THE POWER OF IMPLICIT THEORIES FOR LEARNING IN DIFFERENT EDUCATIONAL CONTEXTS

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THE POWER OF IMPLICIT THEORIES FOR LEARNING IN DIFFERENT EDUCATIONAL CONTEXTS

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EDITORIAL
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Editorial: The Power of Implicit Theories for Learning in Different Educational Contexts

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Editorial on the Research Topic

The Power of Implicit Theories for Learning in Different Educational Contexts

INTRODUCTION

Over the last few decades, members of the field of (educational) psychology have discussed how implicit theories (or mindsets) about one's abilities build an important "meaning system" that can set different learning trajectories and prime particular learning behaviours. For example, these theories might explain why certain students thrive when facing challenges while others languish. Implicit theories are defined as core assumptions about personal abilities or attributes. They can be characterised along a continuum that ranges from an incremental theory (growth mindset), which maintains that abilities can be developed, to an entity theory (fixed mindsets), which views abilities as relatively fixed and unchangeable. However, due to the increasing attempts to replicate previous effects reported for implicit theories, researchers have paid more attention to the questions of whom, why, and under what conditions the effects of an incremental theory (growth mindset) can be expected (Sisk et al., 2018; Yeager and Dweck, 2020; OECD, 2021).

Researchers use questionnaires and alternative assessment methods (e.g., neuroscience, interviews) to understand implicit theories as they apply to different age groups (Mangels et al., 2006; Compagnoni et al., 2019). Thus, paying attention to how and which implicit theories are measured to compare results is important. This is especially important since individuals can simultaneously hold various implicit theories that concern different abilities. For example, implicit theories can address domain-general implicit theories (e.g., intelligence, willpower) or domain- or ability-specific implicit theories (e.g., self-regulated learning, math). Over the last few years, some researchers have argued that domain-specific implicit theories may be better suited for predicting domain-specific behaviour than domain-general implicit theories (Gunderson et al., 2017; Hertel and Karlen, 2021). It might therefore be beneficial to examine both domain-general and domain-specific theories together. Consequently, examining how findings from one domain apply to another is essential. This circumstance calls for studies that aim to replicate previously reported results. Finally, researchers have empirically demonstrated that (short) interventions could change implicit theories (Bostwick and Becker-Blease, 2018; Burnette et al., 2020; Lee et al., 2021). However, the approaches and the effects of those interventions are heterogeneous. One reason for these inconsistent results might be that interventions are likely to be stronger or weaker for different groups and contexts. Therefore, more (intervention) studies that explore the potential for different implicit theories in diverse populations and different cultural contexts and with different approaches must be conducted.

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TABLE 1 | Overview of all 14 studies contributing to the Research Topic.

Authors	Implicit theories (mindsets)	Sample	Research focus	Instruments/methodological approach	Country
Domain-general implicit theories					
Compagnoni et al.	Implicit theories about willpower	147 kindergarteners (M_{age} = 6.47 years)	Behavioural self-regulation, learning goals	Self-report questionnaire with a 5-point semantic differential scale, teacher ratings Regression analysis	Switzerland
Liu	Implicit theories of intelligence	1,201 students (M_{age} = 14.68 years) from secondary schools	Achievement goals, intrinsic motivation, mathematics test scores	Self-report questionnaire with a 6-point Likert scale, structural equation modelling	Singapore
Muenks et al.	Intelligence mindsets, failure mindsets, effort mindsets	304 undergraduate engineering students (M_{age} = 19.56 years)	Perceptions of their professors' mindsets, perceptions of peers' mindsets, motivation, sense of belonging, academic choices	Self-report questionnaire with a 6-point Likert scale, *t*-tests, regression analyses	United States
Montagna et al.	Implicit theories of intelligence	77 university pre-service teacher students (M_{age} = 21.6 years)	Academic self-concept, coping-ability appraisal, cognitive stress appraisal	Self-report questionnaire with a 6-point Likert scale, computer-based mindset intervention	Germany
Bauer and Hannover	Implicit theories of excellence	663 university students (M_{age} = 24.27 years)	Sense of belonging, effects of gender and ethnicity	Self-report questionnaire with a 7-point Likert scale, experimental manipulation, ANOVA	Germany
Yan and Wang	Intelligence mindset, difficulty-as-importance, difficulty-as-impossibility, ease-as-possibility, ease-as-triviality	366 college undergraduates' students (18–41 years)	Course interest and importance, achievement goals, study strategies	Self-report questionnaire with a 6-point Likert scale, person-centred approach, latent profile analysis, regression analyses	United States
Levinthal et al.	Implicit theories about learning	19 parents (M_{age} = 43.84 years) of first- to sixth-grade children	Parental engagement with their children's learning at home	Qualitative study, semi-structured interviews content-analysis method	Finland and Portugal
Domain- or ability-specific implicit theories					
Law et al.	Gender stereotypes beliefs about STEM	143 children (5–12 years)	Age, gender, experimental conditions	Self-report questionnaire with a 10-point Likert scale, experimental manipulation, ANOVA	United Kingdom
Karlen et al.	Implicit theories about self-regulated learning	244 secondary school students (M_{age} = 14.57 years)	Self-concept about self-regulated learning, emotions about learning strategy knowledge, academic achievement	Self-report questionnaire with a 5-point semantic differential scale, strategy knowledge test, path analysis	Switzerland
Wolff	Math-related gender stereotypes	1,424 secondary school students (M_{age} = 15.1 years)	Math self-concept	Self-report questionnaire with a 6-point Likert scale, multiple groups two-level structural equation modelling	Germany
Rechsteiner et al.	Implicit theories of school improvement abilities	1,483 elementary school teachers (M_{age} = 43.31 years)	Collective regulation activities, being on the right track	Self-report questionnaire with a 6-point semantic differential scale, structural equation modelling	Switzerland
Domain-general and -specific implicit theories					
Puusepp et al.	Intelligence mindsets, math mindsets	97 elementary school students (M_{age} = 8.94 years)	Reactions to negative feedback in mathematics	Self-report questionnaire with a 6-point Likert scale, neuroscientific experiment, computer-based math task	Finland
Su et al.	Intelligence mindsets, failure beliefs in math	466 fifth graders (10–12 years)	Math self-efficacy, math achievement	Self-report questionnaire with a 6-point Likert scale, math exam, structural equation modelling	China
Stern and Hertel	Implicit theories of intelligence, failure beliefs, implicit theories about self-regulation	137 parents (M_{age} = 37.42 years) of pre-schoolers	Failure beliefs, goal orientation, co-regulatory strategies	Self-report questionnaire with a 5-point semantic differential scale, person-centred perspective latent profile analysis	Germany

The purpose of this Research Topic is to provide an overview of the latest research on implicit theories. We take a multi-perspective view on implicit theories and bring together current research on different implicit theories (see overview in **Table 1**). This Research Topic includes a total of 14 studies that address implicit theories by using empirical data from samples that were collected from different continents and cultural contexts, including Asia (China and Singapore), Europe (Finland, Germany, Portugal, Switzerland and the United Kingdom), and North America (the United States).

Researchers assessed implicit theories in different age groups: starting from kindergarten, researchers studied children in early childhood education (Compagnoni et al.), followed by primary school students (Law et al.; Puusepp et al.; Su et al.), lower and upper secondary students (Karlen et al.; Liu; Wolff) and up to older learners at colleges and universities (Bauer and Hannover; Montagna et al.; Muenks et al.; Yan and Wang). Besides learners, researchers have also examined other groups such as teachers (Rechsteiner et al.) and parents (Levinthal et al.; Stern and Hertel). Several researchers have assessed domain-general implicit theories such as implicit theories about intelligence (Bauer and Hannover; Liu; Montagna et al.; Muenks et al.; Stern and Hertel; Su et al.; Yan and Wang), implicit theories about learning (Levinthal et al.), implicit theories about willpower (Compagnoni et al.) and implicit theories about failure, difficulty, and efforts (Muenks et al.; Su et al.; Stern and Hertel; Yan and Wang). Other researchers have taken a more domain- or ability-specific approach by assessing implicit theories about self-regulated learning (Karlen et al., Stern and Hertel), implicit theories about science and math (Law et al.; Puusepp et al.; Wolff), and implicit theories about school improvement (Rechsteiner et al.). Many researchers have captured implicit theories using questionnaires; however, these questionnaires are marked by differences. While the majority of researchers have empirically assessed implicit theories as one (bipolar) construct, one researcher used a multidimensional scale (Liu) to assess entity and incremental theory separately. A group of researchers who conducted a neuroscience study applied a different approach by providing new insight into implicit theories' neural foundations (Puusepp et al.). Finally, several researchers who have conducted intervention studies have examined whether people can be triggered into adopting different implicit theories in different situations (Bauer and Hannover; Law et al.; Montagna et al.; Puusepp et al.).

WHAT LESSONS WERE LEARNED FROM THE STUDIES ON THIS RESEARCH TOPIC

How do Implicit Theories Support Successful Learning?

Researchers have found several replicable associations between domain-general and domain-specific implicit theories concerning student learning and performance patterns across different age groups and cultural backgrounds. Additionally, implicit theories, for the most part, relate to students' learning and motivation, which, in turn, positively affects their academic achievement.

For young learners, Compagnoni et al.'s results indicate that Swiss kindergarteners who think of their willpower as a non-limited resource demonstrate better behavioural self-regulation and a higher willingness to exert effort. Su et al. reported that Chinese fifth-graders' implicit theories about intelligence positively relate to students' beliefs about failure and mathematical self-efficacy, and, in turn, to mathematical achievement. Finally, Puusepp et al. found that Finnish elementary students' implicit theories about math (but not their theories about intelligence) are linked to processing feedback concerning their performance in math, which highlights the importance of domain-specific approaches.

Moving to secondary school students, Karlen et al. found a positive relationship between Swiss students' implicit theories about self-regulated learning and their self-concepts, learning emotions, strategy knowledge, and academic achievements. Finally, Lui studied Singapore students' implicit theories about intelligence. Incremental intelligence theory positively relates to mastery-approach goals and, in turn, positively associates with intrinsic motivation and test scores in mathematics.

Regarding university students, Muenks et al. examined U.S. undergraduate students' implicit theories. These students' implicit theories (intelligence, effort and failure) predicted their motivations, belonging, and choices of complex (over easy) tasks, even controlling for gender and prior achievements. For another study that originated in the United States, Yan and Wang used person-centred latent profiles to categorise profiles based on different implicit beliefs (ease and difficulty implicit theories and implicit theories about intelligence). They found that students who endorse motivation-increasing implicit theories are more likely to hold mastery-approach goals. However, implicit theories' profiles do not directly relate to strategy use, but goal orientation does.

Are There Differences Between Implicit Theories in Groups of Students?

