 5–10 percent of scorers in the gifted group. Although there are methodological considerations for obtaining substantial sample sizes, variation in thresholds could potentially lead to differences in outcomes and interpretations of research results. The implications of establishing such thresholds are also profound for educators, specialists in gifted education, and program developers, as standardized criteria could enhance identification processes, inform targeted interventions that meet the specific needs of gifted children and promote equitable access to gifted programs across diverse populations. Thus, the need for a universally agreed-upon threshold for defining giftedness remains.

Giftedness involves a balance of analytical, creative, and practical intelligences (Sternberg, 1985). Therefore, despite their wide popularity traditional intelligence tests may not fully capture an individual's capabilities. It would be beneficial to adopt a more comprehensive approach to identifying giftedness that goes beyond traditional assessments. For example, utilizing existing tools that measure creativity, and practical problem-solving abilities can provide a more complete picture. Besides, incorporating qualitative measures such as teacher evaluations, peer reviews, self-assessments, and observational data might be advantageous in providing a holistic view of a student's abilities. Lastly, encouraging educational policymakers to revise identification criteria for gifted programs to include multiple intelligences could lead to more inclusive and effective educational strategies.

Cognitive abilities

In this section, we summarize the findings related to the cognitive characteristics of gifted children, highlighting their significance in advancing our understanding of giftedness. By examining these results, we aim to provide insights that can inform both theoretical frameworks and practical applications in the field of gifted education.

Group performance was significantly different between gifted children and control children in cognitive tasks in about 70% of comparisons evaluating reaction time, 53% evaluating accuracy, and 59% evaluating both accuracy and reaction time. These findings suggest that reaction times may be a more sensitive metric in distinguishing between gifted and control groups in the cognitive tasks.

Considering working memory tasks, 63% of comparisons showed significant differences in accuracy between gifted and control children. Friedman et al. (2006) specifically showed that working memory is highly correlated with intelligence and showcasing the value of working memory tasks for assessing giftedness. In our review, gifted children showed better results on both forward and backward digit span task (Calero et al., 2007; Fard et al., 2016; Leikin et al., 2013), on recall of categorized words (Coyle et al., 1998; Zhang et al., 2017), as well as manipulating them (Calero et al., 2007; Fard et al., 2016; Leikin et al., 2013). However, gifted children did not show better accuracy in the Corsi task that involves visual–spatial working memory (Leikin et al., 2013; Paz-Baruch et al., 2016). Thus, on working memory tasks gifted children exhibit superior accuracy in storage, manipulation and retrieval, but not in spatial domain, specifically in the Corsi block-tapping task. This discrepancy in results may be attributed to the Corsi task's greater cognitive demands and its motor component, while the digit span and recall tasks are typically less effortful (Piccardi et al., 2019). However, it is worth noting that the studies utilizing the Corsi task did not analyze reaction times, which may limit a comprehensive comparison between gifted and control children; if reaction times had been measured, it is possible that gifted children could have shown advantages in the spatial domain as well, as spatial attention tasks revealed more differences in reaction time than accuracy between gifted and control groups.

Results on attention revealed a trade-off pattern between speed and accuracy. Enhanced speed, rather than accuracy, has been demonstrated by gifted children in alertness, spatial attention (Zhang et al., 2016) and attentional switching (Duan and Shi, 2014; Zhang et al., 2016). While the enhanced precision at expense of superior speed was established in sustained and supervisory attention domains (Zhang et al., 2016). In divided attention gifted children outperformed their control children in both speed and accuracy (Zhang et al., 2016).

A speed-accuracy trade-off was also revealed for gifted group in both automatic and effortful inhibition tasks (Johnson et al., 2003), where they demonstrated enhanced speed rather than accuracy; and go-no-go task (Liu et al., 2011a), in which gifted children answered more accurately than their peers but demonstrate similar reaction time. Gifted children outperformed in both accuracy and reaction time in Eriksen flanker task (Liu et al., 2011b). Critically, inhibition processes that characterize Flanker tasks are considered more cognitively loaded, as competing cognitive processes need to be suppressed, whereas inhibition to the go-no-go task involves the suppression of a dominant response (Hung et al., 2018). Thus, children in the gifted group seem to show better performance on tasks with higher cognitive demands and overall tend to be either faster or more accurate in tasks of inhibition.

Planning and strategy tasks are also typically considered as more cognitively demanding. Gifted children outperform their control peers in geometric problem solving (Vogelaar et al., 2017; Waisman et al., 2016). However, gifted children did not solve the Tower of Hanoi/London planning task with less moves than their peers in control groups (Montoya-Arenas et al., 2018; Vogelaar et al., 2019). This difference in outcomes may be related to varying levels of control within the experimental designs and the differing time constraints during task execution; for example, the relatively unstructured nature of the Tower task allows for more flexibility in the problem-solving process, including variations in time and the strategies employed which could introduce additional confounding variables and make it more challenging to draw definitive comparisons between groups.

A reaction time advantage was demonstrated in 83% of comparisons examining elemental information processing using tasks such as simple reaction time, odd discrimination and abstract matching (Duan et al., 2013; Kranzler et al., 1994). This fact goes in line with our ERP results, which demonstrated shorter ERP latency in gifted children during performance of tasks that require inhibition of irrelevant information (Li et al., 2020; Liu et al., 2011b; Table 6).

Overall, our results demonstrate a consistent advantage of gifted children in verbal working memory, inhibition and geometric problem solving, and shorter reaction time in attentional switching and elemental information processing. Our results align with a recent mini-review that showed the advantages of gifted children in verbal working memory and attentional switching based on the sample of 15 eligible studies (Bucaille et al., 2022). Other researchers (Friedman et al., 2006) specifically showed that working memory is highly correlated with intelligence and showcasing the value of working memory tasks for assessing giftedness, which is also consistent with our results. These findings suggest that verbal working memory and attentional flexibility could be potential cognitive characteristics of giftedness identification. Besides, our results highlight a speed-accuracy trade off pattern, which is mostly prominent in attention and inhibition tasks. We speculate that higher cognitive capacity in gifted children enables them to process the task faster or improve accuracy, particularly in more complex tasks. This mechanism may explain higher reaction time in some tasks and higher accuracy in others in our review. Insights gleaned from psychophysiology data may clarify this trade-off, thereby enriching the discourse on cognitive characteristics associated with giftedness.

Psychophysiology

In this section, we summarize findings on the psychophysiological characteristics of gifted children which might underlie cognitive characteristics mentioned above. By examining brain patterns, researchers can identify specific regions and networks that are more active or efficient in gifted children. This helps pinpoint the neural basis of advanced skills in problem-solving, memory, and attention.

EEG studies of ERPs show that gifted children differ significantly from the control group in both early and late ERP components. The earliest component of the ERP—P1 (100 ms after stimulus onset)—reflects the earliest stages of information processing. Amplitude of the parietal P1 in response to a stimulus when solving geometric problems was increased in gifted older adolescent boys (Waisman et al., 2016). The authors explain this effect by early analytical activation and more focused attention related to the stimuli in gifted in comparison with control children. Meanwhile, latency of P1 in this study was also higher in the gifted group, which shows a possibly compensatory slower brain reaction in gifted adolescents. However, another study that used the identification of facial expressions task found no differences in P1 between gifted and control younger adolescent boys (Liu et al., 2015). This inconsistency may be explained by the fact that the authors used an affective task, whereas previous studies focused on cognitive tasks, which typically show more stable differences. The absence of differences in P1 for younger adolescents might suggest that they have not yet developed the same cognitive processing capabilities as older adolescents. Furthermore, the differing methods used to identify gifted children—RAPM in one study and Cattell's culture fair test in another—could contribute to the varying findings across studies.

Articles also examined ERP component N2, which is believed to be related to both classic response conflict (Liu et al., 2011b) and emotional conflict (Li et al., 2020). According to our review, N2 had a larger amplitude in gifted children, which can be interpreted as enhanced conflict processing. The results are consistent between the two studies despite the fact that authors studied different age groups and used different methods for determining giftedness. The latest study by Li et al. (2020) also revealed lower N2 latency in gifted children, which can be interpreted as a faster reaction to the conflict.

Most articles devoted their analyses to a rather late ERP component P3 related to attention allocation processes (Polich, 2007). Most studies revealed increased P3 amplitude in gifted primary school students and younger adolescents, both in response to a stimulus and in response to a cue (Liu et al., 2011a, 2011b; Zhang et al., 2006), while using different cognitive tasks—from visual search to cognitive control tasks. Also P3 in gifted children had shorter latency (Liu et al., 2011b; Zhang et al., 2006). This is consistent with behavioral findings showing shorter reaction times to cognitive tasks in favor of gifted children. Together, these findings may indicate enhanced and accelerated processes of voluntary or effortful attention processes in gifted children. The increase in P300 during top-down switching was also more pronounced in gifted younger adolescents (Duan and Shi, 2014). Thus, the amplitude and latency of P300 may account for the accelerated reaction times in attentional tasks among gifted children described in the Cognitive ability section.

The N400 is a negative deflection in the ERP waveform of the brain's electrical activity generally linked with language processing, object recognition, facial recognition, action processing, gesture

processing, mathematical cognition, semantic memory, recognition memory, and different developmental and acquired disorders (Kutas and Federmeier, 2011). Our synthesis of past studies showed increased amplitudes in the N400 associated with mental rotation (Anomal et al., 2020) and stimulus discrimination (Liu et al., 2007), presumably reflecting the ability of gifted individuals to devote more cognitive resources to these processes.

In summary, ERP research indicates that gifted children may exhibit more advanced information processing in the later processing stages, such as conflict resolution, top-down attention, discrimination of target stimuli, and mental rotation. Contradictory data have been obtained for the earliest stages of perception. These contradictions might be resolved by considering such experimental factors as age, the specifics of the task, and the method of assessing giftedness. Notice also that gifted children demonstrated increased speed of information processing in the later, more complex processing stages related to attention and conflict resolution, rather than earlier stages of perception (i.e., P1). This may suggest that cognitive differences between gifted children and their peers are more pronounced in complex, late-stage descending processes.

In addition to ERP, EEG activity can be studied by analyzing oscillations obtained using spectral analysis of the EEG signal and reflecting phase-synchronized fluctuations of the membrane potential of neurons (Siegel et al., 2012). Unlike ERPs, studies of EEG oscillations demonstrate not only increased activation related to cognitive processes in gifted children, but also decreased activation. When performing easy tasks for reasoning, gamma rhythm power (30–45 Hz) was lower in gifted older adolescents, which can be interpreted within the framework of neural efficiency hypothesis (Zhang et al., 2015). At the same time, gamma rhythm power increased when the task became more difficult in gifted older adolescents (Zhang et al., 2015). These inconsistent results might also be explained by the relation between task difficulty and the neural efficiency effect and indicate the need to take into account task difficulty in EEG studies of giftedness. It is also important to note that in this study, giftedness was partly determined through mathematical ability. A recent EEG study has shown that when studying the effects of neuronal efficiency, it is important to consider whether math or general giftedness is being assessed (Waisman et al., 2023).

Overall, one could decipher that gifted children demonstrate consistently enhanced and accelerated brain reaction only when performing complex tasks (such as complex reasoning), complex effortful processes (such as cognitive control when processing words) and complex (reflected in late ERP components) stimulus processing processes. This phenomenon might imply the ability to enhance complex information processing that distinguishes gifted children from control children. Our synthesis of results suggests that gifted children demonstrate the ability to activate top-down processing faster and more intensively (excluding at least switching processes). This may indicate an advantage for gifted children in using the limited cognitive resources required to implement this processing. Alternatively, one can entertain that perhaps gifted children have either more resources available or a more optimal functioning of the mechanism for mental effort allocation (Shenhav et al., 2017).

Other indicators of functional brain activity of gifted children in comparison with control children are sparse. BOLD activity in the posterior parietal cortex was increased in gifted older adolescents during a reasoning task (Lee et al., 2006), indicating that superior cognitive ability may stem from enhanced functionality within the fronto-parietal network rather than activation of additional brain regions. Supporting this, Ma et al. (2017) found that gifted children exhibit higher local connection density while relying less on brain hub regions. Furthermore, Nusbaum et al. (2017) demonstrated enhanced inter- and intra-hemispheric white matter integrity in gifted primary school children and young adolescents in frontal, central, and associative pathways, aligning with studies identifying the fronto-parietal network as crucial for intelligence (Dunst et al., 2014; Navas-Sánchez et al., 2014). Additionally, Kimmel and Deboskey (1978) reported that gifted children showed larger initial skin conductance responses and slower habituation compared to average peers, highlighting a connection between autonomic reactivity and intellectual functioning in children.

Overall, the difference in brain activity between the groups is detected only in the late components of evoked potential and in complex top-down processes. This might be explained by the fact that gifted children easily perform better than control children in simple tasks but in order to outperform on complex ones they need to employ additional neural resources. Speculatively, it can be assumed that this brain functioning specificity allows gifted children to outperform their peers in effortful cognitive tasks. However, it is still unclear if it is connected to the greater amount of such neural resources or to their increased motivation in response to the complex task. We will shed some light on this question in the next chapter on psychological characteristics of gifted children.

Psychological characteristics

In this section, we present findings related to the psychological characteristics of gifted children. A deeper understanding of these traits can provide valuable insights into gifted children's motivations and self-perceptions, enabling educators to create optimal conditions for unlocking abilities and ensuring mental wellbeing of such children.

Motivation is believed to be highly correlated with giftedness (Lens and Rand, 2000). Some researchers have even included motivation in the definition of giftedness (Gottfried and Gottfried, 2004). Moreover, according to some theories, motivation is a catalyst or resource for the development of giftedness (Gagné, 1985; Sternberg and Lubart, 1993), and low motivation is considered to be the reason for the academic underachievement of gifted children (Whitmore, 1986).

Studies comparing gifted children with a control group have all found higher scores on intrinsic motivation in gifted children (Bergold et al., 2020; Gottfried and Gottfried, 1996; Guez et al., 2018). Intrinsic motivation can be defined as the most self-determined form of motivation, where a student engages in a behavior spontaneously, out of interest and enjoyment. In developmental studies, intrinsic motivation is usually investigated as academic intrinsic motivation, which includes enjoyment of school learning and characterized by curiosity; mastery achievement motivation; persistence in learning; striving for new challenging tasks (Gottfried et al., 2001). External motivation, i.e., exogenous motivation in which a behavior is driven by external factors like encouragement or punishment, is also increased in gifted younger adolescents according to Guez et al. (2018). It is important to note that the causal relationship between motivation and giftedness remains unknown. Moreover, motivation

can increase the results of intelligence tests (Duckworth et al., 2011), thus influencing the selection of gifted children. Achievement motivation as an independent construct was also found to be more pronounced in gifted children (Wirthwein et al., 2019). Same results were reported by Gottfried et al. (2006), although the article did not pass the criteria of our review.

Often along with motivation, researchers investigate perceived self-efficacy, a characteristic which can be defined as self-esteem of capabilities in various fields of activity (Bandura and Cervone, 1986). Some authors even include it in the concept of motivation (Schunk and Pajares, 2002), while those who consider self-efficacy a separate personality characteristic have shown that it is increased in gifted children. In particular, this result is observed for academic self-efficacy (Guez et al., 2018), math ability self-concept (Bergold et al., 2020), self-esteem intelligence (Wirthwein et al., 2019), as well as self-regulatory efficacy (i.e., self-esteem of the ability to resist peer pressure to exhibit deviant risk behavior). These consistent results indicate that gifted children highly appreciate their abilities in various areas. It is not clear, however, whether high self-esteem is a consequence or a cause of giftedness. Only for social self-efficacy there was no difference between the groups (Guez et al., 2018). Social self-efficacy was defined as self-esteem of different social abilities. This divergent finding may be explained by López and Sotillo's (2009) results, which indicated that gifted children did not differ from the control group in measures of social adaptation based on various questionnaires, thus confirming their self-assessment. Speculatively, it can be assumed that enhanced motivation and self-efficacy are related to the specificity of effort allocation mechanism that allow gifted children to outperform their peers in effortful cognitive functions.

Studies using the Big 5 factors found that gifted adolescents were significantly more Open to experience and did not differ from their peers in Extraversion, Agreeableness and Conscientiousness (Limont et al., 2014; Wirthwein et al., 2019). The authors suggested that openness as the desire for new experience might be necessary for the development of giftedness. However, it is important to note that the results obtained do not indicate whether the revealed psychological characteristics of gifted children are a consequence or a cause of giftedness.

In summary, motivation seems to be consistently associated with giftedness, with gifted children showing higher levels of both intrinsic and extrinsic motivation, as well as enhanced self-efficacy—except for social self-efficacy. Gifted adolescents are also more open to experience.

To summarize the reviewed studies on the distinctive cognitive, psychophysiological, and psychological characteristics of gifted children, we highlight their unique traits across various domains. Our findings suggest a general advantage of gifted children in either reaction time or accuracy across key cognitive domains, including verbal working memory and attentional switching but also inhibition, geometric problem solving and elemental information processing. This advantage aligns with enhanced and accelerated brain activity during complex effortful processes, presumably due to their greater availability of brain resources or higher motivation in gifted children. Our findings further support the notion of generally higher intrinsic motivation in gifted children in comparison with their peers in the control group. Additionally, our investigation revealed heightened self-efficacy and openness to experience in gifted children as well as higher school achievements and different problem-solving strategies.

The importance of these results comes both from insights gained in basic research by uncovering characteristics of giftedness, and from the contribution these findings may make to the development of educational programs tailored for gifted individuals. Advantage in reaction times and accuracy across specific mentioned cognitive domains can aid in developing more targeted assessment methods for children's abilities. The observation that gifted children exhibit enhanced brain activity during complex tasks but roughly equivalent one in comparison with their peers during simple tasks, might suggest to educators that the most developmental environments for gifted students are those that provide increased intellectual challenges. Additionally, by examining the brain patterns of gifted children in general, researchers can clarify the underlying mechanisms behind high intellectual potential. Gifted children's heightened intrinsic motivation, self-efficacy, and openness to experience can offer educators valuable insights into creating environments that support their potential and wellbeing.

In the next section we elaborate on the future research directions to advance the state of the art in the field of intellectual giftedness.

Considerations for future studies

Cognitive function terminology and measurement variability

The review of the literature and the generalized interpretation of the results of research are greatly hampered by inconsistent terminology describing cognitive functions. Different authors rely on different theoretical models of cognitive abilities, which gives rise to an unlimited number of studied functions and their terms. We recorded approximately 50 different terms that describe higher top-down information processing (see column 'Target of analysis' in Supplementary Table 1S). Most terms denoted some form of attention, both in the broadest sense (as cognitive control or executive functions), and its various aspects (divided, selective, spatial, etc.). Many authors have also studied higher-level cognitive abilities, such as reading, abstract reasoning, mental rotation, etc. It was often difficult to decipher specific semantic differences among studied functions, for example, between analogical and abstract reasoning, attentional control and cognitive control. To mitigate this limitation, we used terminology proposed by original articles. We also encourage future studies to add a short paragraph outlining how the terminology they use relates to others in the field (Table 11, step 1).

To examine cognitive functions of gifted and control children a wide variety of tasks was created by researchers. Variability in measurements of cognitive abilities complicates the feasibility of conducting a quantitative meta-analysis due to the heterogeneity of data. Further, the use of complex tasks that activate several cognitive mechanisms at the same time might complicate the comparison between the studies. Although not always possible because of time and resource restrictions it is advisable to include well-established cognitive tasks that can build the literature for ultimately identifying convergence across studies using quantitative meta-analyses.

Lack of standardization in methods

The field "Other tests" takes the second position in the list of widely used test to identify giftedness in children (Figure 2). This category includes all the validated tests which were used for selection.

TABLE 11 Seven step checklist for studying outstanding performers.