We have reviewed if the studies in this Research Topic point out systematic differences between children and students concerning their implicit theories. The results demonstrate that low-achieving kindergartners from Switzerland reported more often that willpower is a limited resource (Compagnoni et al.). Similarly, Swiss secondary school students in lower academic tracks claimed more often that their abilities to self-regulate learning are relatively unchangeable rather than malleable (Karlen et al.). Moreover, several researchers reported gender differences. The results might differ depending on whether an ability is seen as more feminine or masculine (stereotype). For example, Su et al. wrote that Chinese boys have significantly higher mean levels of implicit theories about intelligence and self-efficacy in math than Chinese girls do. Wolff found similar results in Germany: boys demonstrated higher mathematical self-concepts than girls did, and they also held a slightly stronger belief in the stereotype that favours boys in math. Law et al. reported that children from the United Kingdom demonstrated in-group bias in relation to their gender regarding implicit theories about space science. Finally, Karlen et al. found that in a group of Swiss students, the girls reported a higher self-concept for self-regulated learning than the boys did. However, these differences were not exhibited for the implicit theories about self-regulated learning. These results indicate that particular groups of learners (students with learning difficulties and students who are affected by stereotypes) are at risk of having less adaptive implicit theories, which could harm their future development. Therefore, future researchers may want to examine whether group differences exist.

Do Interventions That Aim to Change Implicit Theories Work?

Interventions that aim to change implicit theories build on the idea that ability can be developed and that people can develop their abilities actively through the actions they take. The three intervention studies in this Research Topic involve different intervention approaches, various implicit theories and different populations. The researchers demonstrated that people can be triggered to adopt different implicit theories (Bauer and Hannover; Law et al.; Montagna et al.). Law et al. reported that a group of children who were exposed to an incremental theory intervention reported significantly less gender stereotyping about STEM than the children who were members of the control group. Montagna et al. found that even a one-time computerised intervention of 25 min that focuses on implicit theories about intelligence (an incremental theory message or a saying-is-believing exercise) positively impacts teachers' and students' incremental theories (but not their stress appraisal). Bauer and Hannover developed an intervention using manipulated advertising material and tested its effects on university students' belonging to a "genius" organisation (implicit theories about excellence). Individuals who fit the profile of a gifted student benefited regarding their sense of belonging in the organisation as they had a fixed view of excellence in contrast to students who did not match that profile (for example, females from negatively stereotyped ethnic minority groups). Summarily, the three research groups demonstrated that when interventions on implicit theories are well-crafted and target specific groups, the probability of their effects presumably increases. However, this does not mean that interventions will work in every cultural context or for all student populations. Yeager and Dweck (2020) suggested that intervention effects might be more meaningful when individuals are actively facing challenges or setbacks (e.g., lower-achieving students or stereotype threats) and when the context provides opportunities for students to act on their implicit theories. However, there is much more to learn about heterogeneity in interventions to support students' incremental theories, especially in young children.

The Socialisation of Implicit Theories: Parents' and Teachers' Implicit Theories and the Role of the Learning Context

Where do implicit theories come from, and how are they socialised? One possible answer involves the influence of pedagogical agents' implicit theories. Parents and teachers' implicit theories might impact their learning-related co-regulatory behaviours and might consequently prime leaners' implicit theories. Stern and Hertel identified three profiles of implicit theories among parents of pre-schoolers. Parents in different profiles exhibited different (adaptive) patterns that were affected by their attitudes and co-regulatory strategies. For example, parents who had high incremental theories about self-regulation displayed the most adaptive attitudes and behaviours in comparison to the others. Levinthal et al. found in their qualitative studies that most of the examined parents of young school children adhered to incremental theories. This finding aligned with acknowledging the role of effort in learning, such as pursuing following broader forms of engagement, encouraging persistence and practice, and interpreting difficulties as a natural part of learning.

Moving to the classroom context, the assumption that implicit theories that are held by significant others (e.g., classmates) might influence individual implicit theories becomes crucial. In this context, Wolff demonstrated that gender stereotypes in math that are shared by students' classmates substantially impact students' mathematical self-concepts, even beyond their individual gender stereotypes. In line with this result, Muenks revealed that the classroom context, as operationalised by students' perceptions of their professors' and peers' implicit theories, can predict their motivations, sense of belonging, and academic choices, even controlling for students' implicit theories. Taken together, the results of both studies provide essential empirical evidence that demonstrates that students' implicit theories are also influenced by how individuals experience their contexts (e.g., the social context in a classroom and the implicit theories about teachers and peers).

Rechsteiner et al. focused on teachers' implicit theories about professional abilities and the importance of those theories for school improvement as a collective learning process. They found that the majority of primary school teachers believe that professional abilities can be changed or developed. The results revealed that teachers' incremental theories about professional abilities positively relate to collective emotional-motivational regulation strategies and, in turn, to being on the right track according to school improvement guidelines. The authors noted that implicit theories might not only be necessary for an individual's development but might also be relevant for teachers' engagement in school improvement on an institutional level.

CONCLUSION

The international and inter-cultural mix of data sources, methodological approaches, and perspectives about implicit theories offers new insight into the foundations and effects of implicit theories. The studies demonstrate that implicit theories about different abilities can be assessed for individuals from a young age (kindergarteners) to adulthood and through different methodological approaches (i.e., questionnaires, interviews and neuroscience). In summary, the results demonstrate that implicit theories have the power to influence learning in different educational contexts. Adaptive implicit theories or mindsets can support students' motivations, self-regulation, efforts to learn, as well as influence their sense of belonging and coping with negative feedback. Moreover, the research in this Research Topic presents evidence that through well-crafted interventions, learners' domain-general and domain-specific implicit theories can be manipulated and thus lead to individual adaptations in their motivations, behaviours and reactions. Finally, several

authors demonstrated that implicit theories also provide an essential framework for understanding parents' and teachers' learning-related co-regulatory behaviours.

The findings from the Research Topic point to several future directions for research. First, researchers should understand the origins of learners' implicit theories, the effects that these theories have within different groups of learners, and the socialisation practices that foster them. Second, implicit theories can be assessed from a very early age and are essential aspects of an individual's learning biography in lifelong learning. Third, parents and teachers' implicit theories might shape students' implicit theories. Consequently, helping parents and teachers create environments that support the development of incremental theories and examine the effect of mindset interventions is essential. However, mindset interventions that are administered by teachers have resulted in inconsistent success (e.g., Foliano et al., 2019). Finally, the further investigation of domain specificity or the cross-domain effects of implicit theories and their extension to other ability domains holds much potential.

Implicit theories have the power to influence learning in different educational contexts for various populations of learners. Implicit theories thus build a framework for examining individual differences in learning and academic outcomes. The evidence reveals the meaningful heterogeneity of the effects of implicit theories for learning of different students' populations through various studies in this Research Topic. The researchers have also demonstrated that well-crafted interventions could modify implicit theories. Furthermore, implicit theories also provide an essential framework for understanding parents' and teachers' learning-related co-regulatory behaviours. The more we learn about why and in what context implicit theories are meaningful, the more we can refine theoretical frameworks, improve measures of implicit theories, and develop targeted intervention programs. This will eventually also help increase pedagogical agents' awareness of the importance of implicit theories and support tomorrow's learning.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work and approved it for publication.

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Profiles of Parents' Beliefs About Their Child's Intelligence and Self-Regulation: A Latent Profile Analysis

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This study examined parents' implicit theories of intelligence and self-regulation from a person-centered perspective using latent profile analysis. First, we explored whether different belief profiles exist. Second, we examined if the emergent belief profiles (1) differ by demographic variables (e.g., age, education, child's self-regulation) and (2) are related to parents' failure beliefs, goal orientation (i.e., learning goals, performance-approach goals, performance-avoidance goals), and co-regulatory strategies (i.e., mastery-oriented and helpless-oriented strategies). Data were collected from N = 137 parents of preschoolers who answered an online survey comprising their implicit theories about the malleability and relevance of the domains (a) intelligence and (b) self-regulation. We identified three belief profiles: profile 1 (9% of the sample) displayed an entity theory, profile 2 (61% of the sample) showed a balanced pattern of both domains of implicit theories, and profile 3 (30% of the sample) was characterized by high incremental self-regulation theories. Analyses showed that parents differed significantly in education and their perception of child self-regulatory competence depending on profile membership, with parents in profile 1 having the lowest scores compared to parents of the other profiles. Differences in parents' failure beliefs, goal orientation, and co-regulatory strategies were also found depending on profile membership. Parents in profile 3 reported failure-is-enhancing mindsets, and mastery-oriented strategies significantly more often than parents in profiles 1 and 2. The results provide new insights into the interplay of important domains of implicit theories, and their associations with parents' failure beliefs, goal orientation, and co-regulatory strategies.

Keywords: implicit theories, intelligence, self-regulation, parents, latent profile analysis

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INTRODUCTION

Many parents have concrete beliefs about their children's abilities. For example, parents may view their children's abilities as malleable and changeable by effort or rather believe that their children have innate competencies that are relatively fixed and cannot be changed. Parents' cognitions have important short- and long-term effects on parenting practices and child development (Bornstein et al., 2018). More precisely, parents' implicit theories influence parents' goal orientation, their co-regulatory strategies, and consequently their child's self-regulation (Ames and Archer, 1987;

Grolnick et al., 2002; Pomerantz and Dong, 2006; Blackwell et al., 2007; Moorman and Pomerantz, 2010; Burnette et al., 2013; Jiang et al., 2019).

Although the importance of implicit theories is evident, relatively little is known about how different domains (e.g., intelligence, self-regulation) and dimensions (e.g., malleability, relevance) of implicit theories co-occur in everyday situations affecting parents' attitudes (e.g., failure beliefs, goal orientation) and co-regulatory strategies. This lack of attention to interaction processes of different domains is surprising, given that individuals can hold different implicit theories in different domains and attributes at the same time (Dweck et al., 1995; Tabernero and Wood, 1999; Muenks et al., 2015; Haimovitz and Dweck, 2017). For example, some parents may view their children's ability in one domain (e.g., self-regulation) to be malleable while considering their children's ability in another domain (e.g., intelligence) to be relatively fixed. Other parents may think that both domains of abilities are malleable but that only one of these is relevant for their children's success. To date, research on implicit theories has predominantly focused on implicit theories of intelligence (Dweck, 2000; Moorman and Pomerantz, 2010) while ignoring the domain of self-regulation. Since parents play an important role in children's self-regulatory development, parents' implicit theories of self-regulation should play an important role in predicting self-regulatory processes.

Therefore, this study examined how implicit theories co-occur within parents using latent profile analysis (LPA). LPA is a person-centered approach that aims to identify unobserved subgroups based on the similarity of the sample on observed variables (Collins and Lanza, 2009). The variables used for the LPA comprised two domains of children's abilities: *intelligence* and *self-regulation*, each including two dimensions: *malleability* and *relevance for success*. We then analyzed how the emergent belief profiles are composed with respect to demographic variables. Finally, we explored how different belief profiles relate to parents' attitudes (i.e., failure beliefs, goal orientation) and co-regulatory strategies.

THEORETICAL BACKGROUND

Implicit Theories of Abilities

Implicit theories are belief systems about human attributes and abilities that help individuals to explain and understand their world (Lüftenegger and Chen, 2017). There is a long tradition in research following Carol Dweck's social cognitive theory (Dweck and Leggett, 1988) examining the malleability of abilities. She distinguishes two types of implicit theories: incremental theories and entity theories. *Incremental theories* refer to viewing abilities as malleable and changeable by effort while *entity theories* refer to viewing abilities as innate competencies that are rather fixed. So far, these implicit theories were mainly examined in children and students, showing that incremental theories are related to higher motivation, persistence, adaptive learning strategies, and academic achievement (Dweck and Leggett, 1988; Blackwell et al., 2007).

Although there is a wealth of evidence that implicit theories are relevant determinants of motivation, cognition, and behavior in learning and achievement settings (Blackwell et al., 2007; Burnette et al., 2013), parental implicit theories have gained attention only recently. Parental implicit theories refer to beliefs parents have about the abilities of their children. These can refer to an array of abilities and domains such as intelligence (Dweck, 2000; Pomerantz and Dong, 2006), math and verbal ability (Muenks et al., 2015), or failure (Haimovitz and Dweck, 2016). These implicit theories from various domains can correlate but findings suggest relatively independent constructs (Dweck et al., 1995; Tabernero and Wood, 1999; Haimovitz and Dweck, 2016). This means that individuals can hold an incremental theory in one domain but an entity theory in another domain (Schroder et al., 2016).

In the context of parents, past research has primarily focused on parents' implicit theories of *intelligence* (Dweck, 2000; Pomerantz and Dong, 2006; Moorman and Pomerantz, 2010; Rautiainen et al., 2016). The interest in the domain of intelligence originates from broad evidence suggesting that implicit theories of intelligence have important effects on academic and emotional functioning (for a meta-analytic review see Costa and Faria, 2018). Inspired by research about children's implicit theories of intelligence, researchers have asked if parents' implicit theories are also consequential for children's implicit theories as well as parents' learning and achievement-related behaviors (e.g., Rautiainen et al., 2016) as parents' play an important role in children's socialization (Taylor et al., 2004). Initial studies indicate that parents' incremental theories predict children's outcomes (e.g., children's incremental theories, achievement) and parental learning-related behaviors (Pomerantz and Dong, 2006; Moorman and Pomerantz, 2010; Muenks et al., 2015; Matthes and Stoeger, 2018).

In children's development, intelligence is not the only significant domain that influences parents' and their children's beliefs and in turn the associated consequences. The concept of *self-regulation* receives high attention in both scientific and popular scientific literature and is known as a central construct of psychology (Vohs and Baumeister, 2013). Self-regulation is defined as the ability "to regulate affect, attention, and behavior to respond effectively to both internal and environmental demands" (Raffaelli et al., 2005, p. 54). Self-regulation develops in early childhood and predicts a range of social-emotional, health-related, and academic outcomes (Moffitt et al., 2011; McClelland and Cameron, 2012; Neuenschwander et al., 2012; Valiente et al., 2013). However, what individuals believe about the malleability and relevance of self-regulation remains largely unexplored. Initial studies indicate that these implicit theories of self-regulation are associated with self-regulatory processes such as goal orientation and learning strategy use (Hertel and Karlen, under review; Stern et al., under review), and influence effort and perseverance (Mrazek et al., 2018).

However, research suggests that it is not only the question of whether parents believe that abilities are malleable (Stern et al., under review); another important dimension of implicit theories is the question of the abilities' *relevance for success* (Spinath, 2001). Individuals can hold different opinions about

how relevant abilities are for the success in particular tasks (e.g., the relevance of intelligence for school achievement; Schlangen and Stiensmeier-Pelster, 1997; Spinath and Schöne, 2003). Inspired by Wigfield and Eccles (2000) expectancy-value theory of motivation it can be assumed that the belief about the relevance of a certain ability is an important predecessor of motivation and influences behavior. For example, if parents believe that a certain ability is a relevant variable for their children's success in a specific context, they will promote and support their children's development. These beliefs, in turn, may affect the relation between implicit theories about the malleability of abilities and behavior: Only if individuals believe that a certain ability is a relevant variable individuals' incremental or entity theories may become effective (Spinath and Schöne, 2003). Malleability and relevance for success seem to be moderately correlated dimensions of implicit theories that both have beneficial effects explaining links between implicit theories and learning-related outcomes (Hertel and Karlen, under review; Stern et al., under review). However, a simultaneous consideration of both dimensions is rare in the context of research concerning parents' implicit theories.

Implicit Theories and Failure Beliefs

Implicit theories are most powerful in challenging and demanding situations (Dweck and Leggett, 1988; Blackwell et al., 2007). Dweck and Leggett (1988) argue that implicit theories are related to the attribution of failure and individuals' behaviors: Individuals with an incremental theory attribute failure to a lack of effort. Incremental theorists are more likely to persist through failure as they see failure as an opportunity for learning. In contrast, individuals with an entity theory attribute failure to a lack of ability. Entity theorists tend to give up in the face of failure because they see failure as a sign of being incompetent (Dweck and Leggett, 1988; Blackwell et al., 2007; King, 2017).

In the context of parents, failure beliefs are of special interest. Especially during early childhood, children are still developing their skills and are often in the face of failure. Here, parents play an important role to support their children and enable them to solve challenging tasks (Bernier et al., 2010). Haimovitz and Dweck (2016) have identified two different failure beliefs of parents: a failure-is-enhancing mindset and a failure-is-debilitating mindset. Parents with a *failure-is-enhancing mindset* view failure as "an enhancing experience that facilitates learning and growth [. . ., while parents with a *failure-is-debilitating mindset* believe] that failure is a debilitating experience that inhibits learning and productivity" (Haimovitz and Dweck, 2016, p. 860). Empirically, these beliefs relate to parenting practices and children's intelligence theories: Parents, who view failure as debilitating show more performance-oriented responses, report less support for their children's learning, and more concerns about their children's performance and lack of ability compared to parents with a failure-is-enhancing mindset (Haimovitz and Dweck, 2016). Moreover, parents with a failure-is-debilitating mindset have children who believe that intelligence is fixed. However, the link between parents' failure beliefs and parents' implicit theories is not well-understood so far. There is some evidence that parents' implicit theories and failure beliefs are independent constructs, whereas there is also some suggestion that parents' entity theories are positively correlated to their failure-is-debilitating mindsets (see Haimovitz and Dweck, 2016). The question also arises if the relation between implicit theories and failure beliefs is domain-specific. More specifically, some parents, for example, may believe that failure is debilitating to develop self-regulatory abilities but enhancing to increase intelligence. Therefore, it seems important to examine these mechanisms in more detail and take further domains and dimensions of implicit theories into account (e.g., implicit theories of self-regulation) to better understand how parents' implicit theories and failure beliefs are related.

Implicit Theories and Goal Orientation

Implicit theories are significantly linked to goal orientation (Burnette et al., 2013): Individuals perceiving abilities as malleable pursue *learning goals* to increase their skills, while individuals holding an entity theory pursue performance goals to secure positive judgments (*performance-approach goal orientation*) or avoid challenging tasks to prevent negative judgments (*performance-avoidance goal orientation*) (Dweck, 1986). Applied to parenting, parents with learning goals want their child to develop skills, whereas parents with performance goals want to demonstrate their children's competences (performance-approach) or avoid situations where their child might perform worse than others (performance-avoidance) (Mageau et al., 2016). Parental goal orientation affects parents' co-regulatory strategies (e.g., autonomy support, control; Gonida and Cortina, 2014; Mageau et al., 2016) as well as children's beliefs, motivation, and performance (Gottfried et al., 1994; Grolnick et al., 2002; Gunderson et al., 2013). For example, parents with performance goals provide more controlling behavior to their children compared to parents with learning goals (Grolnick et al., 2002). While performance-avoidance goals have proved predominantly maladaptive (e.g., poor performances, test anxiety, low help-seeking behavior; for a review see Moller and Elliot, 2006), performance-approach goals can have both positive and negative effects (Mageau et al., 2016).

Meta-analytical findings by Burnette et al. (2013) with 113 studies across diverse contexts and populations suggest positive associations between incremental theories and learning goals as well as between entity theories and performance-avoidance goals. No substantial relation for performance-approach goals was found. In contrast, in the specific context of parents, the effect of learning goals but not of performance-avoidance goals could be confirmed (Stern et al., under review). One explanation might be that parents' performance-avoidance goals were low overall. Moreover, parents' implicit theories about the relevance of abilities might play an important role, as these have been found to be positively correlated with parents' performance-approach goals (Stern et al., under review). Previous research has especially used incremental theories of intelligence to predict goal orientation and ignored implicit theories about the relevance of abilities. A simultaneous consideration of two domains of implicit theories about the malleability *and* relevance of abilities might explain the complex pattern of associations between parents' implicit theories and goal orientation.

Implicit Theories and Co-regulatory Strategies

Parents' co-regulatory strategies, in the sense of attempts to modify children's thoughts, emotions, and behavior (Colman et al., 2006; Pauen, 2016), are especially relevant in early childhood when self-regulatory abilities are developing and children are still dependent on their parents' support (Kopp, 1982; Bernier et al., 2010; Valcan et al., 2018). While *mastery-oriented co-regulatory strategies* (e.g., warmth, inductive discipline, scaffolding, autonomy support) are associated with higher self-regulatory abilities, *helpless-oriented co-regulatory strategies* (e.g, control, intrusiveness) are related to lower self-regulatory abilities of children.

Research across different domains and populations has shown that a person's implicit theory predicts mastery- and helpless-oriented strategies (Burnette et al., 2013). Applied to parenting, one may assume that parents with incremental theories are more likely to use mastery-oriented strategies that help their child to learn (e.g., remaining encouraging; holding discussions; calling for self-regulation) because the child's abilities reflect learning processes that can be promoted. In contrast, entity theorists may tend to employ helpless-oriented strategies (e.g., using negative pressure for example by forcing the child to comply; giving in) as a reaction of poor performances that reflect stable abilities and consequently permanent deficits. This line of reasoning is substantiated by evidence that parents' implicit theories are important determinants of parents' co-regulatory strategies: Parents who believe that abilities (e.g., intelligence, math, and verbal abilities) are stable show more controlling and performance-oriented behaviors than parents with incremental theories (Moorman and Pomerantz, 2010; Muenks et al., 2015). Nevertheless, it is unclear whether the effects are stronger for some parents than others because past studies used experimental manipulations (Moorman and Pomerantz, 2010) or measured limited demographic characteristics (Muenks et al., 2015). Using a person-centered approach and examining belief profiles and their relations to parents' co-regulatory strategies could help close this research gap.

Sociodemographic Group Differences in Implicit Theories of Abilities

Regarding sociodemographic variables that shape parents' implicit theories, empirical investigations are rare. Increasing research examines group differences in implicit theories by demographic variables such as gender, age, and educational level. However, it is still under debate if and how demographic variables are and should be related to implicit theories. Gender is mostly unrelated to implicit theories (Pomerantz and Dong, 2006; Burnette et al., 2013; Muenks et al., 2015; Jiang et al., 2019). Anyhow, parents' gender may shape parents' implicit theories, as mothers' and fathers' values and understanding of their children's upbringing may disagree (e.g., Lareau, 2000). Parents' implicit theories may also differ by their children's gender: Parents are more prone to attribute boys' achievement to talent and girls' achievement to effort (e.g., Eccles et al., 1990). Furthermore, some researchers argue that girls (especially high-achieving girls) have a lower tendency for new and difficult tasks and attribute failure to a lack of ability (i.e., holding entity theories), compared to boys who tend to hold incremental theories (Dweck, 1986; Chen, 2012; Diseth et al., 2014). Concerning age differences, some studies report that young students tend to overestimate their skills (Hasselhorn, 2005) and therefore hold incremental theories more likely (Chen, 2012). Given that beliefs stabilize with age, no age differences are expected for adults (Pomerantz and Dong, 2006; Jiang et al., 2019). Regarding parents' educational level, some studies point out that parents' incremental theories are linked to a higher level of education (Pomerantz and Dong, 2006; Muenks et al., 2015; Jiang et al., 2019). Other researchers (Rautiainen et al., 2016) argue that parents with an academic education tend to hold an entity theory because they support the theory of natural giftedness (Räty and Snellman, 1998) but could not support this hypothesis empirically. Finally, the question arises on how parents' perceptions of their children's competence affect parents' implicit theories. Haimovitz and Dweck (2017) have found that parents' perceptions of their children's competence are partly related to parents' implicit theories. Research from extended literature shows that implicit theories of intelligence are largely unrelated to one's actual personality and intelligence (Spinath et al., 2003). Overall, these results represent high inconsistency and more studies are needed to illuminate the contribution of person-specific characteristics.