Step	Title	Description
Step 1	Match terminology	Relate terms used in the current study with one or more constructs in the literature
Step 2	Selection criteria	Provide rationale for assessment tools, metrics and score criterion for group selection
Step 3	Sample	Provide recruitment details and sample demographics in terms of country, age, gender, etc.
Step 4	Paradigm details	Provide paradigm details for all assessments used that include task instruction, task timing, parameters recorded
Step 5	Statistical significance	Provide the threshold used for statistical significance (not applicable to Bayesian statistics)
Step 6	Correlational analysis	Consider performing correlational analysis
Step 7	Availability of data	Make the data available for download in an online repository.

The profusion of tests, even those with established credibility, could potentially impact the coherence among them, further making interpretations more challenging. The use of thresholds in different studies to define giftedness varies significantly, reflecting differences in assessment tools, age groups, and research objectives. This lack of standardization suggests a need for more consistency and clarity in defining and measuring high intelligence in research and educational settings. To ultimately reach consensus we propose that future studies provide a rational for assessment, metrics and score criteria used to classify groups (Table 11, step 2).

Binary group division

We only analyzed data from studies that compared psychological measures between the groups of gifted and control children. However, the idea of dividing participants into two groups may be controversial in its origin. Though, it is necessary to determine the cut-off point when selecting gifted children to study in a gifted class, for research purposes there is no clear ground for such division as linear regression models are always available to identify the relation of giftedness with other characteristics of participants. Besides, categorizing intelligence through precise numerical divisions is somewhat contrived, given that intelligence spans a broad spectrum. Therefore, we suggest that future studies consider correlational approaches or organizing three or more groups specified criteria (Table 11, step 6).

Reporting style

The variability in the reporting styles of the studies also affects the result of systematic reviews and meta-analyses. Missing indication on the method of selection (or unclear definition), age and number of participants, and task descriptions limits the ability to conduct comprehensive and reliable syntheses of existing research. Variability in reporting style also has several implications on research in general. It may hinder the ability of other researchers to replicate the study accurately. Besides, inconsistencies in reporting make it challenging to compare results across different studies and may impact the generalizability of study findings. For these reasons, in our seven steps for studying outstanding performers we propose that future studies clearly define sample recruitment details and demographics, provide details paradigm administration, report statistical significance thresholds and tabulate descriptive statistics.

In summary, current research on gifted children reveals notable methodological, conceptual, and reporting gaps. These include variations in measurement techniques, a lack of standardization in assessment methods, contentious binary group classifications, inconsistent terminology for cognitive functions, and disparities in reporting styles, all of which impede reliable comparisons and synthesis of findings.

Limitations

The review has some important limitations. First, the study included search only from one database Web of Science due to resource constraints. Web of Science is one of the most popular and widely used databases for academic research and publication, which is known for its interdisciplinary coverage. Web of Science is also recognized for hosting high-impact journals and authoritative sources in gifted education and intelligence fields. Prior to finalizing our database selection, we conducted preliminary scoping searches in databases Web of Science and PubMed databases. The search in PubMed revealed substantial overlap with the articles indexed in Web of Science and did not yield a significant number of additional unique studies relevant to our topic. Therefore, we determined that Web of Science alone was sufficient to capture the breadth of literature necessary for our review. Nevertheless, we acknowledge that limiting our search to single database might bias the coverage of the relevant literature. Second, we acknowledge that restricting our review to English-language articles may introduce language bias, limit the comprehensiveness of our findings and affect the generalizability of our conclusions. Future research could benefit from including non-English studies or collaborating with multilingual researchers to provide a more exhaustive overview of the literature.

Third, the study includes only dichotomized information (gifted or non-gifted children), thus ignoring literature that examined correlation between constructs. We acknowledge that this fact diminishes the variability in the data and makes the results harder to interpret, especially with the differing cutoffs across studies. However, in the educational context identification of talented children is always a practical task: children either meet the criterion established by a specific program or not. Thus, in the current systematic review we rely on binary group allocation.

Forth, all the eligible studies were given the same weight when summarizing the results. It was done to ensure that a diverse range of perspectives and findings are considered in the review, which is particularly relevant as the research of giftedness is broad and there is limited consensus in the literature. Assigning equal weight might also help to mitigate potential biases that could arise from selectively emphasizing studies with larger sample sizes or more complex methodologies. This approach promotes a more balanced representation of the available evidence. Nevertheless, giving equal weight to all relevant papers may potentially affect the overall robustness of the review findings. In addition, the review did not

analyze effect sizes of the included studies, since in many articles it was not indicated or was calculated by different metrics.

Conclusion

This systematic review has provided a synthesis of the prevalent intelligence tests in identifying intellectual giftedness in children and the clearer understanding of cognitive, physiological and psychological characteristics which distinguish gifted individuals from their control peers. Our findings delineate a noticeable shift from traditional intelligence tests toward the utilization of more culturally appropriate measures. Comparisons among gifted and control children reveal superior abilities of the former ones in verbal working memory, inhibition, geometric problem solving, increased speed in attention-switching and elemental information processing. Consistently, psychophysiological assessments demonstrate heightened and accelerated brain activity during effortful cognitive processes. Psychological and behavioral tests further demonstrate that gifted children score higher on tests measuring intrinsic motivation, self-efficacy, and openness to experience, as well as achieving higher grades in school and employing better problem-solving strategies. We propose a simple seven step checklist for studying outstanding performers as our review emphasizes the need for continued research and refinement in assessment methodologies to advance the state of the art in the field of intellectual giftedness and address the unique needs of gifted children in educational context.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

EK: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. AL: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. NZ: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. MA: Conceptualization, Supervision, Validation, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2024.1411981/full#supplementary-material

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Turkish teachers' values with rational and non-rational truth and teacher emotions in teaching

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The aim of this study was to clarify the relationships between personal values, truth-related values and emotions among Turkish teachers. The Schwartz's Value Theory and Frenzel's teacher emotion model were used as the theoretical framework. This study used a cross-sectional correlational research design. The data were collected from 279 teachers with the Portrait Value Questionnaire (PVQ) where rational truth and non-rational truth values were added, and with the Teacher Emotions Scale (TES). The circular structure of the Schwartz Value Theory was tested by multidimensional scaling. The data analysis aimed to uncover relationships between personal values, truth-related values, and emotions. Rational truth emerged near self-direction and self-transcendence, yet items measuring non-rational truth were scattered among values. Females had higher regard for self-direction and hedonism than males. Non-rational truth was negatively correlated with enjoyment, while it was positively correlated with anxiety. The implications for gender roles in Turkish society are discussed.

KEYWORDS

personal values, teachers, emotions, Schwartz's value model, truth-related values, gender differences

Introduction

Many social scientists perceive that values have a fundamental importance in explaining human emotions and behaviors (Schwartz, 1992; Kusdil and Kagitcibasi, 2000; Schwartz and Bardi, 2001). Values have been the subject of numerous research (Cieciuch and Davidov, 2012; Demirutku and Sumer, 2010; Roccas and Sagiv, 2017; Schwartz and Butenko, 2014; Schwartz and Cieciuch, 2022) as a guiding concept in explaining cognitive and social structures, processes, and social behaviors in different disciplines. Values are also found to be related to professional behavior (Knafo and Sagiv, 2004) and guiding teachers' decision-making and their justification (Pajares, 1992). Teachers are important socialization agents in their cultures (Schwartz, 1992; Tamm et al., 2020) and role models to children (Thornberg and Oguz, 2016), and thus, their values are essential to examine. The research on teacher education has recently highlighted the importance of teacher-related individual characteristics including motivation, job satisfaction, self-efficacy, and emotions which increase the effectiveness of teaching and learning at schools (Alpaslan and Ulubey, 2017). Within the framework of professional competence in teaching, emotions have a very important role as they are highly influenced and shaped by surrounding the environment while shaping the professional actions and decisions as well as the personal growth of a person (Aral and Mede, 2018). In addition, teachers' emotions affect their instructional behaviors (Becker et al., 2014). There is a wide spectrum of value issues, scrutinizing the motivational goal of values differentially and developing the value list with added (truth-related) values, which form a cross-culturally stable motivational continuum (Ahola, 2017), but they have been the subject of very scarce studies.

In this study, teacher values are examined via the lens of truth-related values and explained with their emotions, which is the first empirical attempt to investigate this relationship among teachers.

Values are known to influence the country's political structure, education system, workplace productivity, and social welfare (Tatto, 2019). One explanation for cultural variation could be cultural tightness or looseness. This dimension, developed by Gelfand et al. (2011) and Uz (2015), refers to the normative pressures in a culture. While social norms are weak and deviant behavior is tolerated more in loose cultures, tight cultures have numerous strong norms and less tolerance for them. Considering the education and teachers in Türkiye[1], respect for spiritual values has come into force to be gained by students in all kinds of educational activities in the Turkish Basic Law of National Education since 1973 [Ministry of National Education (MoNE), 1973]. Hence, Türkiye, where cultural homogeneity is at a high level, represents a tight culture (Gelfand et al., 2011; Uz, 2015). The aim of this study is to examine, how the two motivational constructs, personal values and emotions, are related to each other among Turkish teachers.

TABLE 1 Schwartz's basic values and their contents (Schwartz, 1992).

Value	Content
Power	Societal prestige and controlling others
Achievement	Personal success and competence according to social norms
Hedonism	Pleasure and the satisfaction of sensual needs
Stimulation	Excitement, novelty and challenge in life
Self-direction	Independent action and thought, making one's own choices
Universalism	Understanding, tolerance and protection for the welfare of all people and for nature
Benevolence	Protecting the welfare of close others in everyday interaction
Tradition	Respect, commitment and acceptance of the customs and ideas that one's culture or religion impose on the individual
Conformity	Restraint of actions, inclinations and impulses likely to upset or harm others, or violate social expectations or norms
Security	Safety, harmony and the stability of society, of relationships and of self

Personal values

Currently, Shalom Schwartz's (1992) theory of universal content and structure of values is the most widely used in value research. According to the theory, values are goals and motivations, which serve as the guiding principles of people's lives. As cognitive representations of abstract goals, values motivate people to attain different interests. Universality in the theory means that the meaning of values (content) and their location in the value model (structure) are approximately the same in different cultures. Besides the cognitive component, values include an affective component, and these two components are interconnected. Thus, desiring the goal (e.g., success) indicates that one has a positive effect toward it (Schwartz, 1992).

Schwartz's theory defines values as organized into 10 universal types that serve different interests or motivational goals. Values and their contents are presented in Table 1.

According to Schwartz's (1992) theory, the goals and interests that values serve can be either compatible or conflicting with each other, and based on these compatibilities and conflicts they form a special two-dimensional circular structure on two levels. Firstly, values can serve either individual or collective interests. Power, achievement, hedonism, stimulation, and self-direction are values that serve individual interests; and benevolence, tradition, and conformity serve collective interests. Universalism and security serve both interests and are situated in the boundaries between these two. Secondly, values structure forms two main dimensions, self-transcendence vs. self-enhancement and openness to change vs. conservation (Figure 1). The former represents the extent to which people are motivated to transcend selfish concerns and promote the welfare of others (including such values as benevolence and universalism) compared to enhancing their own personal interests even at the expense of others (power and achievement values). The latter relates to the motivation to follow one's own intellectual and emotional interests (self-direction, stimulation, and hedonism values), compared to preferring the status quo and the certainty provided by relationships with close others, institutions, and traditions (tradition, conformity, and security values). Correlations between values and other variables should demonstrate a sinusoid pattern: for example, empathy shows the highest (positive) correlation with universalism and the lowest (negative) with power, and the remaining correlations increase and decrease systematically as one moves along the circle (Myyrya et al., 2010). The multidimensional structure of values has reached empirical support in different cultures (e.g., Schwartz and Boehnke, 2004).

In Schwartz's (1992) original study and presentation of the value theory, the main target group was schoolteachers because they, according to Schwartz (p. 18), "play an explicit role in value socialization, they are presumably key carriers of culture, and they are probably close to the broad value consensus in societies." Recent studies in different cultures show that self-transcendence and openness to changes values seem to be high in teachers' value hierarchy whereas self-enhancement and conservation values are lower (Barni et al., 2019; Marušić-Jablanović, 2018; Perrin et al., 2021; Tamm et al., 2020). Previous studies in the Turkish context confirm the global empirical data (Ceylan and Yildiz, 2019; Uzun, 2018); however, recent studies show that power, achievement and tradition (Tekin, 2021) and hedonism (Gonluacik et al., 2022) are most preferred value types among Turkish teachers.

Truth related values

Schwartz's (1992) model presents values that are found to be universal by both the content and structure. Less is known about the values that are motivationally mixed and/or non-universal. Wach and Hammer (2003) proposed two truth-related values to be added to Schwartz's value survey: rational truth and non-rational truth. Rational truth refers to theoretical, logical, and predictable truths and non-rational truth refers to belief in magic, intuitiveness, fatalism, and the denial of rationality (Ahola, 2017), pietism (Emre and Yapici, 2015; Yapici et al., 2012) and hospitality, secularism, and male privilege (Kusdil and Kagitcibasi, 2000). The sparse research concerning truth-related values shows that rational truth is located

1 Türkiye is the official international name for the country formerly known as Turkey.

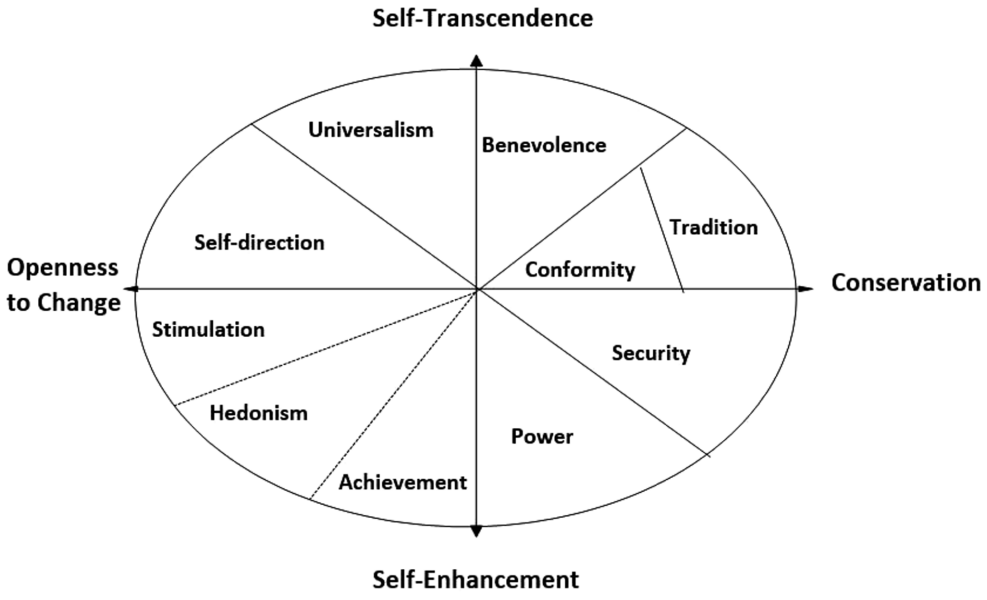

FIGURE 1
Schwartz's model of motivational types of values. Reproduced with kind permission from Elsevier © 1992.

near universalism and self-direction in the Schwartz model whereas non-rational truth has been close to security, tradition, and power (Ahola, 2017; Wach and Hammer, 2003). Ahola (2017) concludes that more studies about truth-related values are needed, and they are especially worth considering when investigating knowledge-related topics. Because teachers possess an important role in educating new generations, it is crucial to examine how truth-related values are related to other values and how they are regarded in teacher samples.

Gender differences in values

It has been discovered that, for both genders, the arrangement of single values within value types and the structure of value types are strikingly similar across a wide range of civilizations (Prince-Gibson and Schwartz, 1998; Struch et al., 2002). Concerning the value preferences, females have generally valued benevolence and universalism more than males, and males have usually higher regard for power and achievement than females (e.g., Papastylianou and Lampridis, 2016; Smith and Schwartz, 1997). Results obtained in the Turkish context are mixed: in some studies, gender does not affect value differences (Imamoglu and Karakitapoglu-Aygun, 1999), whereas some reveal that gender is an important determinant of value differences (Demirutku and Sumer, 2010; Firat and Acikgöz, 2012; Kusdil and Kagitcibasi, 2000; Yilmaz, 2009).

All these results may be interpreted to mean that the Turkish schoolteachers' values in meaning are identical across genders; however, it seems that among them the gender differences might be a bit different from those observed in other cultures. Yilmaz (2009) found that female teachers had higher regard for self-transcendence and conservation values than males. In Aktay and Ekşi, 2009 study female teachers preferred to score on self-direction more than males whereas males scored on universalism more than females. In addition, there exists research in the Turkish context that females gave more importance to hedonism and security than males (Firat, 2008; Memis and Gedik, 2010).

Teachers' emotions

A recently applied model to study teacher emotions is Frenzel (2014) and Frenzel et al. (2016) Teacher Emotions Scale (hereafter TES). According to appraisal theory (e.g., Moors et al., 2013), it is based on the idea that emotions are primarily caused by individuals' subjective cognitive judgments about significant situations and events rather than by the situations and events themselves (Frenzel, 2014). The model considers the three main emotions in teaching to be enjoyment, anger, and anxiety, which are measured by the TES. The TES sees emotions as states more than traits, i.e., temporary experiences, instead of more stable and general feelings (Frenzel et al., 2016). Pleasure derived from either a previous (outcome-related joy) or an upcoming (anticipatory joy) occurrence, or from indulging in a pleasurable activity, is referred to as enjoyment. For enjoyment, the main source seems to be students' success (Frenzel, 2014). Anger is claimed to be the most prominent negative emotion in teaching (e.g., Sutton and Wheatley, 2003), although it might be reported less than it is felt because it is not socially acceptable (Frenzel, 2014). Anger can be caused by blaming others for unwanted incidents (Smith and Lazarus, 1993), for instance, disobedient pupils, or being discontented with one's own behavior (Frenzel, 2014). Threat and incapability to cope with it, evokes anxiety (Smith and Lazarus, 1993). Anxiety can be felt due to poor preparation for teaching or problems with discipline in the classroom, and it is found to be more typical among young teachers (Frenzel, 2014).

Teacher emotions are closely associated with not only teachers' well-being (Gross and John, 2003) but also the quality of education at schools (Alpaslan and Ulubey, 2017; Sutton and Harper, 2009). Likewise, the teachers' academic emotions, in which love (Hargreaves,

2005) and enjoyment (Chen, 2016) are mentioned as the most frequent emotional labor by teachers in class, are very significant for achieving the goals and mission of education (Shariatmadari et al., 2019).

Relationships between personal values and emotions

Because personal values have both cognitive and affective components, they trigger feelings when they are activated; for instance, high regard for independence value may cause anxiety if independence is threatened (Schwartz, 2012a). In general, it seems that values and emotions that share the same goals are related (Nelissen et al., 2007). Tamir et al. (2016) have argued that values can also set standards for emotions, not just behaviors, by pointing out desirable emotions. For instance, the more self-enhancement values were endorsed the more respondents wanted to feel pride in their everyday life. In the teaching context, Büssing et al. (2020) found that universalism and benevolence predicted the anticipated enjoyment of teaching. Van Boven et al. (2010) claim that teachers tend to feel different emotions in class maybe because of values. However, studies examining relationships between value priorities and emotions among teachers are scarce.

Aim and research questions

The aim of this study is to elaborate the location of Turkish teachers' rational and non-rational truth values in Schwartz's value structure in correlation with emotions in teaching. For this purpose, the following research questions are presented:

1 What is the location of Turkish teachers' truth-related values in the Schwartz value structure?
2 Do the value priorities among Turkish teachers differ by gender? If yes, how do they differ?
3 What are the relationships between personal values and emotions among Turkish teachers?

Methods

Research context

Teachers work at private and state schools in Türkiye whose compulsory education lasts 12 years (4 years in each of the three stages of primary education, elementary education, and secondary education). All students who have completed their compulsory education must take a national exam to be enrolled in a higher institution. Turkish Higher Education Institute distributes the students according to their scores and choices that they made after the national exam. Student teachers start their academic life when they are enrolled in a faculty of education. They must enter a national exam after their graduation and obtain a satisfied score for their appointment in a state school. The graduated teacher students can work at any private school if accepted. The students who graduated from institutions or other faculties must obtain a teaching license from a faculty of education to become formal teachers.