A Person-Centered Approach to Implicit Theories

The current study uses a person-centered approach by studying patterns of implicit theories in parents. Whereas *variable-centered approaches* (e.g., regressions, path analysis) examine relationships among variables on average, *person-centered approaches* describe relationships among persons by identifying subpopulations depending on their scores on multiple variables of interest (Lubke and Muthén, 2005). The latent profile analysis (LPA) is one of the person-centered approaches and offers several advantages. First, the number of profiles result from empirical fit indices that specify the optimal number and the researcher does not have to determine a number a priori. Second, individuals are not assigned to a specific profile absolutely, but each individual's probability of memberships for each profile are calculated. LPA is particularly suitable for exploratory research questions and is increasingly used in research on beliefs and attitudes, for example, students' implicit theories and epistemic beliefs (Chen, 2012; Hertel et al., 2019), or parents' self-efficacy beliefs (Junttila and Vauras, 2014). This method is particularly useful in this field of research, as individuals may hold different beliefs and attitudes in various domains simultaneously, which results in different configurations of beliefs. Using a variable-centered method might conceal important results and implications. To our knowledge, no study has used LPA to examine implicit theories of abilities in parents so far.

We assume that implicit theories about the malleability and relevance of different domains may co-occur within persons. The present study aims to explore those individual belief profiles that naturally arise among parents of preschoolers. As already

described, some parents may hold incremental theories (or entity theories) in different domains at the same time, whereas other parents may hold incremental theories in one domain but entity theories in the other domain, for example. Thus, we examine whether different profiles of implicit theories of intelligence and self-regulation exist. Moreover, we argue that different profiles are differentially adaptive or maladaptive concerning parents' attitudes (i.e., failure beliefs, goal orientation) and co-regulatory strategies (i.e., mastery- and helpless-oriented strategies). Past research using a variable-centered method shows that parents' incremental theories are beneficial to learning goals and co-regulatory strategies while entity theories enhance performance-oriented behaviors and children's helplessness (Moorman and Pomerantz, 2010; Muenks et al., 2015; Jiang et al., 2019). However, when incremental and entity theories co-occur within different domains, the positive effects of incremental theories in one domain might be less strong when parents hold entity theories in another domain. Similarly, incremental theories in one domain might partly counteract the effects of entity theories in the other domain. Therefore, we examine which of the emergent belief profiles are most adaptive for parents' attitudes and behavior. More precisely, three different research questions guided the present study:

(1) What different belief profiles emerge from measures of parents' implicit theories of intelligence and implicit theories of self-regulation?
(2) How do these emergent belief profiles differ by parents' and children's demographic variables?
(3) How do these emergent belief profiles relate to parents' failure beliefs, goal orientation, and co-regulatory strategies?

MATERIALS AND METHODS

Participants

Two hundred and fifty-four persons were recruited for an online survey study by social-network-platforms and announcements in kindergartens in southwest Germany. The study was created with the online tool Soscisurvey (Leiner, 2019) and distributed via https://www.soscisurvey.de. As an incentive, participants were offered attractive lottery prizes (six vouchers worth 50–150 Euro). For the present study, we recruited parents of children aged three to six years. One hundred and fifty-two persons finished the questionnaire, leading to a dropout rate of 40% that is slightly higher than the reported average rate of 34% for online studies (Musch and Reips, 2000). The increased dropout rate might be due to technical problems when filling out the questionnaire on smartphones. Fifteen persons were excluded from the analysis because of implausible response patterns, distractions, or not complying with the inclusion criteria (child's age: 3–6 years), leading to a final sample of 137 parents (87% mothers). Parents' mean age was 37.42 years (SD = 4.85) and they had at least one child (75%). The majority of parents had at least a higher technical college qualification (79%), worked part-time (80%), and were not single parents (95%). Parents were asked to refer to their child aged three to six years when filling out the questionnaire; the mean age of the child was 4.65 (SD = 1.08); 55% of the parents thought about their daughter.

Measures

Implicit Theories of Self-Regulation

We used the recently modified and validated *Parents' Implicit Theories of Self-Regulation scale* (PITSR, Stern et al., under review), assessing parents' malleability and relevance theories of self-regulation. The two dimensions were assessed by three items, using a five-point-scale adapted to the item content: *malleability* of their child's self-regulation (e.g., "My child has a certain ability to self-regulate and this ... cannot be changed/can be changed," α = 0.75) and *relevance* of their child's self-regulation for success (e.g., "Good performance of my child... does not require competencies in self-regulation/does require competencies in self-regulation," α = 0.73). Higher values indicated more agreement of an incremental theory and higher relevance of self-regulation for success.

Implicit Theories of Intelligence

We used modified scales assessing parents' implicit theories of intelligence ("Skalen zur Erfassung subjektiver Überzeugungen zu Bedingungen von Erfolg in Lern- und Leistungskontexten," SE-SÜBELLKO-ST, Spinath and Schöne, 2003; Stern et al., under review). Two dimensions were assessed by three items that could be answered using a five-point-scale adapted to the item content: *malleability* of their child's intelligence (e.g., "My child possesses a certain amount of intelligence and this ... cannot be changed/can be changed," α = 0.90) and *relevance* of their child's intelligence for success (e.g., "Good performance of my child... does not require a lot of intelligence/does require a high amount of intelligence," α = 0.71). Higher values indicated more agreement of an incremental theory and higher relevance of intelligence for success.

Failure Beliefs

We used scales assessing parents' failure beliefs (Haimovitz and Dweck, 2016), translated and adapted them by referring specifically to their child's failure experiences. Three items described a failure-is-enhancing mindset (e.g., "Experiencing failure facilitates my child's learning and growth," α = 0.82) and three items described a failure-is-debilitating mindset (e.g., "Experiencing failure debilitates my child's learning and growth," α = 0.77). All items were rated on a scale ranging from *extremely untrue* (1) to *extremely true* (5). Items of the failure-is-debilitating mindset were reverse-scored and averaged with all items to a composite score. Thus, higher numbers indicated a more enhancing view of failure.

Goal Orientation

We used scales assessing parents' goal orientation ("Skalen zur Erfassung der Lern- und Leistungsmotivation"-Questionnaire, SELLMO, Spinath and Schöne, 2019) and adapted them for parents of preschoolers by removing school references. Three dimensions of goal orientation were assessed by eight items each: *learning goals* (e.g., "It is important to me that my child acquires

a deep understanding of the content," α = 0.69), *performance-approach goals* (e.g., "It is important to me that my child shows that s/he masters the contents," α = 0.84) and *performance-avoidance goals* (e.g., "It is important to me that nobody notices when my child does not understand the content," α = 0.83). All items were rated on a scale ranging from *totally disagree* (1) to *totally agree* (5).

Co-regulatory Strategies

We used the revised version of the IMpulse-MAnagement from Infancy to Preschool questionnaire (IMMA 1–6; Pauen et al., 2019) for assessing parents' responses to their child's behavior. M*astery-oriented strategies* were assessed with four items of the dimension *praising* (e.g., "I praise her/him explicitly when s/he does what I desire," α = 0.84), five items of the dimension *negotiating/discussing* (e.g., "I negotiate a solution with the child when s/he does not do what I desire," α = 0.75), four items of the dimension *distraction* (e.g., "I try to distract her/him when s/he is frustrated because of not achieving what s/he has planned," α = 0.84), and three items of the dimension *call for self-regulation* (e.g., "I tell her/him not to get upset when s/he is frustrated because of not achieving what s/he has planned," α = 0.71). One item of *call for self-regulation* was excluded due to poor internal consistency. *Helpless-oriented strategies* were assessed with four items of the dimension *giving in* (e.g., "I give up when s/he does not do what I desire," α = 0.89), and eleven items of the dimension *negative pressure* (e.g., "I force the child to comply when s/he does not do what I desire," α = 0.89). All items were rated on a scale ranging from *never* (1) to *always* (6).

Child's Self-Regulation

Parents' perception of their child's self-regulatory competence was assessed with the subscale *Effortful Control* of the German very short form of the Children's Behavior Questionnaire (CBQ; Putnam and Rothbart, 2006). Parents reported their child's reaction or behavior in the past six months in different situations on twelve items (e.g., "Is good at following instructions," α = 0.68) on a scale ranging from *extremely untrue* (1) to *extremely true* (7).

Analysis

Belief profiles were created through Latent Profile Analysis using Mplus 7.31 (Muthén and Muthén, 2014). Latent Profile Analysis identifies latent homogenous groups (profiles) of individuals that have similar values on the clustering variables (latent profile indicators) by using probabilistic models of subgroup membership (Vermunt and Magidson, 2004). In the present study, four latent profile indicators were used: incremental theory of intelligence, relevance theory of intelligence for success, incremental theory of self-regulation, and relevance theory of self-regulation for success.

Model fit statistics were calculated to identify the number of profiles (Geiser, 2010; Williams and Kibowski, 2016), including Entropy values, Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC), and sample size adjusted BIC (aBIC) with higher Entropy values and lower AIC, BIC, aBIC indicating better fit. Lo-Mendell-Rubin (LMR), where *k* and *k*–1 number of profiles were compared, was also conducted. Furthermore, the characteristics of each profile (e.g., size) and interpretability were also considered in the final solution.

In order to explore how the emergent belief profiles differ by demographic variables, parents' goal orientation, failure beliefs, and co-regulatory strategies (see research questions two and three), Mplus' auxiliary (BCH) function was employed. The BCH method uses a weighted multiple group analysis and estimates the association between the categorical latent variable and the dependent continuous variable using the assigned profile memberships, considering that these contain classification errors (Bakk and Vermunt, 2016). Moreover, in order to examine the association between the latent profiles and the dependent categorical variables (e.g., gender), Mplus' auxiliary (e) function was applied. This approach is based on the Wald chi-square test of statistical significance and uses a pseudo-class method testing the equality of means across profiles (Wang et al., 2005).

RESULTS

Latent Profile Analysis of Implicit Theories

In order to identify profiles of parents' implicit theories of intelligence and self-regulation, latent profile analyses were conducted. Five models with one to five profiles were conducted for model comparisons. Model fit statistics for the optimal number of profiles in the latent profile analysis are displayed in **Table 1**.

Model fit statistics provided inconsistent results for the optimal number of profiles. AIC and aBIC values were lowest for the five-profile solution, indicating that five profiles were optimal. LMR was not significant for solutions with more than three

TABLE 1 | Model fit for the optimal number of profiles in the latent profile analysis.

Number	AIC	BIC	aBIC	LMR	*p*	Entropy
1	1146.987	1170.347	1145.038	–	–	–
2	1125.608	1163.567	1122.441	30.154	0.0182	0.858
3	1089.257	1141.817	1084.873	44.540	0.0066	0.952
4	1087.035	1154.194	1081.432	11.745	0.2290	0.903
5	1070.718	1152.478	1063.898	20.777	0.6242	0.919

AIC, Akaike's Information Criterion; BIC, Bayesian Information Criterion; aBIC, sample size adjusted BIC; LMR, Lo-Mendell-Rubin adjusted LRT Test.

profiles, suggesting a three-profile solution. Entropy increased from two to three profiles and then declined, suggesting a three-profile solution, too. BIC values were lowest for the three-profile solution, which demonstrated that this was the optimal number of profiles. In sum, most of the model fit statistics provided the three-profile solution. Furthermore, the three-profile solution produced a number of interesting comparisons between profiles and had the clearest interpretation. Therefore, the preferred model is a three-profile solution.

The Latent Profiles

Figure 1 illustrates the three latent profiles and their means on implicit theories on intelligence and self-regulation. The emerged profiles are labeled according to the interpretation of findings as *Entity Theorists*, *Balanced*, and *Incremental Self-regulation Theorists*. As shown in **Figure 1**, the profiles differ most in their incremental theories of self-regulation.

Parents in profile 1 (9% of the sample, $n = 13$) reported that their child's intelligence is malleable and moderately relevant for success, while their child's self-regulation is rather stable and relevant for success. Parents in this group showed the lowest values in their incremental theories of self-regulation and thus exhibited the greatest differences in this variable compared to parents in profiles 2 and 3. We refer to this profile as *Entity Theorists*.

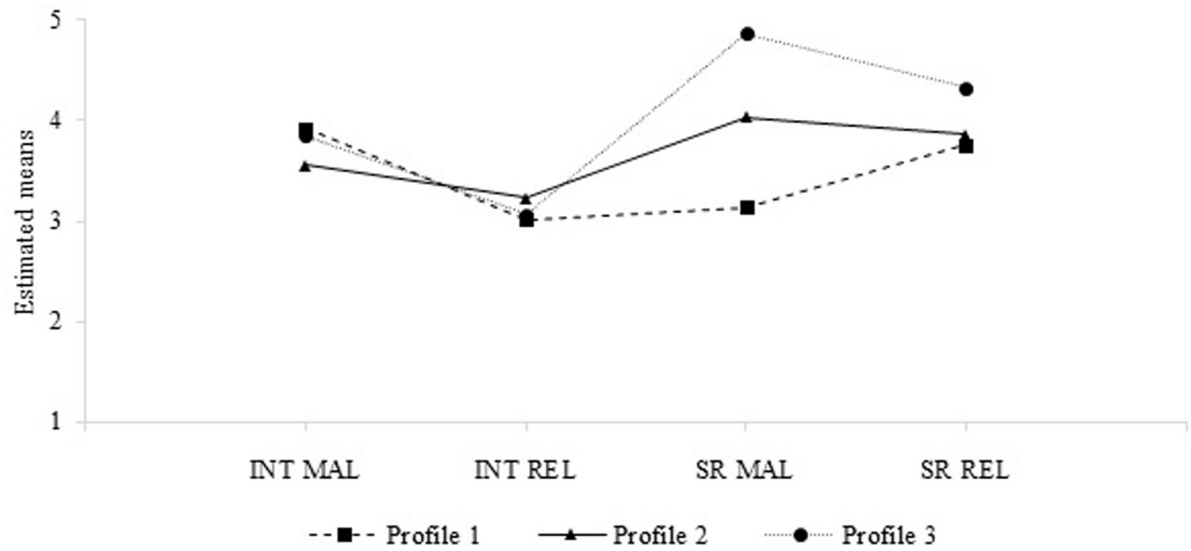
Parents in profile 2 (61% of the sample, $n = 83$) showed similar levels in their incremental theories in both domains as well as in their relevance theories in both domains. They reported that their child's intelligence and self-regulation are neither particularly stable nor malleable or notably relevant for their child's success, reflecting balanced levels of both domains of implicit theories. We refer to this group as *Balanced*.

Parents in profile 3 (30% of the sample, $n = 41$) showed the highest values in their incremental and relevance theories of self-regulation. Regarding their incremental and relevance theories of intelligence, this profile showed a similar pattern to profiles 1 and 2. We label this profile as *Incremental Self-regulation Theorists*.

Differences Between Latent Profiles on Demographic Variables

The data in **Table 2** show the means for all of the demographic variables by latent profiles and the full sample. Significance tests for group differences using the pseudo-class method for categorical variables (e.g., gender) and the BCH method for continuous variables (e.g., age) are also reported in **Table 2**.

Parents in profile 1 showed the most significant differences from other parents. Parents in this profile had the lowest mean score in parent education compared to parents in the other profiles. This means that 47% of the parents in profile 1 had a university degree, whereas, in profiles 2 and 3, 70% and 83% of the parents were academics, with the differences between profile 1 and profile 3 being statistically significant ($\chi^2 = 5.37$, $p = 0.020$). Furthermore, parents in profile 1 reported the lowest self-regulatory competence of their child compared to parents in the other profiles, and these differences were statistically significant (profile 1 vs. 2: $\chi^2 = 6.79$, $p = 0.009$; profile 1 vs.



Note. INT MAL = Implicit theories of intelligence malleability; INT REL = Implicit theories of intelligence relevance; SR MAL = Implicit theories of self-regulation malleability; SR REL = Implicit theories of self-regulation relevance; Profile 1 (Entity Theorist): $n = 13$ (9%); Profile 2 (Balanced): $n = 83$ (61%); Profile 3 (Incremental Self-regulation Theorists): $n = 41$ (30%)

FIGURE 1 | Three-profile solution for the latent profile indicators.

TABLE 2 | Means and standard errors (in parentheses) of demographic variables by latent profiles.

Variable	Full sample		Profile 1[a]		Profile 2[b]		Profile 3[c]		Overall χ^2	Profile 1 vs. 2	Profile 1 vs. 3	Profile 2 vs. 3
Parent characteristics												
Gender[1] (female)	0.87	(0.03)	0.85	(0.10)	0.85	(0.04)	0.93	(0.04)	2.24	0.00	0.54	2.13
Age[2] (years)	37.42	(0.45)	27.90	(4.53)	30.50	(1.97)	32.92	(2.28)	1.22	0.98	0.27	0.64
Education[1]	0.79	(0.03)	0.47	(0.14)	0.70	(0.13)	0.83	(0.06)	5.75	1.45	**5.37***	0.80
Number children[2]	1.93	(0.06)	1.85	(0.22)	1.88	(0.07)	2.07	(0.13)	1.85	0.02	0.82	1.73
Child characteristics												
Gender[1] (female)	0.55	(0.04)	0.53	(0.14)	0.59	(0.06)	0.46	(0.08)	1.74	0.14	0.22	1.86
Age[2] (years)	4.65	(0.09)	4.40	(0.27)	4.61	(0.12)	4.81	(0.17)	1.80	0.49	1.60	0.87
Self-regulation[2] (parent-report)	5.34	(0.06)	4.91	(0.18)	5.37	(0.08)	5.47	(0.11)	**6.98***	**5.39****	**6.79***	0.48

*Means are based on weighted data. Significance tests for group differences are based on [1]pseudo-class method or [2]BCH method with two df for the overall test and one df for the pairwise tests. Statistically significant values are printed in bold; *p < 0.05; **p < 0.01.[a]Entity Theorists (9%).[b]Balanced (61%).[c]Incremental Self-regulation Theorists (30%).*

3: $\chi^2 = 5.39$, $p = 0.020$). Finally, we found on a descriptive level, that parents in profile 1 were younger, and had fewer and younger children, even though these differences were not statistically significant.

Although the contrasts between profiles 2 and 3 were not statistically significant, almost all parents of profile 3 were mothers (93%), whereas 15% of profiles 1 and 2 were fathers. Moreover, profile 3 had the lowest percentage of daughters (46%) and the highest amount of children ($M = 2.07$, $SE = 0.13$) compared to parents in profiles 1 and 2.

Differences Between Latent Profiles on Failure Beliefs, Goal Orientation, and Co-regulatory Strategies

The data in **Table 3** show the means for failure beliefs, goal orientation, and co-regulatory strategies by profile membership. The first column represents the overall mean for the full sample, and subsequent columns represent the means by latent profiles. In order to explore how the profiles differ by parents' failure beliefs, goal orientation, and co-regulatory strategies, equality tests of means across profiles using the BCH procedure were conducted. Results of the overall chi-square test as well as the pairwise single-comparisons between groups are reported in the subsequent column of **Table 3**.

The analysis was clearest in distinguishing parents in profile 3 from the other parents. **Table 3** shows that parents in this profile reported a failure-is-enhancing mindset significantly more often compared to profile 2 ($\chi^2 = 8.74$, $p = 0.003$) and pursued performance-avoidance goals less likely than parents in profile 2 ($\chi^2 = 4.56$, $p = 0.033$). Regarding co-regulatory strategies, parents in profile 3 showed higher values in mastery-oriented strategies. More precisely, parents in profile 3 had higher values in negotiating ($\chi^2 = 3.99$, $p = 0.046$) compared to parents in profile 2, and significantly higher values in call for self-regulation than parents in profile 1 ($\chi^2 = 7.25$, $p = 0.007$).

Descriptively, parents in profile 1 had the lowest failure-is-enhancing mindset and learning goal orientation. Furthermore, parents in this profile showed the lowest mean scores for praising, and call for self-regulation as well as the highest value for distraction compared to the other two profiles. As shown in **Table 3**, the multivariate analysis indicated that at least one of these differences between profiles were statistically significant ($\chi^2 = 6.56$, $p = 0.010$). On a descriptive level, we also found that parents in profile 1 reported to give in and negotiate least compared to parents in the other profiles even though this difference was not significant.

Profile 2 is characterized by higher values in performance-avoidance goals, which significantly differ from parents in profile 3 ($\chi^2 = 4.56$, $p = 0.033$). They showed the lowest mean score in distraction compared to the other two profiles, with the differences between this profile and profile 2 being statistically significant in the multivariate analysis ($\chi^2 = 6.56$, $p = 0.010$).

DISCUSSION

The present study examined parents' implicit theories of intelligence and implicit theories of self-regulation simultaneously from a person-centered perspective. We expected that different belief profiles exist and analyzed how the emergent belief profiles are composed concerning demographic variables. Finally, we assumed that the emergent belief profiles differ concerning parents' attitudes (i.e., goal orientation, failure beliefs) and co-regulatory strategies (i.e., mastery- and helpless-oriented strategies).

Belief Profiles

The results of the LPA showed that three profiles of implicit theories exist and that most parents (61%) engage in balanced levels of the both examined domains of implicit theories (profile 2). The minority of parents (9%) displayed an entity theory (profile 1), while about one-third of the parents (30%) reported high incremental self-regulation theories (profile 3). The profiles overlap a good deal with the groups observed by Hertel et al. (2019) who studied implicit theories of intelligence and self-regulated learning in students. The groups of Hertel et al. (2019) only differ from the results of the current study in the composition of the group sizes that may result from different research contexts.