Participants

Altogether 293 Turkish teachers participated in the study. After the analyses, 14 of the respondents were discarded because of their deficient and inadequate information. The final sample consisted of 279 Turkish teachers, 64 of whom were male (23%) and 215 were female (77%). The respondents worked in private or state schools (87%) in varied cities located in Türkiye. The mean age of the participating teachers was 36.8 years {with Std = 8.04 [female 35.5 (Std = 8.00) and male 41.1 (Std = 8.58)]}. Their teaching experience varied between 1 and 40 years and the mean years of teaching experience was 13.02 (Std = 8.58). The minority (15%) were classroom teachers, and the majority (85%) were subject teachers. Most of the teachers held bachelor's degrees (72%).

Instruments

Portrait value questionnaire

To measure value priorities, the Portrait Value Questionnaire (PVQ; Schwartz et al., 2001) was used. PVQ was conducted in Turkish language which was adapted by Demirutku and Sumer (2010). It consisted of 40 items which represented 40 different people, in other words, 40 portraits. In each portrait, a value type was described in two sentences. For example, 'He thinks it is important to be ambitious. He wants to show how capable he is.' or 'It's very important to her to help the people around her. She wants to care for their well-being.' The respondents made a judgment on how similar they are to the people in the characterized portraits on a six-point scale (1 = not like me at all; 6 = very much like me). Since the Turkish language has a single word for gender pronouns (she or he), one version of the questionnaire (Turkish version of PVQ) was used for both female and male participants.

In this study, additional (truth-related) items were translated into Turkish by the researcher. Then, two English teachers translated the items and made a co-decision on appropriate translations after back-translation procedures. In this data, Cronbach's alphas for PVQ were 0.70 for power, 0.83 for achievement, 0.87 for hedonism, 0.72 for stimulation, 0.87 for self-direction, 0.95 for universalism, 0.80 for benevolence, 0.59 for tradition, 0.78 for conformity, 0.84 for security, 0.83 for rational truth and 0.25 for non-rational truth. Centralized sum variables were employed in the study to prevent unequal usage of the scale: a personal mean of all 40 portraits was determined for each subject independently, and the means of the sum variables were divided by the personal mean.

Teacher emotions scale

Emotions in teaching were measured using the Teacher Emotions Scale (TES; Frenzel et al., 2016) which was adapted into Turkish by Alpaslan and Ulubey (2017). The TES, a 4-point Likert scale (0 = strongly disagree, 4 = strongly agree), consisted of 12 items as a list of statements describing teachers' experiences in teaching. In this data, Cronbach's alphas for TES, which is based on three dimensions, are 0.80 for anger, 0.75 for anxiety, and 0.93 for enjoy. Teacher emotions measure teachers' emotional experiences in teaching; for example, 'I generally have so much fun teaching that I gladly prepare and teach my lessons' or 'I generally feel tense and nervous while teaching'.

Procedure

The online questionnaire was delivered to the volunteering teachers via e-mail after obtaining ethical permission from a state university in Türkiye. The data were collected online in summer 2021. Strict confidentiality was followed in the treatment and reporting of the data without any identifier. The raw data is only available to the researchers and protected in encrypted files. Completing the whole questionnaire took approximately 20 min.

Data analysis

In this cross-sectional correlational study, the data was analyzed using SPSS software package version 26.0. The mean and standard deviation of values show the differences between females and males, MDS scaling introduces the positive and negative correlations between values, and the intercorrelation demonstrates the significance of the differences between values and emotions. The circular structure of the Schwartz Value Theory and how truth-related values are located in it was tested by multidimensional scaling. Due to the violence of the normal distribution of value and emotion variables, the mean differences in values between genders were tested with the non-parametric Mann–Whitney *U* test. The Pearson correlation was used to examine the correlations between values and emotions.

Results

The location of truth-related values in the Schwartz value structure

In order to test whether the circular structure by Schwartz (1992) Value Theory is observed in our sample, SPSS multidimensional scaling (MDS, PREFSCAL) was performed. In MDS schemas, values are represented as points on a multidimensional space, and the distance between points reflects the relationships between values (Kusdil and Kagitcibasi, 2000). In other words, values located in close proximity to each other on a multidimensional space (e.g., benevolence and universalism) are expected to be conceptually positively related and values that are far away from each other (e.g., rational truth and non-rational truth) are expected to show low or negative correlation with each other. In Figure 2, the location of the values shown in the multidimensional space symbolizes their conceptual relationship with other values.

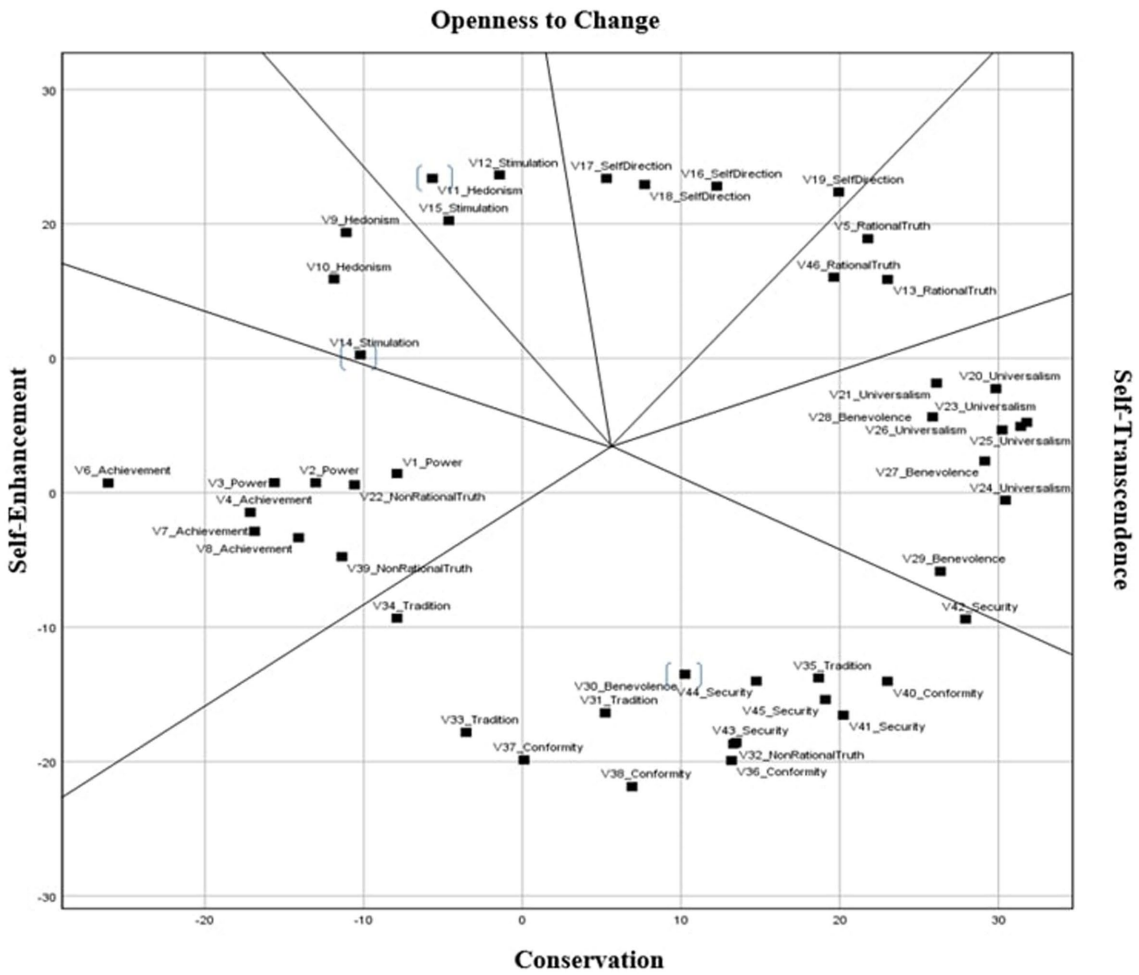

FIGURE 2
Multidimensional scaling of 46 items (MDS, PREFSCAL). *N* =279. The mislocated items are shown in parentheses.

The results broadly confirmed the theoretical model outlined by Schwartz. However, unlike the theoretical model, it was observed that some value types were combined with the value types adjacent to them. Such small deviations are considered quite normal because it was reported that samples in which all 10 value types are detected in distinct locations are very rare (Sagiv and Schwartz, 1995). In this sample, it was found that four values (hedonism/stimulation, self-direction, and rational truth) of the 12 value types (values and added truth-related values) had a distinct location on the multidimensional space, while the rest were combined with a value type on the side. No discernible value was detected in the theoretical sequence, and all values were observed in Schwartz's value structure. And there was no complication with the differentiation of the main value groups (self-enhancement, openness to change, self-transcendence, and conservation).

There were some deviations from Schwartz's model, but mostly the basic value types followed the theory. The most glaring deviation in the value circle in this sample was observed in the non-rational value type. Non-rational truth is located in a fairly dispersed way (close to achievement-power and security-conformity), which was expected in light of previous studies (Ahola, 2017). Nevertheless, this confirmed our hypothesis in the Schwartz value model since these values were located far away and on the opposite side of the rational truth value type.

The fact that the two additional values were located at opposite poles indicates that they conflict with each other as hypothesized. Rational truth value was found to be congruent to the self-direction and self-transcendence types as predicted in the theory. The scattered inclusion of the non-rational items in the theoretical sequence might be a situation specific to this value type or the result of a situation specific to Turkish culture.

Gender differences in values

Table 2 reports the rank of the values and differences in value priorities according to gender. Universalism and rational truth were highest in rank. Power and non-rational values were the least value preferences by teachers. However, those outside of self-direction and hedonism were not significant in gender. And enjoyment had the highest mean among emotions in teaching. It was observed that there were slightly higher scores in females' emotions by comparison with males.

Mann–Whitney *U* test results (Table 2) showed that hedonism ($p = 0.05$) and self-direction ($p = 0.002$) values were significant in genders. The results were interpreted that females attributed importance to hedonism [mean = 1.01 (female); mean = 0.95 (male)] and self-direction [mean = 1.11 (female); mean = 1.04 (male)] more than males. However, the results showed that there was no significant difference between females and males regarding emotions.

Relationships between values and emotions

The correlations between values and emotions were reported in Table 3. There we can see that enjoyment was negatively correlated with anger and anxiety which had a high-sized positive correlation between each other. Enjoyment also had a negative correlation with non-rational truth. Anger showed negative correlation with conformity, security, and benevolence, and positive with power and achievement. Anxiety and security had an inverse relation while anxiety and non-rational truth and tradition were positively correlated.

TABLE 2 Means (M) and standard deviations (SD) for gender.

Values and Emotions	Female (*N* = 215)		Male (*N* = 64)		
	M	SD	*M*	SD	*p*
Universalism	1.18	0.19	1.20	0.17	ns
Rational truth	1.13	0.17	1.12	0.16	ns
Benevolence	1.07	0.16	1.06	0.14	ns
Self-direction	1.11	0.15	1.04	0.17	0.00**
Security	1.06	0.16	1.07	0.12	ns
Conformity	1.02	0.16	1.04	0.16	ns
Hedonism	1.01	0.26	0.95	0.29	0.05*
Stimulation	0.95	0.23	0.90	0.20	ns
Tradition	0.87	0.20	0.92	0.21	ns
Achievement	0.86	0.29	0.90	0.27	ns
Non-rational truth	0.80	0.24	0.75	0.22	ns
Power	0.68	0.35	0.73	0.31	ns
Enjoyment	3.39	0.51	3.32	0.49	ns
Anger	1.82	0.51	1.74	0.46	ns
Anxiety	1.70	0.53	1.61	0.48	ns

N = 279.
ns, not significant, *$p < 0.05$, **$p < 0.01$.

Discussion

Results in the light of the previous literature

This research aimed to reveal the location of Turkish teachers' rational and non-rational truth values in Schwartz's value structure in correlation with emotions in teaching. Three research questions demonstrate; (1) the MDS results of rational and non-rational truths in the circular continuum, not surprisingly, located reversed among the consistent ordering of 10 sets of values, (2) Turkish female and male teachers have some distinct traits in hedonism and self-direction which does not represent the original theory in gender, and (3) the empirical evidence of teaching emotions which supports the predictive and explanatory dynamics of values in relation to emotions.

Firstly, it is legitimate in this research that non-rational truth is scattered in the structure since past research also indicated it was not located in a distinct region but opposite to rational truth (Ahola, 2017). However, rational truth emerged between self-direction and self-transcendence as a distinct region. The unique location of rational truth and its reverse location of non-rational truth revealed that PVQ perfectly reproduced the order of teachers' values around the circle of 10 values in the original theory. Since education values show much similarity with rational truth (Portman, 2014), the current MDS result supporting fine-tuned partitioning provides a precise understanding of the relations between values and education. This implies rational

TABLE 3 Inter-correlation among values and emotions.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Power														
2. Achievement	0.40**													
3. Tradition	−0.16**	−0.17**												
4. Conformity	−0.28**	−0.14*	0.25**											
5. Security	−0.35**	−0.22**	−0.01	0.42**										
6. Universalism	−0.34**	−0.45**	−0.14*	0.01	0.16**									
7. Benevolence	−0.39**	−0.40**	−0.00	0.12*	0.07	0.39**								
8. Self-direction	−0.25**	−0.31**	−0.33**	−0.22**	−0.01	0.25**	0.15**							
9. Stimulation	0.00	−0.04	−0.22**	−0.44**	−0.39**	−0.23**	−0.17**	0.24**						
10. Hedonism	0.10	−0.02	−0.26**	−0.35**	−0.26**	−0.26**	−0.29**	0.03	0.40**					
11. Rational Truth	−0.30**	−0.29**	−0.35**	−0.05	0.21**	0.48**	0.18**	0.35**	−0.08	−0.04				
12. Non-rational Truth	0.07	0.00	0.27**	−0.20**	−0.31**	−0.32**	−0.16**	−0.15*	0.10	0.00	−0.36**			
13. Enjoyment	−0.10	−0.07	−0.06	0.08	0.10	−0.03	0.09	0.09	0.09	−0.01	0.11	−0.22**		
14. Anger	0.17**	0.13*	0.00	−0.17**	−0.14*	−0.09	−0.18**	0.00	0.04	0.04	−0.05	0.10	−0.52**	
15. Anxiety	0.06	0.03	0.14*	−0.11	−0.16**	−0.00	−0.08	−0.05	0.06	−0.05	−0.08	0.20**	−0.47**	0.56**

*$p < 0.05$, **$p < 0.01$.

truth presents some motivation in common with self-direction, universalism, and benevolence in education. Our research result also confirms the previous research (Kusdil and Kagitcibasi, 2000) in which Turkish teachers' universalism and self-direction were positively correlated with secularism whose meaning embraces rational thought (Tejani, 2013).

Secondly, the fact that the value of hedonism, which is a value for enjoying life and was significantly higher in female teachers, may indicate that female teachers try to see the good sides of life more than male teachers. Likewise, the fact that women teachers had higher self-direction values may indicate that they think more individually and that they care more about the responsibility of standing on their own feet in the teaching profession. When Schwartz's value theory is evaluated here, the value confusion of male and female teachers in Türkiye draws attention since our result does not support the previous studies with teachers (Karabacak et al., 2019; Ros et al., 1999; Tekin, 2021). According to Boratav (2009), why hedonism is highly valued by Turkish females is because gaining pleasure and enjoying life are considered feminine behaviors within Turkish culture. The same contradiction was observed in some previous studies with teachers (Firat, 2008; Memis and Gedik, 2010; Turkan and Kaya, 2019) and described as a reflection of Turkish culture on women teachers who are influenced by both the Western and the Eastern culture due to the geopolitical location of Türkiye. Since females are described as having the social role of "being a mother" or "being a good wife" (Firat and Acikgöz, 2012), teaching occupation is generally regarded as a traditional female occupation in Türkiye (Gonluacik et al., 2022). Thus, a possible explanation for hedonism and self-direction might be that Turkish female teachers tend to be stripped of the expected gender roles of today's society and enjoy life independently. The increased education level in society results in females becoming more liberated which may result in females valuing hedonism highly more than males (Dirilen-Gumus and Buyuksahin-Sunal, 2012; Feather, 2004). Dirilen-Gumus and Buyuksahin-Sunal (2012) also argue individuals' tendency to self-direction indicates their tendency to get more individuated; therefore, our results may indicate that female teachers are getting more individuated. Hedonism and self-direction inherently may become more important to female teachers since the importance of certain values increases for one sex as changing societal conditions facilitated their expression and pursuit (Schwartz and Rubel-Lifschitz, 2009).

Finally, correlation differences between values and emotions confirm one of the main features of values defined in Schwartz's theory that values are inextricably linked with emotions (Schwartz, 2006). We discovered that teachers' enjoyment in teaching was negatively correlated with non-rational truth. Not surprisingly as evidenced in previous studies (Malouff et al., 1992; Thyer et al., 1987) anxiety was positively correlated with non-rational truth. These results make sense conceptually, considering that feelings of enjoyment and anxiety are strongly negatively related to each other. Feelings of enjoyment refer to pleasure and satisfaction with something that is achieved (Frenzel, 2014) and anxiety refers to a perception of a threat to ego or self-esteem and not being able to cope with it (Smith and Lazarus, 1993). Non-rational truth values represent a belief in intuitiveness and denial of rationality (Ahola, 2017). Thus, non-rational truth may prompt worry about the unpredictability of the world, compared to the rational truth that emphasizes theoretical, logical, and predictable truth (Wach and Hammer, 2003). This result

captures a meaningful understanding of values that non-rational truth may reduce teachers' enjoyment and even cause anxiety in teaching.

In conclusion, the current study demonstrated the location of the truth-related values in Schwartz's value structure. The findings support Ahola's (2017) research results in which rational truth values were positively associated with self-direction and self-transcendence. The teachers prioritizing rational truth concern that material well-being is secondary or unnecessary for the welfare or exploring. And as demonstrated in the previous study (Ahola, 2017), non-rational truth values were positively correlated with power and achievement, which indicates that those teachers attach importance to being strong or successful in the hierarchy within the group they are affiliated with. This result could be due to the Turkish culture, where social orderliness is predominantly achieved through hierarchical roles as Kusdil and Kagitcibasi (2000) inferred. On the other hand, correlations revealed the positive relation between anxiety and negative relation between enjoyment and non-rational truth. After all, teachers' values could promote their emotions in teaching (Hagenauer and Volet, 2014; Schutz, 2014). Hence, our study provides some implications that teacher education programs may improve teachers' understanding of quality teaching skills and knowledge by value-based pedagogy (Curtis, 2012). It is essential that teacher education programs systematically enhance identifying and clarifying one's own values as a basis for the profession and underlying professional actions. This has been shown to be essential, but a bit neglected aspect in teacher education. The effectiveness of teacher preparedness could be further promoted considering the relationship between teachers' non-rational truth and emotions in teaching as evidence in this study. It is also important to emphasize the influence of teachers' well-being which could benefit from teachers' values (Barni et al., 2019) and their emotions in teaching (Frenzel et al., 2015) in requirement of teacher quality.