The results of the present study support the hypothesis that implicit theories of different domains can co-occur within

TABLE 3 | Means and standard errors (in parentheses) of failure beliefs, goal orientation, and co-regulatory strategies by latent profiles.

Variable	Full sample		Profile 1[a]		Profile 2[b]		Profile 3[c]		Overall χ^2	Profile 1 vs. 2	Profile 1 vs. 3	Profile 2 vs. 3
Failure-is-enhancing mindset	3.88	(0.07)	3.65	(0.25)	3.76	(0.08)	4.19	(0.12)	**9.58****	0.16	3.86	**8.74****
Goal orientation												
Learning goals	4.33	(0.04)	4.22	(0.01)	4.29	(0.05)	4.44	(0.06)	5.21	0.41	3.59	3.55
Performance-approach goals	3.03	(0.06)	3.02	(0.15)	3.01	(0.07)	3.06	(0.12)	0.11	0.02	0.04	0.10
Performance-avoidance goals	2.07	(0.05)	2.00	(0.16)	2.16	(0.07)	1.91	(0.09)	4.72	0.87	0.23	**4.56***
Mastery-oriented strategies												
Praising	4.83	(0.08)	3.95	(1.08)	4.70	(0.09)	5.04	(0.15)	4.42	0.47	0.99	**3.73***
Negotiating/discussing	4.17	(0.06)	4.00	(0.19)	4.11	(0.07)	4.37	(0.11)	4.96	0.28	2.86	**3.99***
Distraction	3.31	(0.08)	3.85	(0.25)	3.16	(0.10)	3.46	(0.15)	**8.07***	**6.56***	1.83	2.98
Call for self-regulation	3.09	(0.09)	2.64	(0.15)	2.94	(0.20)	3.24	(0.16)	**7.26***	1.40	**7.25****	1.40
Helpless-oriented strategies												
Giving in	2.39	(0.07)	2.19	(0.21)	2.42	(0.09)	2.40	(0.13)	0.99	0.98	0.69	0.02
Negative pressure	3.57	(0.06)	3.60	(0.13)	3.57	(0.09)	3.57	(0.12)	0.04	0.03	0.00	0.04

*Means are based on weighted data. Significance tests for group differences are based on BCH method with two df for the overall test and one df for the pairwise tests. Statistically significant values are printed in bold; *p < 0.05; **p < 0.01.[a]Entity Theorists (9%).[b]Balanced (61%).[c]Incremental Self-regulation Theorists (30%).*

persons. Although 60% of the parents reported both domains (i.e., intelligence and self-regulation) to be more or less equally malleable and relevant for success (profile 2), 40% of the parents differed in their beliefs across domains. Parents in profile 1 hold an incremental theory in the domain of intelligence while holding rather an entity theory in the domain of self-regulation. Parents in profile 3 perceived the malleability and relevance of their child's self-regulation to be much higher compared to the domain of intelligence.

Overall, most parents across profiles believed that intelligence and self-regulation are rather malleable and relevant for success, reflecting a ceiling effect. Nevertheless, the greatest differences between profiles became visible in parents' incremental theories of self-regulation. Compare, for example, profiles 1 and 3. Although both groups were nearly identical in their implicit theories of intelligence, their implicit theories of self-regulation diverge. One explanation might be that parents of preschoolers get to observe and experience situations more often in which their child's self-regulation becomes more obvious (e.g., respond to external demands, face prohibitions, deal with failure; see Pauen et al., 2019) than their child's intelligence (that might become more evident later in school life). In early childhood, self-regulatory competencies are developing (Kopp, 1982; Posner and Rothbart, 2000) and parents recognize interindividual differences in children (Bechtel et al., 2016; Pauen et al., 2019). These individual experiences and observations might result in the observed interindividual differences in parents' incremental theories of self-regulation. Thus, this finding highlights the importance of considering implicit theories of self-regulation beyond the more general implicit theories of intelligence.

Based on the demographic statistics, parents with entity theories (profile 1) were significantly less educated and rated their child's self-regulatory abilities as lower than parents with high incremental theories (profile 3). These results are in line with research using variable-centered methods (Pomerantz and Dong, 2006; Muenks et al., 2015; Haimovitz and Dweck, 2016; Jiang et al., 2019) finding associations between parents' implicit theories, education and children's competencies. Our findings suggest that interventions targeting parents' implicit theories might especially address low educated parents. As parents' educational attainment is a significant predictor of children's self-regulatory abilities (for a meta-analysis see Lawson et al., 2018), interventions are substantial to promote child self-regulation and to buffer the potential negative effect of low educational attainment. However, the associations between profile membership and children's self-regulatory abilities are possible in both directions (i.e., profile membership predicting child self-regulation and vice versa). For example, parents with entity theories view their child's self-regulation as stable, show less support for their child, which may result in lower self-regulatory abilities. Otherwise, parents with low self-regulated children may observe less progress and therefore believe that self-regulation is stable. In contrast, parents with high self-regulated children have observed child development and, therefore, think that self-regulation is malleable. As this study is limited to cross-sectional data, we cannot draw any conclusions on the directions of effect. Therefore, these mechanisms have to be addressed in further research.

Relations Between Latent Profiles and Parents' Attitudes and Co-regulatory Strategies

The third research question aimed to examine whether the latent belief profiles were associated with parents' attitudes and co-regulatory strategies. Our findings suggest that parents in different profiles show differentially adaptive or maladaptive patterns concerning their attitudes and co-regulatory strategies. Parents in profile 3 showed the most adaptive attitudes and behaviors compared to the others. They reported to hold more failure-is-enhancing mindsets and to engage in less performance-avoidance goals. These findings are in line with research using variable-centered methods (Burnette et al., 2013; Haimovitz and Dweck, 2016). Regarding co-regulatory strategies, our results add to Moorman and Pomerantz's (2010) findings that parents with

high incremental theories (profile 3) report not less helpless-oriented strategies but more mastery-oriented strategies such as praising, negotiating, and call for self-regulation compared to the other profiles. The only exception emerged for distraction with parents in profile 1 showing higher values than parents in profile 3. As distraction can be both adaptive (Manimala et al., 2000; Stern et al., 2018) as well as maladaptive (Dahlquist and Pendley, 2005) in different situations, the context seems to be a relevant factor. As distraction was measured in a more context-general way in this study, future research should examine parents' distraction strategies in specific situations. Besides, the relation between profile membership and distraction strategies might also be related to children's self-regulatory abilities and failure beliefs: Parents who believe that self-regulation is stable engage in distraction strategies in order to avoid frustration and failure since the child cannot self-regulate due to low self-regulatory abilities (see profile 1). Thus, these parents believe that failure is debilitating because failure cannot enhance stable abilities. One may argue that this pattern can be an adaptive response when abilities are low and stable because parents do not overstrain their child. Actually, ample evidence indicates that self-regulatory abilities are malleable (Kopp, 1982; Huizinga et al., 2006; Bernier et al., 2010) and can be enhanced by training and interventions (Kaminski et al., 2008; Diamond and Lee, 2011; Walk et al., 2018; Diamond et al., 2019).

Although there is empirical evidence that parents' incremental theories of intelligence are negatively associated with controlling and performance-oriented behaviors (Moorman and Pomerantz, 2010), our results show that holding an incremental theory in one domain is not the only important predictor. The positive effects of parents' incremental theories of intelligence might be less strong when parents hold an entity theory in the domain of self-regulation at the same time (see profile 1). This finding supports the assumption that implicit theories of self-regulation are stronger predictors for domain-related attitudes and behavior than more general implicit theories of intelligence. Here, parents' implicit theories of self-regulation counteracted the effects of the domain of intelligence.

Limitations and Further Research

Our study should be interpreted in the light of their limitations. First, we used data from one single sample of preschoolers' parents and did not replicate the emerging profiles in a second, larger sample, which raises the question of generalization. Anyhow, our three-profile solution is supported by studies examining implicit theories in students (Hertel et al., 2019). Nevertheless, future research should study implicit theories in other samples of parents and examine whether the profiles are the same as in our study. Moreover, even though we did not find any age differences in our sample of three to six years old children, it would be interesting to examine the relations in other age groups, for example, in parents of toddlers or school-aged children. Here, more research is needed.

Second, one might be concerned about the recruitment of the sample via the Internet because we finally could not validate participants' status as parents. However, most of the participants were recruited via announcements in kindergartens. Thus, we may assume that only parents participated. Nonetheless, we cannot rule out a selection bias of the sample because the caption of the study was related to the role of self-regulation in early childhood. The study might especially have addressed parents who believe that self-regulation is malleable and highly relevant, explaining the high ceiling effect of implicit incremental theories of self-regulation. Furthermore, the sample shows a high proportion of mothers and high-educated parents. In future studies, other cultural contexts and a higher proportion of fathers should be considered. A validation of the emerging profiles in other cultural contexts might be an important next step in further research. For example, cross-cultural studies with Chinese and Finnish students illustrate both similarities and differences in students' implicit theories with regard to academic achievement (Zhang et al., 2019, 2020). As this study was conducted with a German sample, the question arises if different profiles would emerge when other cultural contexts would be considered: Cross-cultural studies with parents show that Chinese parents seem to emphasize good grades and competition in comparison to Western parents who place a high value on individual growth (Tobin et al., 1989; Sang, 2017). Therefore, considering different cultural contexts might have important implications for parents' belief profiles.

Third, our study is a cross-sectional study that does not allow any causal interpretation of findings. Future research could use an experimental design where implicit theories of multiple domains can be manipulated, and their effects on parents' attitudes and behavior can be examined. Besides, future research could examine if the profiles are stable or if parents change profile membership over time. Here, it would be interesting to analyze factors that predict changes in profile membership as well as associated changes in parents' attitudes and behavior, for example by using analytical techniques such as latent transition analysis.

Finally, we relied on self-reports of all study variables which may increase the risk of common-method variance (Podsakoff et al., 2012) and may be associated with problems of social desirability explaining the null effects for helpless-oriented strategies. We took several steps to reduce social desirability. Data were collected anonymously, participants were asked to fill out seriousness checks, and those who reported not having answered seriously and conscientiously were excluded from the analyses. Additionally, we included a questionnaire testing social desirability, thus ruling out that no social desirability bias as well as no significant correlations with parents' implicit theories were found. However, future studies should also include observational methods to assess parent-child-interactions.

CONCLUSION

Our study showed that implicit theories of intelligence and self-regulation occur in different configurations within parents, with 60% of the parents holding a balanced profile. These differences in belief profiles of parents were also associated with differences in their attitudes and co-regulatory strategies. Incremental self-regulation theorists emerged as the most adaptive configuration for parents' attitudes and strategies, whereas entity theorists

showed rather maladaptive patterns. Our results emphasize the crucial role of implicit theories of self-regulation. This knowledge can be used for interventions targeting parents' implicit theories. By illustrating that children's self-regulation is malleable and relevant for success, adaptive configuration for parents' attitudes and strategies can be promoted. This might in turn impact children's implicit theories, learning, and development (Blackwell et al., 2007).

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Commission of the Faculty of Behavioral and Cultural Studies, Heidelberg University. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MS and SH conceptualized the study. MS collected the data, analyzed them, and wrote the first draft. SH supervised the project. Both authors contributed to the article and approved the submitted version.

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My Brain Needs a Break: Kindergarteners' Willpower Theories Are Related to Behavioral Self-Regulation

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Is the way that kindergarteners view their willpower – as a limited or as a non-limited resource – related to their motivation and behavioral self-regulation? This study is the first to examine the structure of beliefs about willpower in relation to behavioral self-regulation by interviewing 147 kindergarteners (52% girls) aged 5 to 7 years ($M = 6.47$, $SD = 0.39$). A new instrument was developed to assess implicit theories about willpower for this specific age group. Results indicated that kindergarteners who think of their willpower as a non-limited resource showed better behavioral self-regulation than children who adopted a more limited theory, even when controlling for age and gender. This relation was especially pronounced in low achieving children. Mediation and moderation analyses showed that this relation was partly mediated through the children's willingness to invest effort to reach a learning goal. Findings suggest that fostering metacognitive beliefs in children, such as the belief that willpower is a non-limited resource, may increase behavioral self-regulation for successful adjustment to the demands of kindergarten and school.

Keywords: implicit theories about willpower, self-regulation, motivation, kindergarten, goal-orientation, self-control, willpower, meta-cognition

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INTRODUCTION

Childhood behavioral self-regulation is the capacity to focus and maintain attention on tasks and follow instructions to consciously regulate the self in line with goals, including the capacity to inhibit unwanted thoughts, feelings, or impulses; it is a key predictor for successful learning and adjustment to school and life (McClelland et al., 2007; Moffitt et al., 2013; Baumeister et al., 2018). Research suggests that successful self-regulation and goal striving depend on people's beliefs – or implicit theories – about the nature of willpower (Job et al., 2010, 2015b). These implicit theories capture whether people think of their willpower as a limited resource that becomes depleted easily and needs to be replenished by taking a break, eating, or resting (limited willpower theory) or as something that is more stable and even becomes energized by previous strenuous self-control tasks (non-limited willpower theory). Previous studies with adults have shown that people who believe that willpower is non-limited (vs. limited) exhibit better self-control in tasks in the laboratory (Job et al., 2010; Miller et al., 2012) and better self-regulation in everyday life (Bernecker et al., 2015; Job et al., 2015b). Even if the beneficial effects of a non-limited theory in adults are well-understood,

it is not known whether young children already have ideas about willpower and whether those ideas affect their self-regulation. To investigate these research gaps we conducted a study in kindergartens in Switzerland, where children attend a two-year program in their local public schools starting at age 4 or 5. In line with previous research on willpower theories (Job et al., 2010, 2015b), we propose that non-limited theories are especially beneficial when demands on self-regulation are high, which is often the case for academic underachievers. We further assume that the relation between willpower theories and behavioral self-regulation is mediated by children's willingness to exert effort to learn something (i.e., learning goal orientation; Compagnoni et al., 2019).

In summary, four main questions guided the present study: (1) Can willpower theories be reliably assessed in kindergarteners? (2) Are kindergarteners' willpower theories related to their behavioral self-regulation? (3) Is this association stronger in children with low academic ability levels? and (4) Is the relation between willpower theories and behavioral self-regulation mediated by children's learning goal orientation?

Self-Regulation in Children

There is a consensus that self-regulation is a key predictor of success in school and life, and childhood years are seen as a sensitive period for development of self-regulation (Cameron Ponitz et al., 2008; Kubesch, 2014; Blair and Raver, 2015; McClelland et al., 2018). However, there is no common definition of childhood self-regulation and the different research directions lack integration (for a discussion see Panadero, 2017; McClelland et al., 2018). Early childhood research has emphasized basic skills that underlie self-regulated action, such as focusing and maintaining attention on tasks, working memory, and inhibitory control (Sektnan et al., 2010). Some researchers refer to these self-regulatory skills as executive functions and focus on cognitive processes (Blair and Razza, 2007; Rothlisberger et al., 2010; Moriguchi and Hiraki, 2013). However, other researchers term this set of skills "behavioral self-regulation" and subsequently adopt a broader view of the regulation of behavior (McClelland et al., 2007; Suchodoletz et al., 2014). Research on self-control (or willpower), in turn, focuses more on one specific skill – inhibitory control – and defines willpower as the capacity to override unwanted thoughts, feelings, or impulses to align the self with long-term goals (Mischel et al., 2011; Baumeister et al., 2018). But Mischel et al. (2011) also state that willpower "requires that individuals encode only information from the environment that is relevant, keeping wanted information active in working memory and suppressing unwanted information and selecting desired responses while withholding responses that are not optimal" (p. 254), which refers to a very similar set of underlying basic skills. The conceptual clutter and overlap in constructs related to early behavioral self-regulation can partly be explained by different measurement methods (McClelland et al., 2019) but also by the high correlations between the basic components of behavioral self-regulation (Willoughby et al., 2011; Bull and Lee, 2014). They often cannot be distinguished in young children, seem to gradually differentiate with age, and subserve successful context-specific behavioral self-regulation and self-control (Hofmann et al., 2012).

Impaired behavioral self-regulation has been described as being accountable for many educational and societal issues, ranging from learning difficulties, job underperformance, behavioral problems at school, and violence to obesity (Duckworth and Seligman, 2005; Baumeister et al., 2007; Moffitt et al., 2013). Mixed results emerge regarding the strength of the relation with academic achievement level, depending on cultural context, measurement method, or academic domain. However, overall, previous research makes a strong case for the importance of behavioral self-regulation in the educational context (McClelland et al., 2007; Gestsdottir et al., 2014). As children who improved their self-regulation – independent from their initial level – showed better outcomes in adulthood (Moffitt et al., 2011), the question of how to promote self-regulation is occupying teachers and researchers around the world. The assumption that self-regulation can be trained analogously to a muscle (Baumeister et al., 2007) led to several successful programs for developing self-regulation through repeated practice in challenging situations (Diamond and Lee, 2011; Rothlisberger et al., 2012; Rybanska et al., 2018). Whereas the research presented above focuses on innate prerequisites and the training of self-regulation, other research suggests that successful self-regulation also depends on people's beliefs – or implicit theories – about the nature of their abilities (e.g., intelligence, Dweck and Leggett, 1988; or willpower, Job et al., 2010).

Over the last decades, Dweck and colleagues (Dweck and Leggett, 1988; Mueller and Dweck, 1998; Gunderson et al., 2013; Haimovitz et al., 2019) have shown that children develop implicit theories about their abilities as being either fixed (fixed mindset) or capable of growing (growth mindset) based on experiences such as praise and feedback for success and failure. Children with a growth mindset show better behavioral self-regulation, as they embrace challenges as learning opportunities to grow and improve their abilities (Molden and Dweck, 2006; Burnette et al., 2013; Compagnoni et al., 2019). In contrast, children with a fixed mindset, who view their abilities as stable traits, are concerned about their performance (Perry et al., 2019) and show poorer behavioral self-regulation (Dweck and Leggett, 1988; Dweck, 2017). As a consequence, they are more likely to avoid challenging tasks, see effort as a sign of weakness, and adopt poor self-regulation strategies (for a meta-analytic review see Burnette et al., 2013). Researchers have found that people not only hold such implicit beliefs about their abilities but also about other characteristics, such as individual traits (e.g., Chiu et al., 1997). Most important for research on self-regulation is the finding that people also have specific implicit theories about their willpower (Mukhopadhyay and Johar, 2005; Job et al., 2010). When people think of their willpower as a limited resource that becomes easily depleted and needs to be replenished by taking a break, eating, or relaxing (limited theory), their self-control capacity becomes impaired when they face self-regulatory challenges (Job et al., 2010). In contrast, people who believe that their willpower is something that is more stable and that even becomes energized by previous strenuous self-control exertion (non-limited theory) are better

able to sustain their self-control at high levels when they encounter difficulties.

Willpower Theories as Predictor of Behavioral Self-Regulation

Previous studies with adults have shown that people who believe that willpower is non-limited (vs. limited) showed better self-regulation in everyday life, such as procrastinating less and following a healthier diet (Job et al., 2015b), more progress on personal goals (Bernecker et al., 2015), greater sustained learning (Miller et al., 2012), higher academic achievement in university students facing high demands (Job et al., 2015b), and improved self-efficacy regarding upcoming tasks (Bernecker et al., 2015). The relation between willpower theories and self-control holds in adults when beliefs about willpower are measured as an individual difference and also when they are manipulated experimentally (Job et al., 2010).

As studies with experimentally induced as well as measured willpower theories in adults show that a non-limited willpower theory is associated with various aspects of self-regulation, we expect a relation with behavioral self-regulation in children. Especially in Swiss kindergartens, which offer children the possibility to choose tasks, task level, and task engagement during free play, demands of self-regulation are high (Hauser, 2013). Thus, willpower theories are expected to have a strong impact on behavioral self-regulation. We assume that a child with a non-limited willpower theory might persist in the face of difficulties, inhibit the impulse to give up or take a break, and therefore train self-regulation, improve self-efficacy, and choose more challenging tasks in the future. Children who struggle with a task and, in contrast, think of their willpower as something limited will be motivated to rest and replenish their resources when experiencing a task as exhausting. They might not persist and therefore their self-efficacy regarding upcoming tasks will be diminished. As a consequence, they might choose fewer challenging tasks in the future. Since only one study has examined the correlates of willpower theories in young children (Haimovitz et al., 2019), there is a paucity of research examining the role that willpower theories play in explaining early self-regulation. Haimovitz et al. (2019) found that children with experimentally induced non-limited theories (through a model in a storybook who experiences exerting willpower as energizing) showed more self-control strategies in the face of temptation, spent more time on the strategies, and showed longer delay of gratification than the group of children with a experimentally induced limited theory. The results imply that diverse behavioral self-regulation may develop not just as a set of skills learned through repeated practice on challenging tasks, as examined in past research (Diamond and Lee, 2011). A general approach to willpower that encourages children's generation and use of self-control strategies by shaping their willpower theories might be effective too. Although this is promising, further research still needs to establish if children in kindergarten already have naturally occurring beliefs about their willpower and if they are related to a set of skills such as behavioral self-regulation, which subsequently leads to better academic outcomes.

According to Haimovitz et al. (2019), in early childhood children may not yet have well-formed beliefs about their willpower. They found that in children aged 4–5 years, the exposure to a storybook model that experiences exerting willpower as energizing leads to improved behavioral self-regulation. But as they did not measure children's beliefs about willpower before and after the manipulation, they could not distinguish whether an existing willpower theory was modified or a new idea about willpower was implanted. Based on some researchers, it seems even plausible that most children generally have a non-limited theory, as they are usually overoptimistic and think that with enough effort they can master almost anything (Hasselhorn, 2005). Given the lack of research on willpower theories in children, it remains unclear whether kindergarteners already have well-formed willpower theories, if they vary between children, if they can be measured reliably, and if they are already related to behavioral self-regulation as early as kindergarten age.

Taken together, we assume that willpower is not just a skill but is already rooted in a mental model about the nature of willpower that might encourage children to seek (or discourage them from seeking) effective strategies to meet high self-regulatory demands that can help them execute high behavioral self-regulation (Yeager and Dweck, 2012).