Methodological reflections and limitations

The current study has investigated the location of truth-related values in relation to emotions in a sample of Turkish teachers. Despite the contribution to the literature on teachers' values and emotions, the limitations of this study are in question and future researchers should always pay regard to them in interpreting the presented results. The data were collected at one time and shortly after the lockdown. When we consider the stability of values across time distinguishes them from needs and motives and therefore change more readily (Sagiv and Schwartz, 2022), both values and emotions could have been influenced during the lockdown. Possible factors that would affect teachers' emotions or the relationship between them in a teaching process that they had no previous experience with were ignored. However, since the current research was applied to the teachers in Türkiye which constitutes a tight culture (Gelfand et al., 2011), it will be worthwhile for future work to include diverse societies to compare teachers' values and emotions in teaching in tight and loose nations. The current study, which is original in its field, will undoubtedly shed light on future studies. Future research of this article generates an interesting study on the location of teachers' truth-related values in Schwartz's value structure and the relationship of them with emotions from the point of gender differences. Since teachers' emotions are key components of teachers' psychological well-being (Frenzel et al., 2015), teacher training programs might benefit the positive relationship between rational truth values and enjoyment in teaching. Moreover, because emotions are essential for teachers' work and outcomes of teaching, in teacher education it is essential to help pre-service teachers to find adaptive ways to cope with negative emotions such as anger and anxiety. Since teachers' value priorities can vary with culture (Fischer and Schwartz, 2011), in-depth cross-cultural studies may also be conducted in tight and loose cultures exploring gender-based similarities and differences to enhance the generalizability of the findings of the study.

On the other hand, the fact that item 42, which is related to national security, was located near the value dimension of self-transcendence demonstrates the teachers associate national security with benevolence and universalism. Item 11 and item 14, which are about enjoying life and enjoying adventure, were dislocated between hedonism and stimulation. This finding is plausible when we examine their meaningful content. And item 30, caring about forgiveness, was located close to conformity and tradition, rather than within benevolence, which indicates that the teachers might perceive forgiveness as a factor of adapting to the environment in a communitarian culture as Türkiye (Sargut, 2015).

Lastly, even if we did not find any meaningful difference between value priorities and age, there exists a meaningful age difference in hedonism between males and females without using centralized sum variables. However, it does not affect our result as it was systematical in research that hedonism was negatively associated with age without a moderation effect of culture (Borg et al., 2017; Robinson, 2013), younger teachers also had higher regard for hedonism than older ones in our study. And the reliability of some of the values was low due to the tiny number of entries in each value's index. However, significantly lower reliabilities have also been seen in other studies (Myyry and Helkama, 2001; Sagiv and Schwartz, 1995). Nevertheless, the correlations between the values and other variables confirm the sinusoid curve hypothesis (Schwartz, 1992). Thus, despite the weaknesses in the Cronbach alphas, the pattern of correlations suggests the reliability of the measure.

Conclusion

As a result of this study, the location of rational and non-rational truth values in the value structure confirms the previous results (Ahola, 2017). It was proved that rational and non-rational values had a confirmed location among global values. Considering that teachers are important socialization agents in their cultures (Barni et al., 2018; Schwartz, 1992; Tamm et al., 2020) and role models to children (Thornberg and Oguz, 2016), the high regard of the rational truth value – being the second highest in the value hierarchy for both females and males – and its positive link to self-transcendence values universalism and benevolence, are notable. Self-transcendence values aim to promote the welfare of others (Schwartz, 1992), and especially universalism is related to mature moral thinking (Myyry, 2022). Rational truth emphasizes theoretical, logical, and predictable truth instead of intuitive thinking characterized by non-rational truth (Wach and Hammer, 2003). Thus, the results suggest that teachers at least in our sample emphasize transmitting collective instead of personal interests (Schwartz, 1992) and the importance of rational thinking. Nevertheless, how endorsing rational or non-rational truth values is associated with professional practices of teachers is an interesting question that should be scrutinized in future research.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Social and Humanities Scientific Research and Publication Ethics Committee at Trabzon University, Türkiye (E-81614018-000-574). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from the participants or the participants' legal guardians/next of kin in accordance with the national legislation and institutional requirements.

Author contributions

KÜ: Conceptualization, Formal analysis, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing. LM: Conceptualization, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing. AT: Conceptualization, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Reviews in Educational Psychology (Frontiers in Psychology 2010–2024): typology, topics, regional comparative and methodology toward digital and AI approaches

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This study presents a systematic review of reviews published in Frontiers in Psychology (2010–2024) to examine methodological and conceptual advances in educational psychology. The objective is to synthesize research trends over 14 years and explore global challenges, such as the digitalization of education and the integration of emerging technologies. Following PRISMA guidelines, a comprehensive search was conducted in Frontiers in Psychology, Web of Science, and Scopus, identifying 392 reviews. The selection process involved duplicate removal, title and abstract screening, and full-text evaluation, applying predefined inclusion and exclusion criteria to ensure methodological rigor. Data extraction and classification were carried out using an Excel-based structured database, analyzing publication years, methodological design, data sources, statistical and qualitative analysis methods, validation approaches, theoretical frameworks, thematic areas, geographical distribution, study limitations, reported results, practical applications and study populations. The methodological analysis highlights the predominance of systematic reviews, the increasing adoption of qualitative and mixed-method approaches, and a growing emphasis on digital tools and artificial intelligence. The study also reveals significant regional disparities in research output, with some regions being notably underrepresented. Beyond identifying trends, this review of reviews illustrates how psychology adapts to contemporary educational challenges through interdisciplinary methodologies and evidence-based strategies. The findings provide valuable insights into the evolving challenges in educational psychology, reinforcing the role of Frontiers in Psychology in driving methodological innovation and scholarly discourse. Furthermore, they contribute to the advancement of inclusive and sustainable educational practices aligned with the Sustainable Development Goals (SDGs). Future research should focus on meta-analyses of emerging trends, longitudinal methodological studies, and strategies to address regional imbalances, fostering a more globally representative perspective.

KEYWORDS

psychology and education, systematic review, meta-analysis, sustainable, development, regional comparative

Highlights

- This study synthesizes and critically evaluates educational psychology reviews published in *Frontiers in Psychology* (2010-2024).
- By analyzing 392 studies using PRISMA guidelines, the study identifies methodological patterns, validation techniques, and key constructs explored.
- The research compares educational psychology trends across different regions, highlighting methodological and thematic variations.
- The special issue provides an innovative and integrative approach to educational psychology, emphasizing self-regulated learning, inclusive methodologies, and the impact of family and social contexts on academic achievement.
- The structured database developed allows for further meta-analyses, longitudinal trends exploration, and interdisciplinary applications in psychoeducational research.

1 Introduction

Psychological reviews are fundamental tools for synthesizing and analyzing accumulated knowledge in specific fields, providing a robust foundation for advancing research (Higgins et al., 2024; Luyten et al., 2024). However, despite the growing number of reviews in psychology, there are still notable gaps regarding their methodological rigor, thematic focus, regional distribution or practical applications in educational contexts. In particular, the extent to which these reviews address contemporary educational challenges, integrate interdisciplinary approaches, and contribute to evidence-based practices remains unclear. This study seeks to bridge these gaps by systematically analyzing review articles published in *Frontiers in Psychology*, identifying predominant trends, methodological advancements, and areas where further research is needed to strengthen their impact on global educational goals.

Frontiers in Psychology was selected as the focal journal for this study due to its high volume of published reviews, its interdisciplinary nature, and its impact on advancing psychological research. As one of the largest open-access journals in psychology, it provides a broad and diverse collection of systematic reviews, meta-analyses, and theoretical contributions spanning multiple subfields, including educational psychology. Additionally, *Frontiers in Psychology* is recognized for its commitment to methodological innovation, often publishing studies that explore emerging trends in research design, data analysis, and technological advancements. Compared to other leading psychology journals, its open-access model facilitates greater visibility, accessibility, and international collaboration, making it a valuable resource for examining global trends in review methodologies. Given its strong presence in educational psychology research and its role in shaping methodological discussions, this journal serves as an ideal platform for analyzing the evolution of review practices and their contributions to the field.

While systematic reviews and meta-analyses have been widely used to synthesize empirical research, comparatively fewer studies have focused on how review methodologies themselves evolve over time. A key innovation of this study is that it constitutes a review of reviews, a methodological approach that has been applied in various disciplines but remains relatively underexplored in *Frontiers in Psychology*. Unlike previous systematic reviews or meta-analyses that focus on empirical studies, this study provides a comprehensive synthesis of the methodological and conceptual evolution of review articles published in the journal from its inception to the present. Although *Frontiers in Psychology* has published some reviews of reviews, no prior study has systematically examined how these methodologies have evolved within the journal as a whole. This unique approach offers a deeper understanding of editorial and methodological trends shaping psychological research, particularly in the field of educational psychology. By examining the evolution of review practices, this study contributes to a broader understanding of how systematic reviews and meta-analyses have adapted over time to address emerging challenges in psychoeducational research (Prothero et al., 2018; Topa et al., 2022; Troncoso Skidmore and Thompson, 2010).

Grant and Booth (2009) identify various types of reviews with specific objectives: narrative reviews synthesize literature qualitatively to provide an overview; systematic reviews apply rigorous criteria to identify and evaluate relevant studies; integrative reviews combine qualitative and quantitative methodologies; meta-analyses perform statistical analyses of combined results; critical reviews evaluate literature from a theoretical perspective; conceptual reviews develop new theories based on previous studies; and rapid reviews synthesize information within short timeframes. These typologies ensure the quality and relevance of conclusions by adapting to different objectives (Kreuder et al., 2024; Su and Yang, 2024).

Recent literature highlights systematic reviews and meta-analyses as pivotal in addressing complex questions and generating reproducible evidence. Updated classifications emphasize qualitative reviews (Graham, 2018), PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) systematic reviews and added quantitative reviews (Díaz-Prieto and García-Sánchez, 2016), meta-analyses (Botella and Gambara, 2006; Peng et al., 2019), reviews of reviews, meta-analysis reviews, and meta-analyses of meta-analyses (Hempel et al., 2014; Bouskill et al., 2019). This classification has been adopted in the present study to analyze selected articles.

Methodological rigor in academic reviews is often ensured through frameworks such as PRISMA (Page et al., 2021) and SALSA (Search, Appraisal, Synthesis, and Analysis). PRISMA provides clear guidelines for identifying, selecting, and evaluating studies, promoting transparency and reproducibility, while enabling the creation of visual maps illustrating relationships between studies (Miller et al., 2018; Scott et al., 2018). SALSA, on the other hand, focuses on comprehensive literature searches, critical appraisals, synthesis of findings, and pattern analysis, offering flexibility to integrate diverse types of evidence (Bathaei and Štreimikienė, 2023; Mengist et al., 2020). Both methodologies are essential for systematic reviews and meta-analyses, and their combination with tools for ensuring the quality of researches selected for analysis, such as the Research Quality Model (RQM) ensures robust evaluations (Moher et al., 2009).

Complementing these methodologies, frameworks such as PICOS (Population, Intervention, Comparison, Outcomes, Study design) provide a structured approach to formulate clear research questions and establish rigorous inclusion and exclusion criteria. This framework enables researchers to define the target population, intervention under evaluation, comparison group, expected outcomes, and methodological design, ensuring the alignment of selected studies with the research objectives. Additionally, tools like PROSPERO, an

international registry for systematic review protocols, enhance transparency by preregistering the objectives and methods of reviews. The MARS (Meta-analysis Reporting Standards) guidelines further standardize the reporting of meta-analyses, promoting consistency and reliability in findings. For qualitative reviews, the SPIDER (Sample, Phenomenon of Interest, Design, Evaluation, Research type) framework facilitates comprehensive searches and analysis in non-experimental studies. These strategies, when integrated, provide a robust and adaptable foundation for validating the methodological rigor and reproducibility of systematic reviews.

These methodological frameworks are not only essential for ensuring transparency and rigor but also pivotal for addressing contemporary challenges in an increasingly digitalized world (Lim and Kumar, 2024; Passas, 2024; Pradana et al., 2023; Rojas-Sánchez et al., 2023). The integration of advanced technologies, including artificial intelligence and specialized software, has transformed the execution of systematic reviews in psychology. Tools such as Comprehensive Meta-Analysis and R enable researchers to analyze large datasets, conduct sophisticated statistical analysis, and visualize trends more effectively (Ciampa et al., 2023; Wei, 2024).

In particular, reviews play a crucial role in synthesizing evidence related to psychoeducational variables. These reviews not only highlight trends in the literature but also facilitate the identification of patterns and the development of evidence-based interventions tailored to evolving educational and psychological challenges (Farias-Gaytan et al., 2023; Utaminingsih et al., 2023). By leveraging these tools, researchers can address limitations in existing studies and propose new frameworks that advance the understanding of psychoeducational processes (Basilotta-Gómez-Pablos et al., 2022; Díaz-Burgos et al., 2023; Gutiérrez-Ángel et al., 2022).

Given the growing role of reviews in shaping psychoeducational research, it is essential to examine not only general trends but also how specific initiatives contribute to methodological advancements in the field. In this regard, special issues play a key role in consolidating innovative perspectives and fostering interdisciplinary dialog. As part of this evolving landscape, a recent special issue in *Frontiers in Psychology* serves as a particularly relevant case, exemplifying innovative approaches to educational psychology and methodological integration.

Aligned with these developments, the present article examines review articles from *Frontiers in Psychology* to explore their contributions to educational psychology. Particular emphasis is placed on a special issue that offers an innovative perspective on the integration of tools within educational and collaborative environments. Titled *"Reviews in Educational Psychology,"* this special issue directly aligns with the core focus of our systematic review, making it particularly relevant to our analysis. By highlighting this issue, we aim to underscore its significant contribution within *Frontiers in Psychology*, as it explicitly reflects the journal's emphasis on systematic reviews in educational psychology.

The methodology employed in this study synthesizes predominant characteristics, identifies research trends, and critically evaluates how the special issue advances knowledge in this area. By addressing the intersection of psychoeducational variables and learning processes, the special issue provides valuable insights into fostering holistic development (DeCuir-Gunby and Schutz, 2024; Mayer, 2024).

Categorizing review findings provides a visual and systematic representation of the analyzed information. Systematic reviews focus on exhaustive information collection under defined criteria, synthesizing patterns and results with high reproducibility. Meta-analyses, by contrast, integrate quantitative data from multiple studies to conduct robust statistical analyzes. Both typologies have evolved to address specific research questions, contributing to methodological diversity (Agrawal et al., 2024; Arya et al., 2021; Paul and Barari, 2022).

Beyond meta-analyses and systematic reviews, several other methodologies were frequently employed by the authors. Scoping reviews emerged as a prominent approach, particularly for mapping the breadth of existing research and identifying gaps without the stringent quality assessments typical of systematic reviews. This flexibility makes scoping reviews ideal for exploring emerging areas or complex fields.

Literature reviews were also commonly utilized, providing a narrative synthesis of current knowledge. While less structured than systematic approaches, they are invaluable for establishing theoretical contexts or summarizing broad research areas. Similarly, critical reviews gained prominence for their ability to rigorously evaluate existing studies, highlighting methodological limitations, biases, and areas for improvement. Finally, configurative reviews, which integrate qualitative data to generate new interpretations or theoretical insights, and synthetic reviews, which combine findings from multiple studies into a coherent framework, were notable for their contributions to advancing theoretical and practical understanding.

A complementary approach involves analyzing reviews by geographic region to highlight how cultural, economic, and social contexts shape research priorities. Regional differences may reflect local needs, available resources, and academic traditions, offering a more inclusive view of psychology (Kumar et al., 2024; Morris et al., 2025; Susilawati et al., 2025). The analysis of topics covered in reviews further underscores the diversity of psychological research, spanning educational psychology, social psychology, clinical psychology, and quantitative psychology (McPhetres et al., 2021; Möller, 2024).

Finally, these efforts align with the United Nations' Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education) and SDG 3 (Good Health and Well-being). By integrating technology with socio-emotional skills, these initiatives foster equitable and inclusive education while respecting psychological and emotional health (Castaño Muñoz et al., 2023; ElSayary, 2023). The special issue analyzed in this study exemplifies how digital competencies can transform educational and psychological landscapes, providing a roadmap for future research and applications.

This context underscores the need to analyze how reviews related to educational psychology are addressed in *Frontiers in Psychology*. Within this framework, the following research questions are proposed: RQ1: What are the main characteristics defining the reviews published in *Frontiers in Psychology* from its inception to 2024 included, considering methodological, thematic, and focus aspects?; RQ2: How do systematic reviews differ from meta-analysis in terms of scope, methodology, and scientific contributions?; RQ3: What emerging trends are observed in the topics addressed and data analysis approaches in the journal's reviews?; RQ4: What are the most relevant results obtained from the comparative analysis of reviews by geographic regions, and what regional patterns can be identified?; RQ5: How has the use of tools and software in published reviews evolved over time?; and RQ6: What specific contributions and added value does the special issue provide compared to the overall set of articles analyzed in the journal?

The general objective of this study is to conduct a comparative analysis of the reviews published in *Frontiers in Psychology*, identifying predominant characteristics such as typology, constructs, methodology, and software used, and evaluating the specific contributions of the special issue within the current context. To address the research questions, the following Specific Objectives (SO) are established: SO1: determine the predominant characteristics of the reviews published in *Frontiers in Psychology*, considering aspects such as typology, methodological approaches, and investigated constructs; SO2: compare systematic reviews and meta-analyzes in terms of methodologies and scientific contributions to establish key differences between these approaches; SO3: identify emerging trends in topics and data analyzis approaches in the reviews, highlighting their impact on advancing psychological knowledge; SO4: analyze the reviews from a geographical perspective, identifying patterns and regional differences in study approaches and results; SO5: examine the evolution of tools and software usage in published reviews; and SO6: evaluate the specific contributions and added value of the special issue in comparison with the set of published reviews, identifying its relevance and differentiating contributions.

Based on the proposed objectives, the following forecasts (F) are established: F1: the reviews published in *Frontiers in Psychology* are characterized by a predominance of systematic reviews and meta-analysis, with a wide variety of thematic and methodological approaches reflecting trends in psychology; F2: current trends in topics and data analysis reveal a growing interest in interdisciplinary areas, such as ICT and its impact on educational psychology; F3: significant regional differences exist in the approaches and outcomes of published reviews, influenced by geographical, cultural, and socioeconomic contexts; F4: the use of tools and software in reviews has evolved significantly over time; and F5: the special issue provides significant added value compared to the set of reviews, standing out for identifying research gaps and promoting innovative approaches.

2 Methods

This study employed a systematic review approach following the PRISMA guidelines (Page et al., 2021). The process included the following steps: (i) the bibliographic search began with the creation of a diagram highlighting key terms and main thematic axes, utilizing Frontiers website or databases such as Web of Science and Scopus (Figure 1); (ii) inclusion and exclusion criteria were established, incorporating additional parameters such as the selection of studies published in peer-reviewed scientific journals, recognized databases, and citation indexes (Cooper et al., 2009; Miller et al., 2018; Scott et al., 2018); and (iii) once the criteria were defined, they were applied to conduct both qualitative and quantitative analysis.

The inclusion of Web of Science (WOS) and Scopus databases, despite the final selection of articles exclusively from *Frontiers in Psychology*, was part of a deliberate search triangulation strategy designed to ensure comprehensiveness, validity, and methodological rigor. Keywords were combined using the logical operators "AND" and "OR." In the search engine, results were filtered based on inclusion and exclusion criteria, such as the publication period (2010–2024), open access, English language, and document type ("Review"). The database search was conducted between December 2024 and January 2025, ensuring the inclusion of all relevant publications available up to that period. Specifically, the main keywords employed were "educational psychology" and "review," intended to identify publications explicitly focused on reviews within the field of educational psychology. An example of a search string used in Web of Science was as follows: TS = "review" AND "educational psychology." Filters included publication period (2010–2024) and open access. Additionally, a search was conducted on the Frontiers website using the keyword "educational." This search was specifically filtered to include only documents published in the journal Frontiers in Psychology and further restricted to articles classified as review or systematic review.

The following criteria were implemented through a rigorous process based on the PRISMA model, documenting each stage: identification, removal of duplicates, screening, and final eligibility assessment. This process resulted in the selection of 392 relevant studies, which formed the foundation for the comparative analysis presented in this work.

2.1 Inclusion/exclusion criteria

Studies published between 2010 and 2024 were included, covering the entire publication period of the journal *Frontiers in Psychology* up to the date of this article. Reviews related to the field of educational psychology were selected due to their capacity to comprehensively synthesize existing literature. Articles available in full text were required to allow for a detailed assessment and ensure analytical transparency, as incomplete access would limit the ability to critically evaluate methodological and theoretical contributions.

To maintain methodological rigor and enhance the reliability of findings, non-peer-reviewed studies, conference proceedings, and gray literature were excluded, as these sources often lack standardized review processes and methodological transparency, which could compromise the consistency of the analysis. Publications had to be in English to ensure uniformity in data extraction and minimize the risk of misinterpretation due to translation inaccuracies. Duplicate articles were removed to prevent redundant inclusion of the same study. Additionally, only articles published in *Frontiers in Psychology* were considered, ensuring coherence in editorial policies, peer-review standards, and methodological approaches. The removal of duplicates was carried out manually by the authors, ensuring careful evaluation to avoid any redundancy. This manual process was essential to maintain the rigor and quality of the review.

The dataset included all studies retrieved from the *Frontiers* website and both databases (Web of Science and Scopus) after applying the search string. As a result, some studies with a predominant focus on clinical or social psychology were also incorporated when they intersected with educational psychology, particularly in areas related to learning processes, teacher well-being, and cognitive development. Similarly, conceptual analyses were included alongside systematic reviews and meta-analyses, given their role in advancing theoretical discussions in educational psychology. However, studies lacking methodological clarity or explicit review criteria were excluded to preserve the validity and reproducibility of the findings.

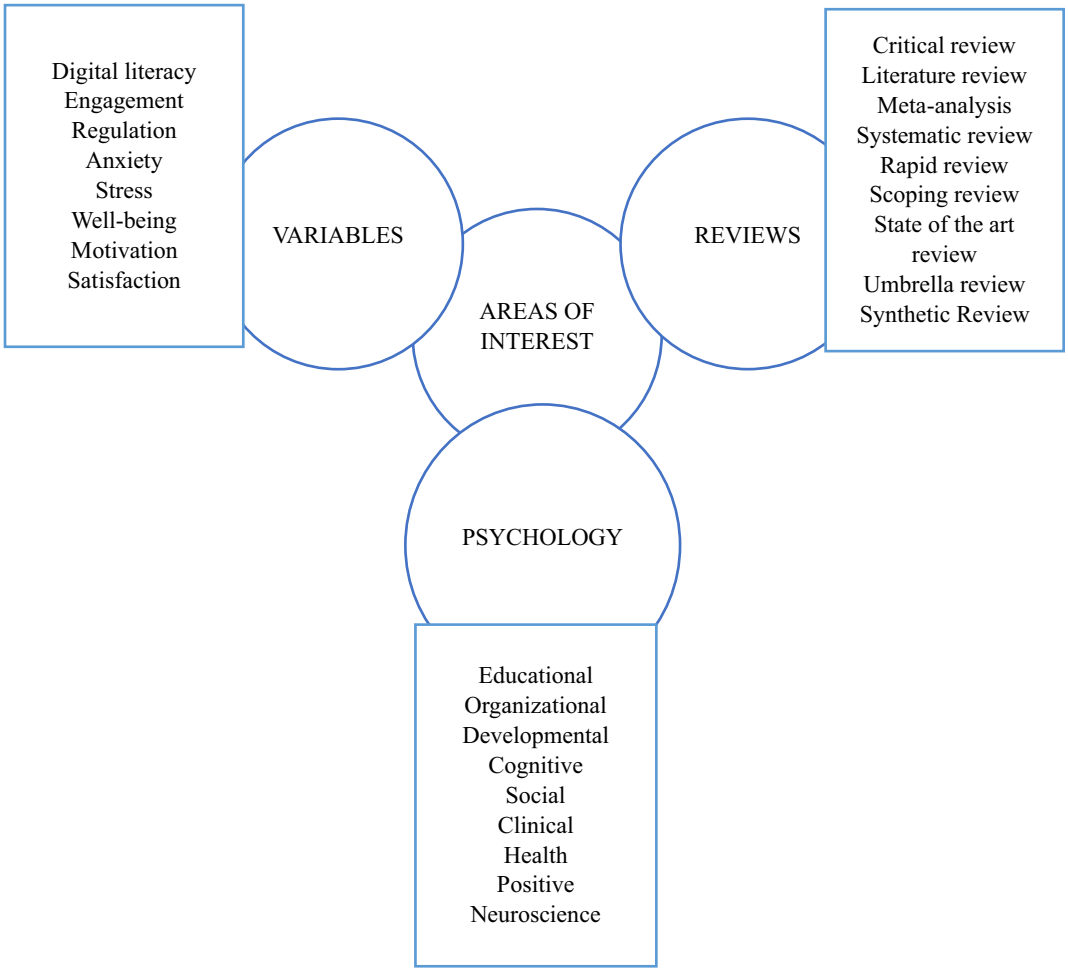

FIGURE 1
Diagram of key terms. This diagram provides an overview of the main thematic axes and specific keywords used in the bibliographic search process.

Once the inclusion and exclusion criteria were applied, the selected studies were systematically organized to facilitate subsequent analysis, as detailed in the following section.

2.2 Procedure

The information gathered from the selected studies was organized into tables created in Excel, classifying the articles based on multiple categories extracted from the analyzed sheets. These categories included data on authors and year of publication, country or region of origin, type of review, number of studies reviewed, age group analyzed, constructs addressed, main topics, theoretical frameworks used, digital tools and software employed, reliability, validation, period reviewed, database used, quality analysis, applied methodologies, types of data analysis conducted, added value of the study, main results, identified limitations, and proposed applications. This approach allowed for a comprehensive systematization of the information, providing a solid foundation for subsequent analysis.

A categorization process was then conducted to divide the studies according to various approaches, such as the investigative topics covered, geographic regions, and type of review performed. This division was specifically designed to facilitate comparisons between articles within each group, enabling a deeper analysis of methodological and thematic differences as well as trends observed in each category. The use of Excel for systematic categorization ensured consistency and reproducibility, allowing future researchers to replicate or adapt the methodology for similar analysis.

Additionally, the articles from the special issue were separated into a specific sheet, allowing for a detailed analysis of their added value and innovation compared to the other studies. This procedure ensured that the specific contributions of the special issue could be evaluated in isolation, highlighting its unique contributions in terms of digital tools, methodologies, and investigative approaches. The entire process of data categorization and separation was designed to facilitate the observation and extraction of relevant conclusions, identifying patterns in the reviewed literature.

To guarantee the application of all the steps and process of this systematic review of reviews published in *Frontiers in Psychology*, the inclusion and classifications were agreed upon by at least three of the authors. This guarantees agreement between coders.

To complement this tabular organization, graphs were generated to provide a visual representation of the key trends and relationships

identified in the data. These graphs facilitated comparisons between different approaches, such as the evolution of digital tool usage over time, differences in applied methodologies based on the type of review, and investigative dynamics across geographic regions. By offering a visual perspective, the graphs allowed for a more intuitive interpretation of the results, simplifying the identification of emerging trends and providing a comprehensive framework for discussing and analyzing the conclusions obtained. This integrated methodological approach, combining systematic categorization and graphical representation, ensured a rigorous and detailed analysis of the reviewed articles, optimizing the clarity and depth of the results.

3 Results

A total of 392 articles published in *Frontiers in Psychology* were reviewed, obtained through a systematic search following the PRISMA model (Figure 2). Each article was analyzed and categorized into tables that organized the information based on various criteria, such as the geographic distribution of studies, the type of review conducted, the topics addressed, the type of data analysis employed, and the tools used in the research processes. These results were cross-referenced and represented through graphs to identify key trends and patterns in the reviewed literature.

To facilitate the localization and management of references, all articles analyzed have been compiled in Supplementary Table S1. This table serves as a centralized repository, enabling readers to efficiently access and manage the references used throughout this study.

Regarding the type of review, the articles included systematic reviews and meta-analyses, showing how each approach contributed to the synthesis of knowledge. Additionally, the use of different types of data analysis was evaluated, classifying them into qualitative, quantitative, and mixed approaches. This categorization revealed a wide variety of methodologies, reflecting the diversity in approaches applied to address research problems.

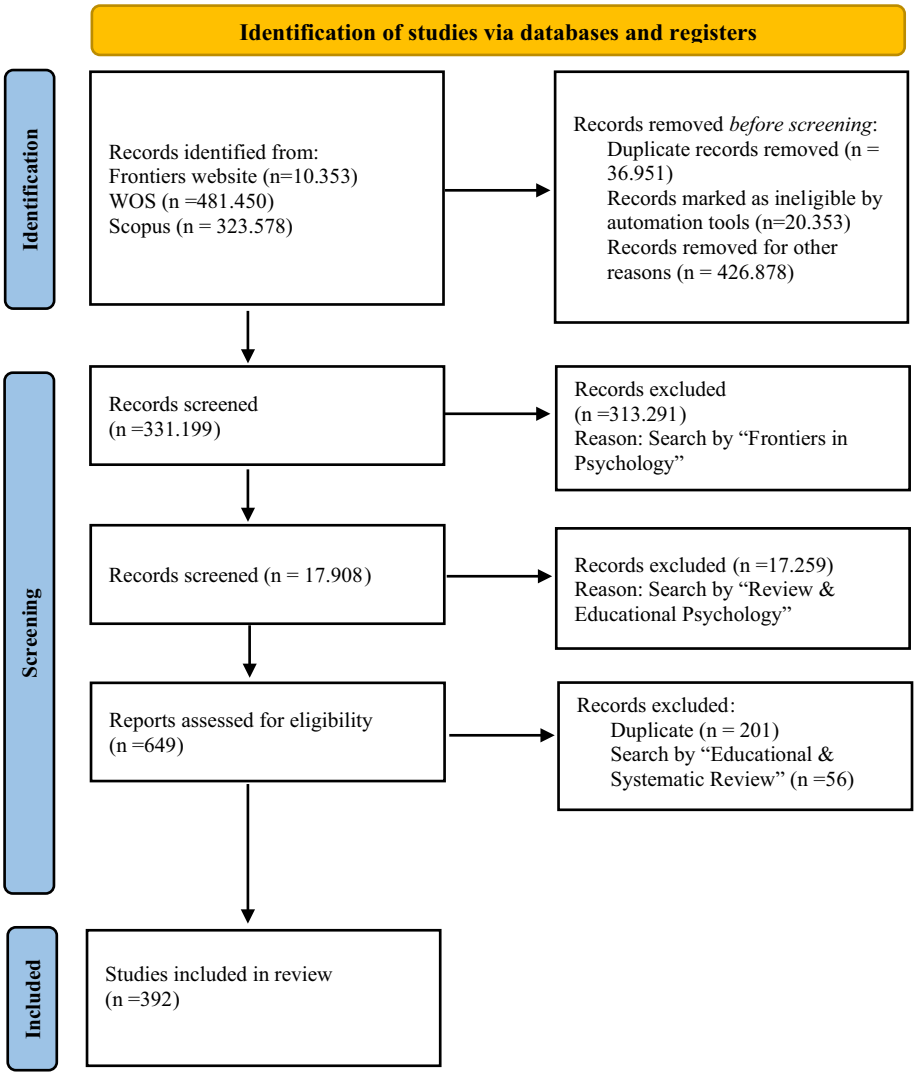

FIGURE 2
PRISMA flow diagram. This flow diagram outlines the systematic review process, detailing each step from the initial identification of studies to the final inclusion (Moher et al., 2009; Page et al., 2021).

As this is a review of reviews, the analyzed studies collectively comprise more than 33,000 individual studies, as outlined in column N of Supplementary Table S2. The column provides specific counts for each review, allowing a detailed exploration of their scope. On average, each review analyzed around 88 studies, reflecting the substantial breadth of these reviews. The analysis of the age groups of participants in the studies reviewed by the selected reviews reveals a diverse focus. For example, around 110 reviews targeted adults, while 130 focused on youth or young populations. Reviews involving children accounted for 32 entries, and 93 reviews included a mixed age range. This categorization, presented in column 6 of Supplementary Table S2, highlights the broad demographic scope of the reviewed studies.

A thorough analysis of the main topics addressed in the articles was conducted, including areas such as clinical psychology, educational psychology, social psychology, and health-related studies. Within educational psychology, recurring constructs included "learning styles" and "educational outcomes," as explored in studies like Clinton-Lisell & Litzinger and Dreer. Social psychology frequently addressed themes such as "social identity" and "social integration," as highlighted in Hu & Cheung, as well as "social sustainability" and "social connectedness," discussed in studies by Kobal Grum & Babnik and Petersen et al. Health-related studies commonly focused on constructs like "mental health" and its interplay with factors such as "digital impact" (Chen et al.) and other psychological dimensions, as examined by Limone and Toto.

Each construct and topic analyzed for the reviewed articles can be verified in Supplementary Table S2, where all relevant details are documented for transparency and further exploration. This table organizes information across different categories, providing a comprehensive view of the approaches and characteristics of the articles included in the analysis. Columns in the supplementary table include essential data such as the study title, year of publication, country of origin, and continent, allowing for an exploration of the geographic distribution of the investigations.

This supplementary table serves as a valuable resource for readers, offering detailed access to the information that supports the general analysis presented in this work. Its structure enables the identification of patterns, the exploration of specific trends, and a deeper examination of the particular characteristics of the included studies, providing a solid foundation for future research and academic synthesis.

To facilitate the categorization of the reviewed studies, the identified constructs were grouped into overarching topics based on an iterative analytical process. The categories were not predefined but rather emerged from a systematic dataset analysis, through multiple rounds of review, refining and consolidating the thematic structure. This approach enabled the classification of studies published in Frontiers in Psychology into distinct topical categories that best captured their focus while aligning with existing research in educational psychology.

The overarching topics were defined through a structured dataset review, with initial classifications iteratively refined to ensure consistency. This process involved examining recurring themes, research objectives, and conceptual frameworks across studies. Consequently, the final categorization represents a data-driven synthesis, integrating patterns and thematic clusters identified in the dataset.

Intersections between different psychological domains (e.g., clinical, social, cognitive, or educational psychology) were determined based on the stated objectives of each study. Instead of imposing arbitrary classifications, interdisciplinary connections were identified through an in-depth examination of how constructs from various fields contributed to psychoeducational research. This method ensured that interdisciplinary relationships were grounded in the focus and intent of each study, rather than in an externally imposed taxonomy.

The geographic analysis considered the distribution of studies by continents and regions, distinguishing between Eastern and Western contexts. This approach facilitated the observation of how research priorities and methodologies varied across regional contexts. It allowed the identification of significant differences in predominant areas of interest and methodological approaches between the studied regions.

For geographic regions, distinguishing between East and West posed challenges, particularly in cases where studies involved authors from multiple regions. In such instances, articles were counted once for each relevant region, which may impact the totals. Detailed information on excluded categories and their respective studies is provided in the Supplementary materials, offering a comprehensive and transparent account of the dataset. This approach ensures that the analysis remains focused on the most relevant and widely adopted methodologies and typologies.

Finally, the use of tools and software proved to be fundamental for data analysis and management. Their increasingly frequent application highlights a significant trend toward the adoption of advanced technologies and artificial intelligence within the field of scientific and psychological research. This shift underscores the growing integration of digital methodologies in academic investigations, reflecting an evolution in how systematic reviews are conducted. The generated graphs visualized these interrelationships and trends over time and by region, providing a comprehensive perspective of the obtained results.

The discrepancy between the total number of analyzed studies and the figures presented in the graphs arises from several methodological considerations. First, only meta-analyses and systematic reviews have been included in the typology analysis, excluding other review types with significantly smaller representation (Aslaksen & Lorås; Burris & Brown). Similarly, the focus on qualitative, quantitative, and mixed methodologies for data analysis reflects their predominance within the dataset, while other approaches were considered residual due to their limited occurrence and scope (Di; Tinajero et al.). Additionally, the software analysis only included studies explicitly reporting the use of digital tools, further narrowing the scope.

3.1 Comparative analysis by type of review

A detailed comparison was conducted between studies employing systematic reviews and those utilizing meta-analysis, enabling the exploration of methodological and thematic differences between both approaches. This classification is available in Supplementary Table S3, where each sheet contains articles classified according to the type of review. This analysis identified key patterns related to the number of studies, the tools employed, and the types of data analysis applied in each case.

Figure 3 demonstrated a sustained increase in the number of publications over time, reaching its highest point in recent years. The temporal distribution revealed marked growth in both systematic reviews and meta-analysis, indicating a general increase in interest in these methodologies within the scientific literature (Hobbs et al.; Kritikou & Giovazolias; Lauder et al.). This increase was more pronounced for systematic reviews, although meta-analysis also exhibited a growing trend, as observed in Figure 4.

Specifically, Figure 4 highlighted an evolution in the methodologies employed. Systematic reviews have increased the use of qualitative and mixed approaches in recent years (Akram et al.; Amores-Valencia et al.; Kuznetsova et al.), while meta-analysis have maintained a prevalence in the use of quantitative analysis analysis (Carrus et al.; Jinmin & Qi; Subara-Zukic et al.). These trends have allowed the identification of variations in methodological approaches over time, contributing to a better understanding of research practices in both types of review.

The temporal distribution of systematic reviews and meta-analyses also reveals a significant peak in publications during 2022. This increase aligns with broader scientific trends observed in the post-pandemic period, where researchers faced restrictions on conducting empirical studies in educational and psychological settings. As a result, systematic reviews became a preferred methodological approach, allowing scholars to synthesize and evaluate accumulated knowledge in the absence of direct experimental data.

Regarding the software utilized, Figure 5 highlighted differences in the tools employed for each type of review. Meta-analysis predominantly used statistical programs such as Comprehensive Meta-Analysis and R (Amlashi et al.; Andersen et al.; Chen), while systematic reviews demonstrated greater diversity, incorporating tools like EndNote and Excel for data management and organization (Beaudoin et al.; Bi et al.; Sharif Nia et al.). These differences in software usage reflected the distinct methodological demands of each type of review, which were influenced by the nature of the analysis conducted.

3.2 Analysis by studied topic

A detailed analysis was conducted on the studies grouped by main topics, categorized into seven areas: Clinical Psychology, Cognitive Psychology, Developmental Psychology, Educational Psychology, Health Psychology, Quantitative Psychology, and Social Psychology. These data are available in Supplementary Table S4, presented in tables detailing the articles included in each topic. This approach allowed the identification of key trends in research areas, their evolution over time, and their relationship with other methodological and regional factors.

This categorization by topics aims to facilitate comparisons and provide a clearer understanding of the research landscape. While grouped under broader topics, the specific constructs studied in each article can be consulted in the Supplementary material, ensuring detailed access to the nuances of the research. This level of granularity allows for a more comprehensive interpretation of the findings.

Although the articles span diverse topics, they share a connection to educational psychology, either directly or through overlapping constructs such as well-being, motivation, or cognitive development. This thematic overlap justifies their inclusion in the study, as it highlights the interdisciplinary nature of educational psychology and its intersection with other areas of psychological research.

Figure 6 revealed a predominant distribution in the topic of Educational Psychology (Aslaksen & Lorås; Attwood; Di), followed by Social Psychology and Clinical Psychology, which together encompassed the majority of the analyzed studies (Andersen et al.; Salgado & Moscoso; Tokuhama-Espinosa et al.). Topics with lesser representation included Quantitative Psychology and Health Psychology, reflecting a

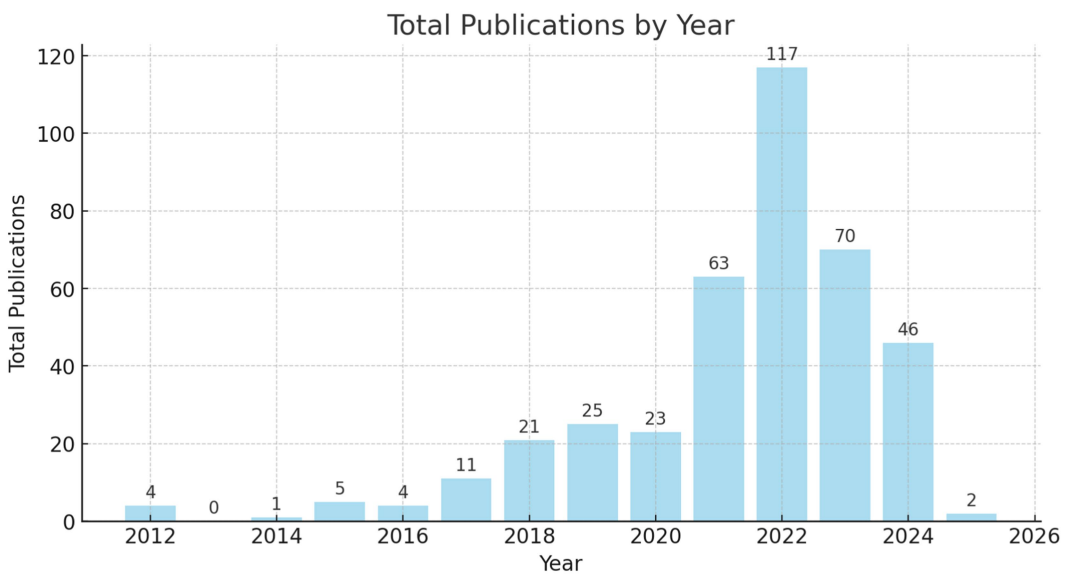

FIGURE 3
Sustained increase in publications over time. This figure shows the consistent growth in the number of publications.

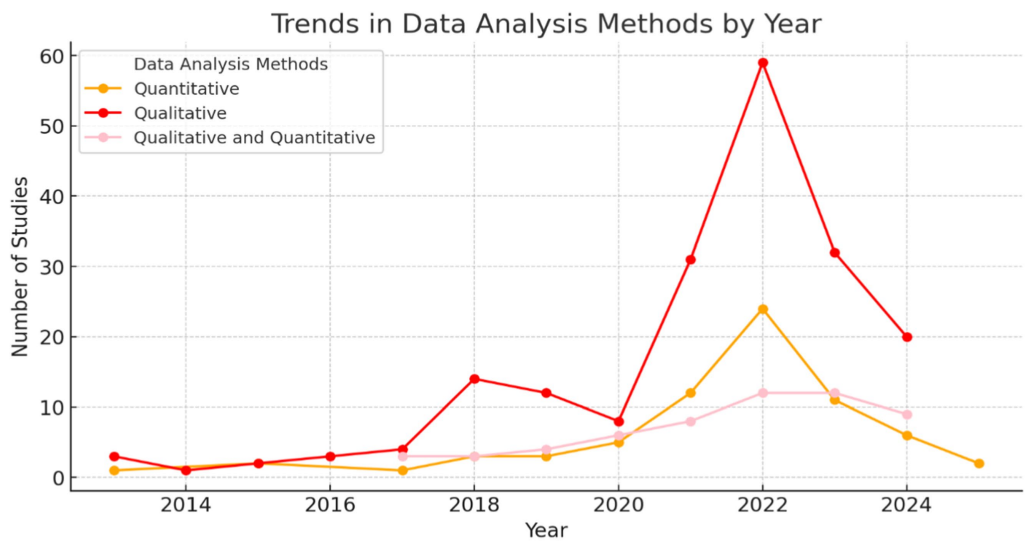

FIGURE 4
Evolution of methodologies used in systematic reviews and meta-analysis. The figure demonstrates trends in the adoption of qualitative, quantitative, and mixed methods over time.

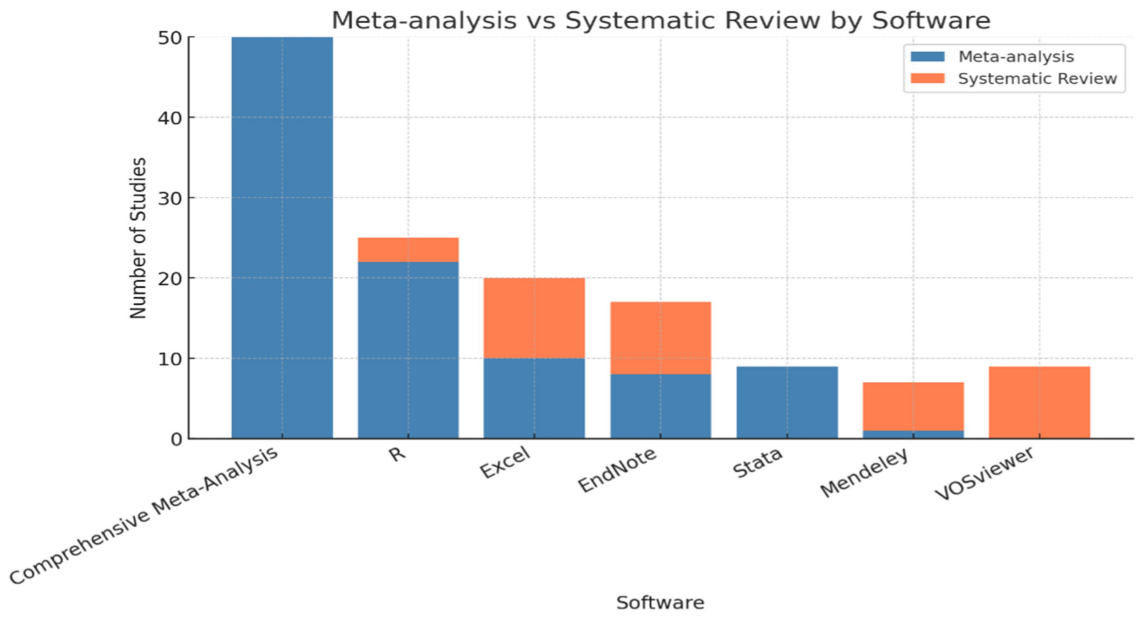

FIGURE 5
Software usage trends by year. This chart highlights the increasing adoption of digital tools in research.

concentration of research efforts in specific areas (Peña-Sarrionandia et al.; Pérez-Fernández et al.; Sáiz-Manzanares et al.).

In the analysis by years, Figure 7 evidenced a progressive increase in the number of publications across all topics, with a significant peak in recent years, particularly in Educational Psychology and Social Psychology (O'Grady & Nag; Para et al.; Xu & Wang). This increase has been consistent with the growing interest in these research areas, while other topics, such as Quantitative and Cognitive Psychology, have shown more moderate growth (Aryadoust et al.; Bono et al.; Gegenfurtner).

The analysis of data analysis types (Figure 8) revealed a clear predominance of qualitative approaches, especially in Clinical Psychology, which stood out significantly compared to other topics (Dumont et al.; Gao; Nadmilail et al.). In contrast, quantitative methods were more dominant in Social Psychology. Notably, Educational Psychology was prominently represented in both qualitative and quantitative approaches, as evidenced by the substantial segment sizes in both categories (Fuller et al.; Hancock et al.; Zhou et al.). Mixed approaches (qualitative and quantitative) were generally less frequent than qualitative but remained more common than quantitative in certain fields, particularly in Health Psychology, where their presence indicated a greater methodological diversity (He et al.; Marino & Capone; Sánchez-López et al.). Overall, while qualitative methodologies

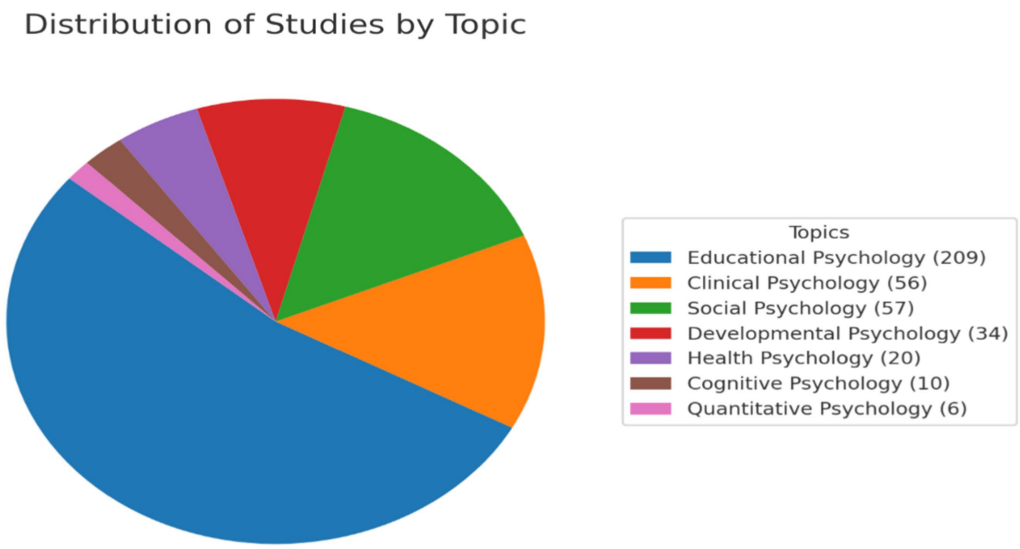

FIGURE 6
Distribution of publications by research topic. The figure shows the predominance of topics.

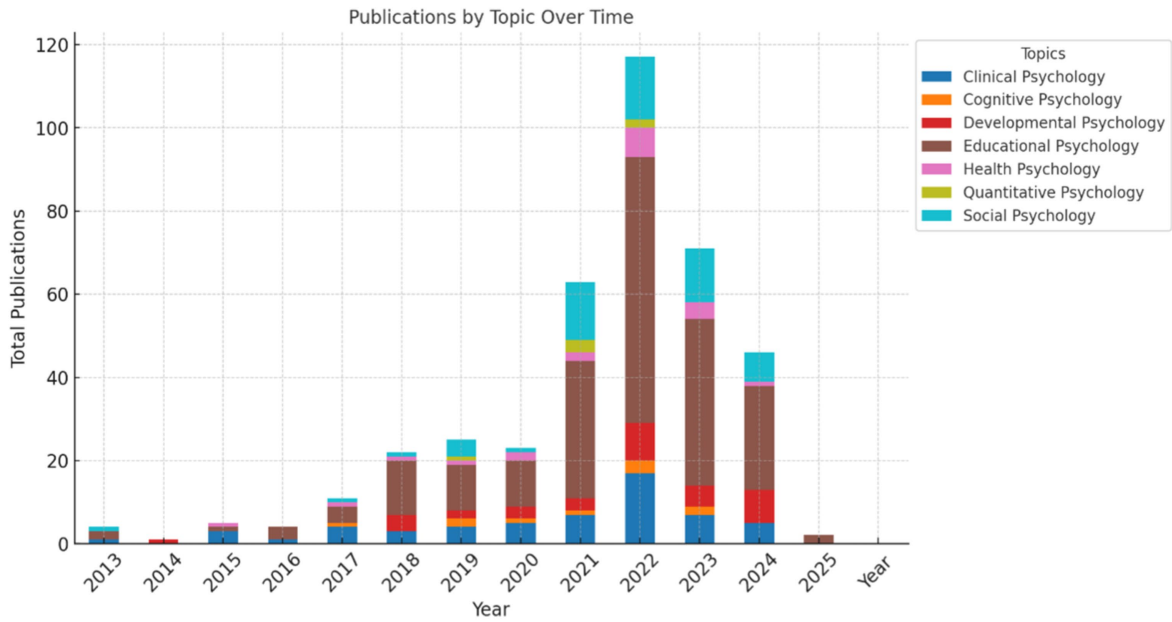

FIGURE 7
Temporal growth of publications across topics. This chart reveals the progressive increase in publications.

were the most widely used, the chart illustrates a notable variation in methodological preferences across different topics, with some fields demonstrating a stronger inclination toward mixed-method research.

3.3 Comparative analysis by geographic regions

To provide a comprehensive understanding of geographical trends, this study employs two complementary classification approaches: the East–West regional division and the continent-based analysis. The East–West classification was chosen to group research traditions that transcend political borders, capturing historical and methodological influences that shape the prevalence of Systematic Reviews and Meta-analyses in different regions. This approach allows for an understanding of broader scientific paradigms, highlighting distinct methodological preferences, such as the qualitative emphasis in the West versus the statistical rigor observed in the East.

Specifically, for the purposes of this study, the East–West division was operationalized as follows: "West" includes all countries in North, Central, and South America, Western Europe, Oceania, and Western

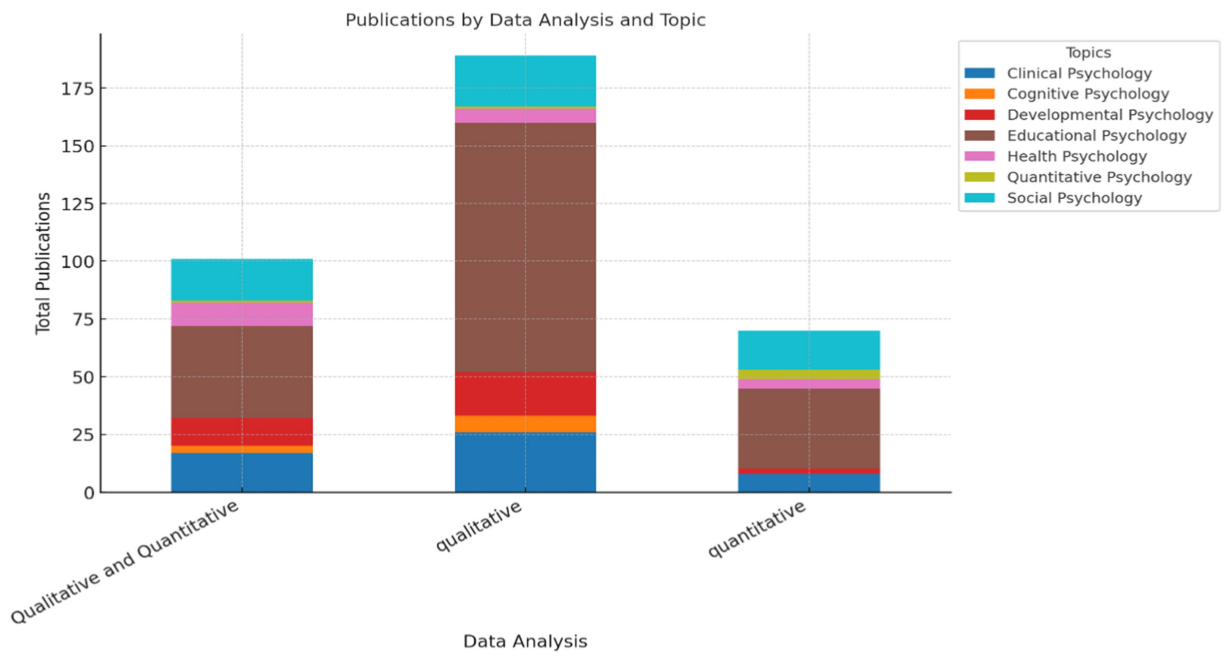

FIGURE 8
Types of data analyses by research topic. The figure analyses the prevalence of qualitative, quantitative, and mixed methods across different research areas.

Africa; whereas "East" encompasses Asia, Eastern Europe, Russia, the Middle East, and Eastern Africa.

Conversely, the continent-based classification was applied to analyze temporal growth and thematic distribution, as this framework provides a more granular and widely recognized geographical categorization. This distinction also explains why Systematic Reviews vs. Meta-analyses were not analyzed by continent—since the methodological divide observed is primarily driven by scientific traditions rather than geographical boundaries. Unlike research output trends or thematic priorities, which vary considerably by continent, methodological preferences tend to be structured around historical, epistemological, and institutional factors that are better captured by an East–West division.

Similarly, the annual publication trends and topic distribution were not analyzed using an East–West classification because such an approach would have limited explanatory power in these contexts. The number of publications and their thematic focus are shaped more by national and institutional research funding, policy changes, and global academic collaborations, which are more accurately reflected when analyzed at the continental level. Applying an East–West division to these analyses would not provide additional insights, as the primary variations occur at a regional and national level rather than between broad research traditions.

By incorporating both classifications where they are most methodologically relevant, this study ensures a macro-level comparison of methodological preferences while also facilitating a micro-level exploration of research dynamics across continents. This dual perspective enhances the depth and accuracy of the findings while preserving conceptual clarity in the interpretation of geographical trends.

The general analysis of the reviewed studies revealed geographical differences across various analyzed focuses (Supplementary Table S5). Methodologically, the distribution of studies between Systematic Reviews and Meta-analyses in the East and West regions was highlighted (Figure 9).

In the West, Systematic Reviews were significantly more prevalent, with a total of 116 studies, clearly surpassing Meta-analyses, which accounted for 52 (Delfa-Lobato et al.; Hammerstein et al.; Lisboa et al.). Conversely, in the East, Meta-analyses were more numerous, reaching 66 studies compared to 48 Systematic Reviews (Bolton et al.; Gong et al.; Tang & He). This pattern highlights a regional preference in research methodologies, with the West favoring a more qualitative and comprehensive approach, while the East leans toward a more quantitative and statistical perspective.

Furthermore, the distribution of publications by year and continent showed sustained growth in Europe and Asia, with notable peaks in recent years that reflected an increase in research activity in these regions, primarily in 2022 (Shi et al.; Tronchoni et al.; Wang & Wang). America, although maintaining a consistent production, lagged behind Europe and Asia (Bravo-Sanzana et al.; Jebb et al.; Lentz et al.), whereas Africa and Oceania exhibited a much more limited representation (McLean et al.; Orth et al.; Ware et al.). This highlighted the centralization of academic output in regions with greater resources and infrastructure for research (Figure 10).

Finally, the thematic analysis by continent revealed clear differences in research priorities. Europe led in the number of studies, with a strong emphasis on Social, Clinical and Educational Psychology (Beer & Mulder; Dreer; Maier et al.). Asia ranked second, also demonstrating a significant focus on Social and Educational Psychology (Aziku & Zhang; Jianping et al.; Yoon et al.). America showed a notable emphasis on Educational Psychology, reflecting a

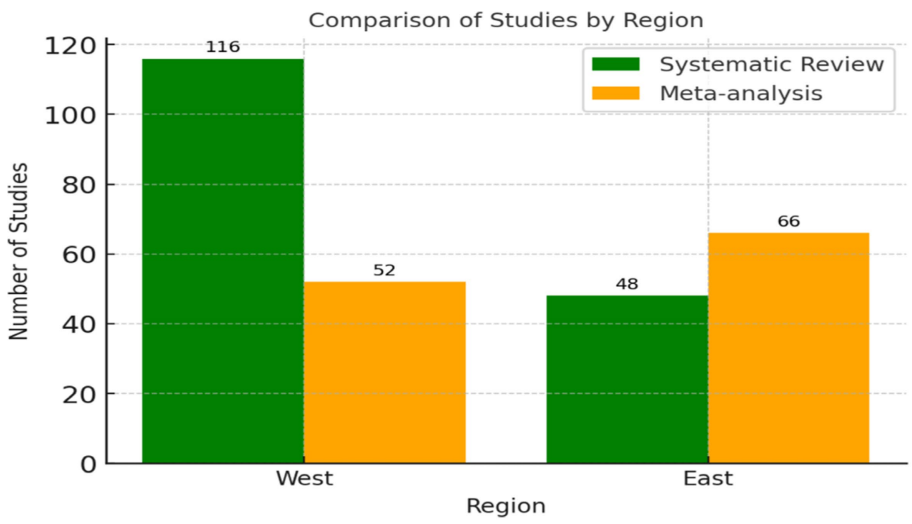

FIGURE 9
Distribution of systematic reviews and meta-analysis by region. This figure compares the prevalence of systematic reviews and meta-analysis in Eastern and Western regions.

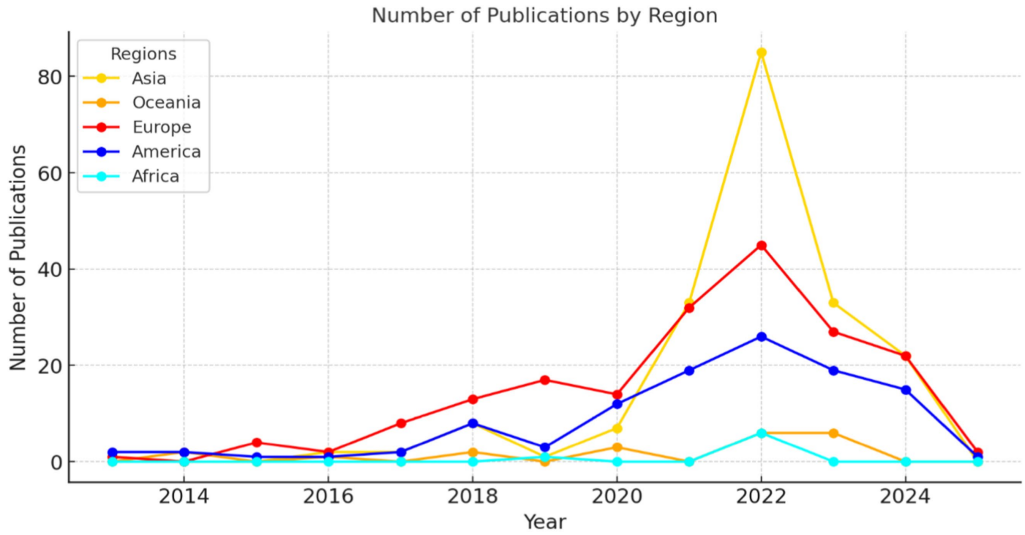

FIGURE 10
Yearly and regional distribution of publications. The figure highlights the steady growth in research activity across continents.

strong interest in educational and social psychological topics (Molina et al.; Clinton-Lisell & Litzinger; Kenny et al.). Africa and Oceania had a smaller representation, with fewer studies distributed across different topics, but without a clearly dominant area (Annous et al.; Frantz et al.; Zhao & Wang; Figure 11).

3.4 Software analysis

The analysis of software usage was conducted considering the growing presence of digital tools in scientific reviews and the consequent importance of acquiring digital competencies. The specific use of each software can be found in Supplementary Table S2, which includes dedicated columns recording the programs employed in each reviewed article.

Figure 12, which illustrates software usage by year, evidenced a significant increase in the adoption of digital tools in recent years. Notably, the consistent and predominant use of Comprehensive Meta-Analysis (CMA) peaked in 2022–2023, followed by a decline in 2024 (Chen et al.; Jiang et al.; Ni et al.). Concurrently, the use of R has shown an increasing trend since 2018, with fluctuations but remaining one of the primary tools in recent years (Haberstroh & Schulte-Körne; Sanchez-Alvarez et al.; Zhan et al.). Other tools, such as EndNote and Excel, exhibited specific peaks in usage, indicating their relevance in data management and organization for systematic reviews (Finell et al.; Pit-ten Cate & Glock; Vigdal & Brønnick).

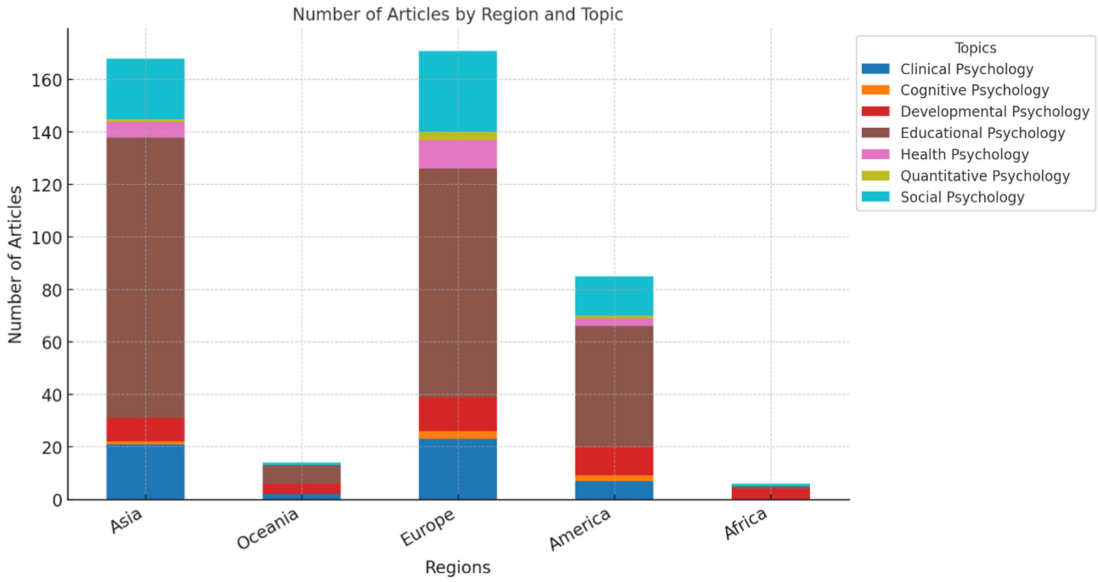

FIGURE 11
Key research topics by continent. This visualization categorizes research topics into six main areas, showing the dominant focus by continent.

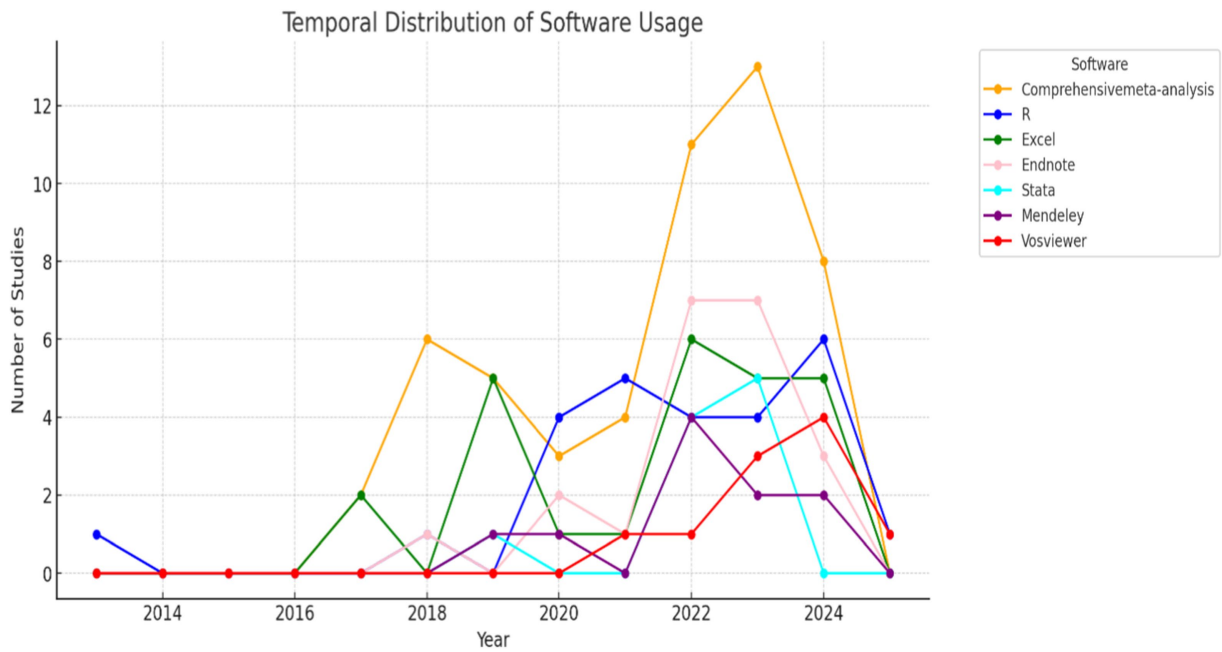

FIGURE 12
Software adoption trends over time. This visualization explores the growing use of digital tools.

The graph depicts the frequency of software usage for data analyzis in reviewed studies, categorized by year. Data were extracted from the "Software" column, with each software mentioned in a cell separated by "/" being counted individually. For example, if a cell contains "Excel/R," both Excel and R received one count each. Instances marked as "Not Specific" were excluded from the analysis. The results illustrate the evolution and trends in software adoption over the years, with notable peaks for Comprehensive Meta-Analysis and other tools reflecting methodological preferences.

The analysis in Figure 13, which links software usage to the investigated topics. The distribution of software usage across topics reveals that Comprehensive Meta-Analysis (CMA) is the predominant tool, particularly in Educational Psychology, where it has the highest

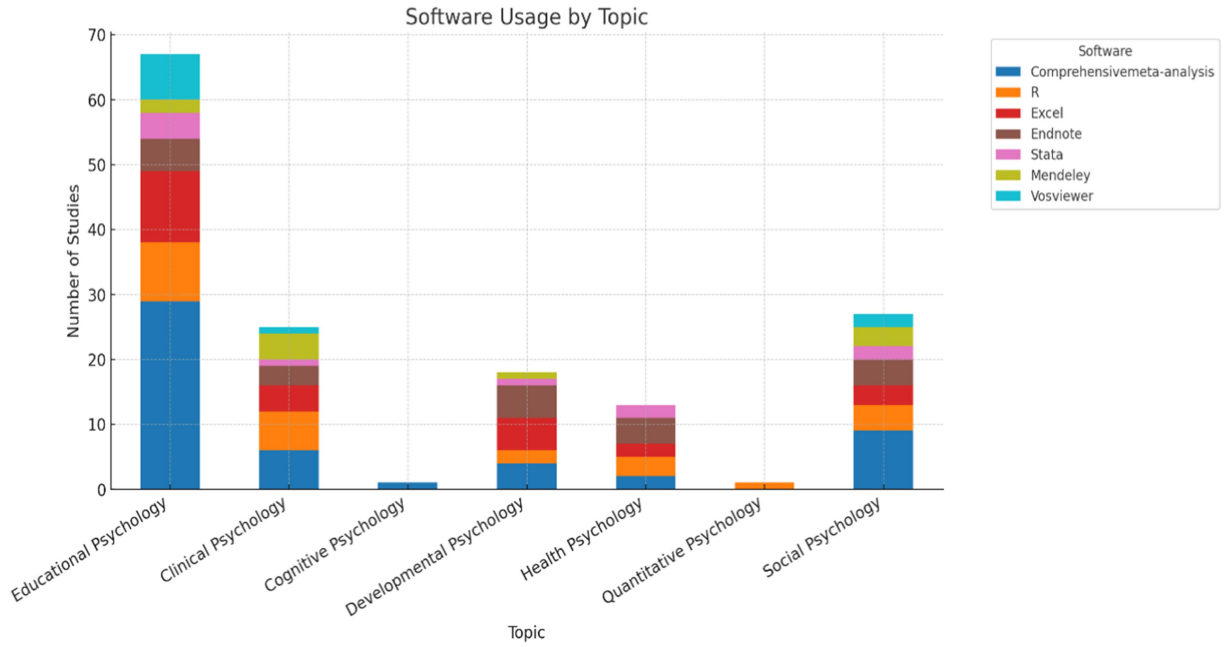

FIGURE 13
Software usage by research topic. The figure links specific software preferences to research topics.

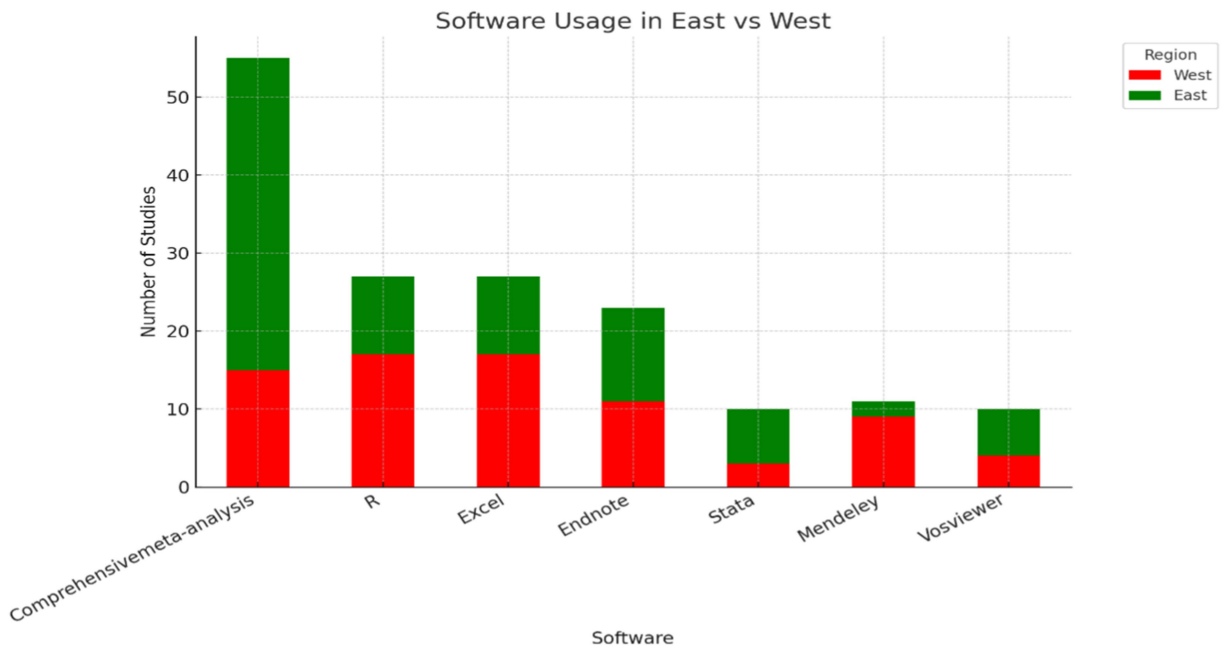

FIGURE 14
Regional software preferences. This chart highlights the differences in software usage between Eastern and Western regions.

number of studies. In Social Psychology, CMA also holds a strong presence, followed by R, which is widely used across multiple topics, including Clinical Psychology (Kievit et al.; Xu & Xue; Xuan et al.). Excel and EndNote show notable peaks in Clinical and Educational Psychology, reflecting their role in data management for systematic reviews. Meanwhile, Stata appears in a smaller number of studies, with representation across multiple topics but a higher presence in Clinical and Educational Psychology (Kenny et al.; Llistosella et al.). This distribution suggests a relationship between the methodological demands of specific topics and the tools used to address them.

Figure 14 shows the distribution of software usage. Comprehensive Meta-Analysis (CMA) is the most used tool, particularly in the East,

where it surpasses its usage in the West. R is also widely employed in both regions, though slightly more in the West (Pascual et al.; Smale-Jacobse et al.; Xu & Xue). While Excel and EndNote have similar usage in both East and West, their presence suggests an integration of qualitative and organizational analysis processes (Cao et al.; Norouzkhani et al.; Peng). This indicates that both regions value technology in their research, albeit with different emphases. Meanwhile, Stata has a lower representation in both regions, reinforcing its role as a complementary rather than primary tool (Ding et al.; Yu et al.).

3.5 Special issue

The special issue, comprising a collection of studies, presented an innovative and cohesive approach that stood out in several key aspects compared to other reviews (Supplementary Table S2). These works, in an integrated manner, addressed educational sustainability through theoretical and practical approaches that promoted inclusive and adaptable development in the fields of education and psychology. Additionally, they emphasized collaborative models and highlighted the impact of familial and social contexts on learning. This framework provided a unified perspective that transcended traditional boundaries, integrating social, emotional, and educational aspects.

A core theme was the emphasis on self-regulated learning and instructional strategies to enhance academic achievement. For example, research by Shao et al. demonstrated how scaffolding techniques significantly improved students' ability to manage their own learning, fostering autonomy and better performance. This study highlights the importance of structured support systems in helping students develop independent learning habits, ultimately leading to better academic outcomes.

A second important connection among the studies was the implementation of inclusive and innovative teaching methodologies. Cochon Drouet et al. highlighted the benefits of the Jigsaw method in fostering social relationships and increasing academic motivation through peer collaboration. Their findings suggest that collaborative pedagogical approaches not only improve academic engagement but also enhance students' social integration, reinforcing the value of inclusive learning environments.

Another significant link was the development of creativity as a fundamental educational outcome. Fan et al. provided evidence that parental involvement plays a crucial role in fostering creativity in children and adolescents. Their study emphasizes how family dynamics contribute to creative growth, illustrating that creativity is not solely developed within academic settings but also shaped by external social factors.

The special issue also addressed the psychosocial factors influencing academic persistence and well-being. De La Fuente & Martínez Vicente introduced the Conceptual Model of Stress Management and Psychological Well-being (CMMSPW™), linking stress regulation to overall mental health in education. Their model suggests that effective stress management strategies can serve as protective factors against academic burnout, helping students maintain long-term engagement with their studies.

Finally, it examined career readiness and adaptability in professional contexts, linking educational development to long-term career success. Wang & Li assessed vocational adaptability and professional identity, providing insights into tools and interventions that enhance career trajectories. Their findings highlight the importance of developing flexible career-oriented skills early in education to ensure students can effectively transition into professional roles.

Overall, the special issue distinguished itself through its interdisciplinary approach, focusing on inclusive and practical solutions to address challenges in education and psychology. By integrating innovative methodologies, psychoeducational variables, and fostering collaboration across diverse contexts, the collection advanced the understanding of key trends and set the stage for future research in these critical areas.

4 Discussion

4.1 Key findings and novelty

This study provides a distinctive contribution to the field of educational psychology by conducting a systematic review of reviews, an approach that represents a significant methodological innovation in the field. Traditional systematic reviews and meta-analyses, while valuable, often focus on synthesizing empirical findings within a specific domain, limiting their scope to individual studies or a narrowly defined research question. In contrast, a review of reviews enables a higher-order synthesis, integrating insights from multiple systematic reviews and meta-analyses to identify overarching trends and methodological patterns that would otherwise remain fragmented across different studies (Branquinho et al., 2021; Furley and Goldschmied, 2021; Topping, 2022).

As advancements in psychology and education accelerate to address increasingly complex societal challenges, comprehensive meta-research becomes essential for contextualizing existing knowledge and evaluating the evolution of methodologies and theoretical frameworks. While systematic reviews and meta-analyses are widely used in educational psychology, reviews of reviews remain significantly less frequent, despite their potential to provide a broader and more integrative perspective on the field. Unlike traditional systematic reviews that aggregate empirical data, this study systematically examines authors and years of publication, countries or regions of origin, review types, age groups, constructs addressed, main topics, theoretical frameworks, digital tools, reliability, validation, review periods, databases, quality analyses, methodologies, data analysis techniques, added value, results, limitations, and applications. By integrating findings across multiple reviews, this research not only maps emerging patterns but also establishes a roadmap for future priorities, refining theoretical frameworks and methodological approaches in educational psychology. This approach encompasses key focal points such as publication trends, regional influences, review typologies, methodological rigor, and the role of digital tools in evidence synthesis, ensuring a nuanced understanding of how research practices evolve over time (Lange-Smith et al., 2024; Stier-Jarmer et al., 2021; Oswald et al., 2024).

At the methodological level, the study highlights the role of structured data analysis in synthesizing complex research trends. The use of Excel for database structuring enabled a systematic confrontation of multiple focal points, revealing significant insights into how psychoeducational and economic factors shape research priorities over time and across regions. This methodological approach

RQ1: What are the main characteristics defining the reviews published in Frontiers in Psychology from its inception to 2024 included, considering methodological, thematic, and focus aspects?	SO1: Determine the predominant characteristics of the reviews published in Frontiers in Psychology, considering aspects such as typology, methodological approaches, and investigated constructs.	F1: Reviews are characterized by a predominance of systematic reviews and meta-analysis, with a wide variety of thematic and methodological approaches.	Result: Predominance of systematic reviews and meta-analyses; wide thematic and methodological diversity.
RQ2: How do systematic reviews differ from meta-analysis in terms of scope, methodology, and scientific contributions?	SO2: Compare systematic reviews and meta-analyses in terms of methodologies and scientific contributions to establish key differences between these approaches.	F1: Reviews are characterized by a predominance of systematic reviews and meta-analysis, with a wide variety of thematic and methodological approaches.	Result: Clear methodological differences between systematic reviews and meta-analyses.
RQ3: What emerging trends are observed in the topics addressed and data analysis approaches in the journal's reviews?	SO3: Identify emerging trends in topics and data analysis approaches in the reviews, highlighting their impact on advancing psychological knowledge.	F2: There is a growing interest in interdisciplinary areas, such as ICT and its impact on educational psychology.	Result: Strong presence of interdisciplinary topics and data analysis trends (e.g., ICT, mental health, well-being).
RQ4: What are the most relevant results obtained from the comparative analysis of reviews by geographic regions, and what regional patterns can be identified?	SO4: Analyze the reviews from a geographical perspective, identifying patterns and regional differences in study approaches and results.	F3: Significant regional differences exist in the approaches and outcomes of published reviews, influenced by geographical, cultural, and socioeconomic contexts.	Result: Regional differences influenced by cultural, political, and socioeconomic factors.
RQ5: How has the use of tools and software in published reviews evolved over time?	SO5: Examine the evolution of tools and software usage in published reviews.	F4: The use of tools and software in reviews has evolved significantly over time.	Result: Significant growth in digital tools and software use over time (e.g., R, CMA, Excel).
RQ6: What specific contributions and added value does the special issue provide compared to the overall set of articles analyzed in the journal?	SO6: Evaluate the specific contributions and added value of the special issue in comparison with the set of published reviews, identifying its relevance and differentiating contributions.	F5: The special issue provides significant added value compared to the set of reviews, standing out for identifying research gaps and promoting innovative approaches.	Result: The special issue adds value through interdisciplinary, inclusive, and practical innovations.

FIGURE 15
Summary table aligning the research questions (RQ), specific objectives (SO), forecasts (F), and main results of the study.

underscores the importance of leveraging digital tools to enhance meta-research while maintaining rigorous analytical frameworks.

Due to the strict analysis, the general objective of this study—to conduct a comparative analysis of reviews published in *Frontiers in Psychology* by identifying predominant characteristics, methodologies, trends, and regional patterns—has been achieved by systematically categorizing reviews across typology, thematic, methodological, and geographical dimensions. The review utilized a multi-layered approach, analyzing studies to uncover methodological trends and providing examples that validate the diversity and rigor of psychological research.

The findings not only address the study's overarching goals but also provide a foundation for understanding how psychological research aligns with global challenges. This sets the stage for a more detailed analysis of the specific objectives, research questions, and forecasts, which will be examined individually in the following paragraphs (Figure 15).

The results of this study show a broad and comprehensive characterization of the reviews published in *Frontiers in Psychology*, a leading journal in the field with a high Journal Citation Reports (JCR) impact factor, addressing RQ1 and achieving SO1. These reviews span a wide variety of topics, including educational psychology, teacher well-being, and the integration of digital literacy, reflecting the journal's commitment to addressing contemporary challenges in psychology. The study highlights a clear predominance of systematic reviews and meta-analysis, which provide rigorous frameworks for analyzing and synthesizing information. For example, Aziku and Zhang conducted a systematic review of research on teacher well-being during the COVID-19 pandemic, highlighting trends in methodology and focus areas. Meanwhile, Clinton-Lisell and Litzinger performed a meta-analysis on the learning styles matching hypothesis, assessing the empirical evidence for its effectiveness. These findings showcase a rich methodological diversity suitable for interdisciplinary challenges. This methodological emphasis demonstrates the maturity of psychological research and its ability to adapt to interdisciplinary demands. By categorizing reviews by their thematic focus, methodological approaches, and investigated constructs, this study offers a nuanced understanding of the trends and priorities in the field,

validating F1 by showing the diversity and evolution of research practices.

The observed increase in systematic reviews, particularly in 2022, reflects broader shifts in scientific inquiry during and after the COVID-19 pandemic. This global event represented a turning point in history, not only for society but also for scientific research, prompting scholars to reassess existing knowledge. Given the disruptions to in-person research activities, many researchers turned to systematic reviews as a means to consolidate and analyze the accumulated body of work up to that moment. The objective was to understand how this historical milestone had influenced scientific paradigms, methodologies, and research priorities. The trend highlights the adaptability of systematic reviews as a research strategy capable of navigating exceptional circumstances, ensuring continuity in scientific production, and facilitating evidence-based decision-making. Moreover, the increasing reliance on systematic reviews suggests a paradigm shift in research methodology, where synthesizing and critically analyzing prior studies has become as essential as generating new empirical data, allowing researchers to reflect on the profound impact of the pandemic on the evolution of knowledge.

The comparison between systematic reviews and meta-analysis addresses RQ2 and contributes to achieving SO2, validating F1 by highlighting fundamental differences in scope and methodology. Systematic reviews, with their flexibility, adapt to broad and exploratory questions, as seen in Amores-Valencia et al., who explored how Augmented Reality (AR) influences academic motivation and performance in secondary education. Meanwhile, meta-analyses, such as Shao et al., focus on synthesizing quantitative data, evaluating the impact of regulated learning scaffolding strategies on self-regulated learning and academic outcomes. These differences reflect their complementary roles in advancing psychological research, enabling it to address interdisciplinary challenges while meeting the growing demand for robust scientific evidence.

The thematic diversity observed in published reviews reflects an effort to adapt to current challenges in psychology. Areas such as educational psychology and teacher well-being have gained significant relevance, likely due to their close connection with global issues like digital transformation and the need to promote well-being in high-demand contexts. Fan et al. conducted a three-level meta-analysis, showing that parental involvement positively predicts student creativity, with autonomy support and behavioral control having the most significant effects. Meanwhile, Chen et al. explored the role of digital technology in promoting mental health among children and adolescents, highlighting the effectiveness of interventions like mobile applications, VR, and serious games in addressing depression, anxiety, and other mental health challenges. This thematic focus addresses RQ3 and achieves SO3, as anticipated in F2, underscoring how reviews in *Frontiers in Psychology* strategically position themselves to address global priorities in psychological research.

The comparative analysis by regions addresses RQ4 and achieves SO4, validating F3 by highlighting how geographical, cultural, and socioeconomic factors influence research approaches and priorities. For example, the predominance of educational psychology in Asia reflects government policies that prioritize education as a key driver of economic growth, particularly in countries like China, Japan, and South Korea, where high-stakes testing systems and rigorous academic expectations shape research agendas. This emphasis aligns with a broader cultural and economic focus on early educational interventions, which aim to build foundational skills essential for academic success and workforce competitiveness.

In contrast, the focus on educational and developmental psychology in America appears to be driven by policies that integrate psychological research into both healthcare and education systems. The strong emphasis on mental health and student well-being reflects public concerns about social–emotional learning, neurodevelopmental disorders, and the psychological impacts of education policies, which are actively addressed through federal funding programs and interdisciplinary research initiatives. Additionally, psychology research in America shows a significant presence of social psychology, which may be linked to the region's focus on issues such as equity, diversity, and inclusion within educational contexts.

Meanwhile, European research stands out for its long-term commitment to equity, inclusion, and sustainability in education, aligning with EU policies that promote lifelong learning and social cohesion. This emphasis is evident in research priorities that focus on educational accessibility, multicultural education, and psychological interventions aimed at reducing disparities. The diversity of research topics across these regions demonstrates how local priorities, cultural values, and institutional frameworks shape psychological inquiry, influencing both research questions and methodological approaches. Consequently, reviews in *Frontiers in Psychology* address both global trends and region-specific challenges, ensuring a nuanced understanding of how educational psychology adapts to different societal needs.

For example, Cao et al. conducted a meta-analysis on computer-based training programs aimed at enhancing children's executive functions, reinforcing Asia's emphasis on early cognitive development as a foundation for academic success and economic growth. In Europe, Dreer highlights the integration of educational and social psychology to address equity, inclusion, and sustainability challenges, aligning with EU policies on lifelong learning and social cohesion. Attwood analyzed the role of multiple intelligences theory in American education, highlighting how evidence-based frameworks integrate psychological research into instructional design. This reinforces America's focus on student well-being, inclusion, and the psychological foundations of education.

Regarding software and tools, the findings address RQ5 and achieve SO5, confirming F4. The increasing adoption of programs such as R and Comprehensive Meta-Analysis reflects significant progress in researchers' digital competencies, while the continued use of tools like Excel highlights the persistence of qualitative and organizational approaches in systematic reviews. This development underscores the shift toward digital tools and AI-driven methodologies, aligning with broader trends in technological innovation in educational psychology. Chen exemplifies this shift by conducting a meta-analysis on self-regulated learning interventions, demonstrating the increasing sophistication of statistical methods in educational research. However, traditional approaches remain relevant, as evidenced by studies like Beaudoin et al., which emphasize systematic reviews in developmental psychology, reflecting the methodological diversity in psychological research.

The special issue represents a significant milestone in educational psychology, offering a cohesive and integrative framework that

distinguishes it from prior reviews. By blending psychoeducational variables with collaborative and inclusive methodologies, it emphasizes the interplay between familial, social, and emotional contexts. This holistic approach creates actionable frameworks to address real-world challenges in psychoeducation, effectively bridging gaps between theory and practice.

Addressing RQ6 and achieving SO6, as anticipated in F5, the special issue's unified approach underscores its role in fostering sustainable and adaptable interventions across diverse educational settings. Unlike prior reviews focusing on isolated aspects, this issue integrates emotional regulation, collaborative learning, and innovative methodologies, aligning with contemporary educational psychology trends. Its comprehensive synthesis offers a roadmap for implementing interdisciplinary solutions that respond to modern educational and psychological complexities.

For instance, Kuznetsova et al. explore giftedness assessment through cognitive, psychological, and cultural dimensions, advocating for more holistic identification methods. Meanwhile, Hurtado et al. (2024) examine doctoral student persistence through a multi-factorial framework addressing individual, academic, and institutional challenges. Collectively, these contributions illustrate the special issue's relevance in advancing adaptable, evidence-based educational solutions.

The results and analyses presented in this review align with the principles established by the Sustainable Development Goals (SDGs), particularly SDG 4: Quality Education. By categorizing and analyzing thematic and methodological trends, the study reflects a commitment to promoting equitable and accessible education. The focus on educational psychology and the integration of diverse approaches underscores the importance of tailoring educational strategies to cultural and socioeconomic conditions, further advancing inclusive and equitable education.

Moreover, this research indirectly supports SDG 3: Good Health and Well-being by emphasizing strategies that promote emotional regulation and collaborative learning. The findings highlight the role of psychological health in fostering supportive and effective educational environments. The special issue's cohesive framework reinforces the connection between educational outcomes and mental health by integrating psychoeducational and emotional variables.

As part of this shift toward evidence-based and technology-enhanced education, AI-driven methodologies are increasingly being integrated into psychological and educational research. These tools offer potential advantages, such as accelerating systematic reviews, improving data analysis, and identifying research gaps more efficiently. However, while AI-powered tools have improved efficiency, their use also raises critical challenges.

One major limitation is the lack of transparency in AI-based decision-making, particularly in automated article selection, bias detection, and quality assessment, which could lead to the unintentional exclusion of relevant studies or the amplification of pre-existing biases in research. Additionally, current AI tools still face significant gaps in semantic comprehension and contextual analysis, making it difficult to accurately interpret complex psychological constructs and theoretical frameworks. As a result, human oversight remains essential to ensure accuracy, reliability, and ethical integrity in AI-assisted reviews.

Moving forward, AI should be integrated into educational psychology research as a complement rather than a replacement for human analysis, with a focus on developing hybrid models that combine AI efficiency with expert validation. Strengthening algorithmic transparency, improving contextual understanding, and refining bias mitigation strategies will be crucial to enhancing the reliability of AI-driven research tools.

Through its exploration of digital and AI methodologies, this study also aligns with SDG 8: Decent Work and Economic Growth and SDG 9: Industry, Innovation, and Infrastructure. By showcasing methodological advancements and evolving research tools, it underscores the importance of preparing the workforce for a digital research environment while ensuring that AI adoption remains ethically sound and methodologically rigorous. The integration of advanced research tools reflects a growing emphasis on leveraging technological progress to enhance educational and psychological research.

4.2 Limitations and future directions

The structured database developed in Excel provides a versatile and efficient resource for organizing and analyzing data, offering extensive opportunities for future research. This tool enables detailed meta-analyses (e.g., examining the number of studies reviewed and their participants), classification of study types (e.g., interventions, developmental studies, program validations), and exploration of methodological trends across time or regions. These capabilities reinforce the foundational value of this study, allowing psychoeducational research to advance by identifying key trends and gaps.

Beyond its methodological applications, this study highlights the practical, theoretical, and technological implications of systematic reviews. Methodologically, it underscores the importance of comparative analyses to synthesize findings and refine research frameworks. Theoretically, it provides a framework for understanding emotional regulation, equity, and global priorities in psychoeducational research. Practically, its findings offer insights into designing action plans to address emerging challenges, such as those posed by ICT, digitalization, and AI, within the context of the Sustainable Development Goals.

To further advance scientific knowledge in psychoeducational research, future studies should expand the methodological diversity of systematic reviews and meta-analyses. In particular, intervention-based studies assessing the practical impact of educational policies and psychological frameworks could provide valuable insights. Longitudinal studies tracking how research trends evolve would help contextualize shifts in methodologies and thematic priorities. Additionally, as digitalization and AI continue to shape education, research should examine their influence on learning processes, teacher training, and student outcomes. Finally, cross-cultural comparative analyses could deepen our understanding of how educational psychology reviews address global challenges and adapt to different socio-economic contexts. Integrating these research directions will enrich the field and ensure systematic reviews remain central to addressing contemporary educational and psychological challenges.

Despite these innovations, this study has certain limitations. First, it focuses exclusively on reviews published in *Frontiers in Psychology* related to educational psychology, which may limit the generalizability of the findings to other journals or psychological domains. However,

to mitigate potential selection biases, a triangulation strategy was employed by conducting searches in Web of Science (WOS) and Scopus databases, ensuring a comprehensive retrieval of relevant studies. While this approach enhances methodological rigor, future research could expand the scope by incorporating systematic reviews from multiple journals, enabling comparative analyses of editorial policies, methodological approaches, and thematic trends across different academic platforms. Additionally, meta-analyses could be conducted to quantitatively synthesize findings from a wider range of sources, providing deeper insights into evolving research trends in educational psychology.

Furthermore, regarding the representativeness of the included studies, it is important to acknowledge that while this review captures a significant portion of systematic reviews and meta-analyses in educational psychology, it does not encompass the full diversity of global research output. Variations in institutional research priorities, funding availability, and regional publication trends may influence the distribution and methodological approaches of the studies analyzed. Future research could address this by incorporating cross-journal comparisons and exploring geographic, institutional, and disciplinary variations in the development of systematic reviews and meta-analyses within the field.

By encouraging further exploration of these trends and patterns, this study provides a lasting contribution to the advancement of knowledge and practice. The structured database developed in this research represents a key resource for uncovering new insights, conducting innovative analyses, and driving interdisciplinary research in response to global challenges.

5 Conclusion

This study underscores the pivotal contributions of reviews related to education in advancing psychology, emphasizing their capacity to synthesize extensive knowledge, uncover patterns, and address interdisciplinary challenges. By conducting a systematic review of reviews, this research introduces a methodological innovation that reflects the rapid evolution of psychology in addressing the complexities of contemporary educational and societal needs. The study's approach highlights the necessity of analyzing prior reviews to map trends, identify gaps, and provide a comprehensive synthesis that guides future research. This added value not only positions the study as a significant contribution to the field but also sets a precedent for similar efforts across related disciplines.

The novelty of this study lies in its ability to offer a critical, comparative analyses across multiple dimensions, including typology, thematic focus, regional perspectives, and methodological approaches. By systematically categorizing reviews published in *Frontiers in Psychology*, this research highlights the importance of synthesizing diverse findings to keep pace with the rapid advancements in psychoeducational research. Such an approach is essential in a field as dynamic as psychology, where the constant emergence of new challenges and priorities necessitates innovative strategies for synthesizing existing knowledge.

The inclusion of the special issue within *Frontiers in Psychology* underscores the journal's commitment to advancing the field by addressing pressing global challenges through innovative and interdisciplinary approaches. By fostering inclusivity and adaptability, this special issue complements the broader contributions of this study, offering actionable insights and advancing sustainable solutions for contemporary educational and psychological needs.

This study achieves its main objective of systematically analyzing reviews related to education, offering a comprehensive synthesis that aligns with the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education) and SDG 3 (Good Health and Well-being). By addressing themes such as emotional regulation, inclusive practices, and educational sustainability, the findings emphasize the need for interdisciplinary strategies that promote equity and well-being in diverse psychoeducational contexts. Additionally, the study's forward-looking perspective underscores the growing importance of transitioning towards digital and AI-driven methodologies, highlighting their potential to revolutionize how educational systems adapt to global challenges.

In summary, this study highlights the value of conducting reviews of reviews as a methodological innovation in psychology. It provides a robust foundation for future research by demonstrating how these meta-analyzes can synthesize complex findings and guide global strategies in education. This research not only enriches academic discourse but also motivates researchers and practitioners to adopt innovative and inclusive approaches, fostering sustainable and impactful solutions that address the evolving needs of educational psychology in a rapidly changing world.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

AD-B: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. JG-S: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. M-LÁ-F: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. SB-C: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. DK: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. T-CH: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. JF: Conceptualization, Data curation, Formal analysis, Funding

acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Generative AI statement

The author(s) declare that Gen AI was used in the creation of this manuscript. For text translation and graphic generation, the ChatGPT artificial intelligence was used (GPT-4 version, ChatGPT model, source: OpenAI). All AI-generated content was manually reviewed by the authors to ensure its accuracy, consistency with the original content, and overall quality. This verification process aimed to guarantee the fidelity of translations and the reliability of the generated materials. We appreciate the support of this tool in improving the accessibility and presentation of the content while maintaining rigorous academic standards.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2025.1588242/full#supplementary-material

SUPPLEMENTARY TABLE S1
References of all analyzed studies.

SUPPLEMENTARY TABLE S2
General analysis with additional details and comparative data from the call of paper.

SUPPLEMENTARY TABLE S3
Analysis of articles split into two sheets: systematic review and meta-analyses.

SUPPLEMENTARY TABLE S4
Overview of research topics and their categorization.

SUPPLEMENTARY TABLE S5
Analysis of articles divided into Eastern and Western publications.

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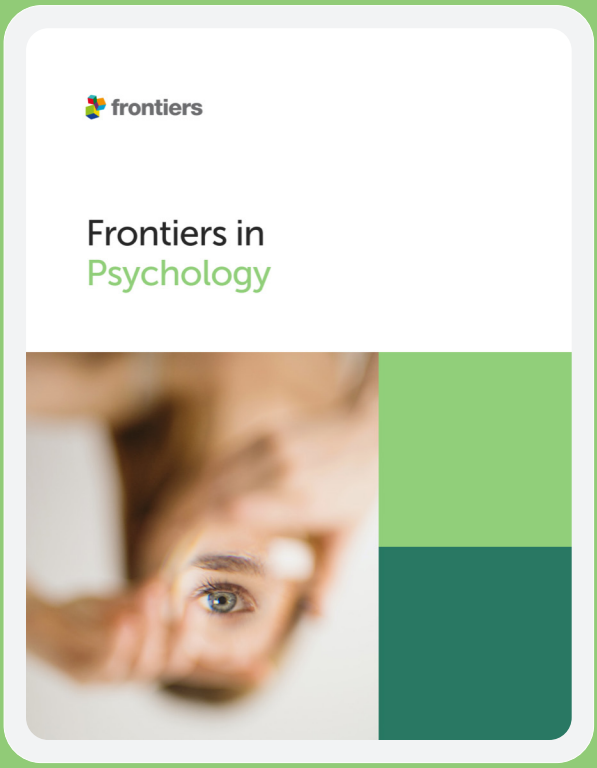

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