Academic Ability Level as Moderator

Educational research on diverse motivational beliefs has demonstrated that a growth mindset (Paunesku et al., 2015) or high self-concepts (Compagnoni and Losenno, 2020) are especially beneficial for academic underachievers. This finding has been explained by the notion that motivational beliefs play an important role especially in challenging situations when behavior must be actively self-regulated and when automatisms and routines can no longer be maintained. Similarly, research on implicit theories about willpower documented that endorsing a non-limited theory is mostly beneficial when a person is facing high self-regulatory demands (Bernecker et al., 2015; Job et al., 2015b). Since everyday life in kindergarten is associated with greater challenges for children with lower academic ability levels, especially in open learning environments (Helmke, 2009; Hauser, 2013), a greater impact of willpower theories in children with low academic abilities can be expected. As children with low academic abilities might generally experience tasks as more challenging, those with a limited theory might often find themselves in situations where they readily give up when they struggle with a task. As a consequence, they spend less time training their self-regulation than children with low academic ability levels and a non-limited theory. Additionally, children who are perceived as having low academic achievement levels by teachers might be allowed to take a break after strenuous tasks when they ask for it (or even be encouraged to do so), which might undermine their self-regulation. A non-limited theory might prevent low achieving children from prematurely asking teachers for a break or switch tasks when faced with difficulties. To date, there are no studies examining the moderating effect of children's academic ability level on the association between willpower theories and behavioral self-regulation.

Research on adults' implicit theories about willpower,however, suggests that when demands are high, a non-limited willpower theory promotes self-regulation directly, by keeping self-efficacy high (Chow et al., 2015) and by preventing a premature shift of motivation away from a task and toward rest and recovery (Job et al., 2015a). Including academic ability as a moderator will allow us to determine if the positive relation between willpower theories and behavioral self-regulation is especially pronounced in low achievers.

Goal Orientation as Mediator

We propose that non-limited willpower theories additionally affect self-regulation indirectly through the children's higher willingness to exert effort in order to learn and increase their competencies by embracing challenging tasks. This orientation toward mastery motivates children to approach opportunities to train behavioral self-regulation and is based on the conviction that learning requires time and effort. It has been termed "learning goal orientation" or "mastery approach goal orientation" (Dweck and Leggett, 1988; Perry et al., 2017). A learning goal orientation is positively related to persistence in the face of failure and enhanced motivation toward challenging tasks (Dweck and Leggett, 1988) and seems to be a hallmark for training self-regulation (Perry et al., 2017). Past findings suggest that a learning goal orientation plays a pivotal role in linking implicit theories about intelligence and self-regulation processes (Smiley and Dweck, 1994; Compagnoni et al., 2019). Growth mindset interventions have found that children who were led to adopt a learning goal orientation changed their view of challenges (Burnette et al., 2013).

In the present study, we suggest that children with a non-limited willpower theory might be more prone to adopt a high learning goal orientation due to their enhanced willingness to invest effort. In turn, they should be more likely to choose more difficult tasks, which train their behavioral self-regulation. In contrast, children with a limited theory might choose easy tasks that they already master to not deplete their resources. For example, a kindergarten child with a learning goal orientation might choose to play a new difficult game with numbers over replaying a familiar game, even though it requires attention and persistence and success is not guaranteed. In contrast, a performance orientation is associated with engaging in easy tasks that one can master quickly with minimal effort (Bakadorova et al., 2020).

This study extends past literature on willpower theories in adults and takes up questions raised in Haimovitz et al. (2019) experimental study with preschoolers. We measured kindergarten children's beliefs about willpower and looked into the relation between these beliefs and behavioral self-regulation. We hypothesized that kindergarteners already have varying beliefs about their willpower, which can be measured reliably when age appropriate measurement methods are applied. Further, we expected that the more kindergarteners view their willpower as non-limited, the better their behavioral self-regulation. In line with previous research on willpower theories in academic contexts, we proposed that non-limited theories are especially beneficial when demands on self-regulation are high, which is often the case for academic underachievers. We therefore hypothesized that the direct relation between willpower theories and behavioral self-regulation is more pronounced for children on lower academic ability levels. We further assumed that the relation of willpower theories and behavioral self-regulation is mediated by the children's learning goal orientation.

MATERIALS AND METHODS

Participants

The sample included 147 children at 19 kindergartens in urban and rural areas that reflect the demographic composition of the German-speaking part of Switzerland. Only children whose parents had given written informed consent participated. For six children there was no consent to participate because the teacher only provided information to the parents the day before the assessment; parents of five children did not consent for personal reasons (religion, parents in divorce); and two children did not give a reason. We received parents and children's informed consent to participate for 91% of the children attending the kindergartens. The children were in their second year of kindergarten and had an age range of 65–86 months (M = 6.47 years, SD = 0.39 years). Approximately half of the sample (52%) consisted of girls, 72% of the children in the sample were of Swiss nationality, and 45% spoke Swiss German as their first language, 10% spoke Albanian, 3–7% spoke Serbian/Croatian, Turkish, German, Portuguese, English, German, Spanish, and Arabic, respectively, and the rest spoke other first languages. In Switzerland kindergartens are part of the public education system, and 95% of children attend a 2-year kindergarten program in their local public schools starting at age 4 or 5 (Swiss Conference of Cantonal Ministers of Education, 2017), resulting in a body of children with diverse economic status and ethnicities. All participants were following the official curriculum guidelines for kindergartens in Switzerland, where free play in an open learning environment is emphasized (Hauser, 2013).

Procedure

Due to the short attention span in children of this age, the children were visited twice in their kindergartens with an interval of 2 to 4 weeks between the assessments. The questionnaires were each administered in the context of a larger battery of cognitive tasks in a session that lasted approximately 30 min. Given the kindergarten children's lack of reading and writing skills, tests were administered through an individual interview procedure. Willpower theories and goal orientation were assessed at both visits with Versions A and B of the questionnaires (see **Supplementary Material**). Behavioral self-regulation was measured at the end of the second visit. Teachers completed an online questionnaire between the two visits. All children received a small gift for participating, and the class received a math game. Missings in the data were due to children who were absent at one of the two measurement points (t_1: $n = 4$, t_2: $n = 5$) or technical network failures.

Measures

Behavioral Self-Regulation

Behavioral self-regulation, the ability to focus and maintain attention on a task and inhibit inappropriate actions, was measured with the Head-Toes-Knees-Shoulders (HTKS) task (Cameron Ponitz et al., 2008). We used the newer, more complex version of the HTKS that was developed for older children (see McClelland et al., 2014) to prevent ceiling effects (Gestsdottir et al., 2014). This direct observational measure taps into the three aspects of executive functions: inhibitory control, attention, and working memory. A single measure was used for behavioral self-regulation, as replicated findings of several studies in preschool-aged children found a lack of differentiation into distinct components (Bull and Lee, 2014; Clark et al., 2014). Children were asked to play a game in which their task was to do the opposite of what the experimenter said (e.g., "touch your head!" and then they had to touch their toes instead). The first 10 trials included two types of paired commands, for the next 10 trials two new paired commands were added, and for the last 10 trials, all four commands were re-paired into new commands combinations (e.g., "touch your shoulder!" and then they had to touch their toes instead). The 30 items were scored with 0 for an incorrect response, 1 for a self-corrected response, and 2 for a correct response ($M = 41.70$, $SD = 10.36$, Cronbach's $\alpha = 0.89$). Higher scores indicated higher levels of behavioral self-regulation.

Willpower Theories

To assess limited and non-limited willpower theories in kindergarteners, we developed a self-report method with age-appropriate items based on the measure used by Job et al. (2010) and inspired by the Berkeley Puppet Interview (Measelle et al., 1998). A researcher asked two identical puppets named "Mi" and "Mo" standardized questions (e.g., "Does your brain need many breaks during strenuous thinking?"), and the children listened to the puppets' answers delivered on a touchscreen. One puppet expressed a limited theory (i.e., "Yes, whenever I have done something strenuous, my brain needs a break") and the other a non-limited theory (i.e., "Not at all, my brain can think as long as it wants"). The children indicated on a 5-point semantic differential scale displayed on the touchscreen between the two puppets (1 = *limited theory*, 5 = *non-limited theory*) which of the puppets they could identify themselves with ("Are you more like Mi or more like Mo?"). As suggested by Marsh et al. (2002), a double binary response strategy was used to counter the tendency to select endpoints and neglect intermediate points: The identification with one puppet (by pressing a button) was always followed by a second probe ("Do you totally agree with this puppet, or do you agree only a little?"). Items from Job et al. (2010) were translated and adapted to the age group. In a pilot phase with 10 children using think aloud method, items were tested and adapted in several iterative loops resulting in six items (see **Supplementary Material**). Although we chose visually identical, gender neutral puppets, the puppets statements were randomized to ensure that childrens' answers did not express sympathies for one puppet. Children completed the two questionnaires during the two visits. Version A and B were similar in content and were combined to create a single willpower theory score for each child. Confirmatory factor analyses (CFA) confirmed a one factor solution [$\chi 2(9) = 12.696$, $p = 0.177$, RMSEA = 0.055, *p-close* = 0.399, TLI = 0.949, CFI = 0.970, SRMT = 0.042]. A more restricted two factor solution [$\chi 2(8) = 12.671$, $p = 0.124$, RMSEA = 0.065, *p*-close = 0.307, TLI = 0.928, CFI = 0.962, SRMT = 0.042, $\Delta\chi 2$ (1) = 0.025, $p = 0.874$] showed a slightly worse fit and revealed a correlation of 0.980 between version A and B, indicating the stability of the construct. The final willpower theory scale consisted of 6 items, $M = 2.89$, $SD = 1.05$, skew = 0.327 (0.206), kurtosis = −0.532 (0.410), Cronbach's $\alpha = 0.71$, with higher scores associated with a non-limited theory.

Learning Goal Orientation

Children's learning goal orientation, their willingness to exert effort to learn something (Compagnoni et al., 2019), was assessed with 6 Items adapted from Gunderson et al. (2013)'s motivational framework measures. To capture learning goal orientation, the same procedure was used as for willpower theories. A researcher asked two puppets standardized questions, and the children listened to the puppets' answers delivered on a touchscreen. One puppet expressed a stronger learning goal orientation (i.e., "I like to do difficult tasks to learn something") than the other (i.e., "I like to do easy tasks to get it right"). The children indicated how much they could identify with one of the two puppets on a semantic differential scale with five points displayed on the touchscreen between the puppets. Items on learning goal orientation were mixed with items on willpower theories and assessed during the two visits. Version A (three items) and B (three items) were similar in content and were combined to create a single goal orientation score for each child. Higher scores are associated with a higher learning goal orientation. The learning goal orientation scale consisted of six items, $M = 3.66$, $SD = 1.18$, Cronbach's $\alpha = 0.88$.

Covariates

Gender, age, and academic ability level were assessed with an online questionnaire administered to the teachers. As no formal grades are given in kindergarten, we asked teachers to assess students' academic abilities in mathematics and language. To increase the comparability and validity of the teachers' global performance assessments, the teachers were given three examples each to integrate in their assessment of the mathematics domain (knowing numbers, calculate, count) and language domain (knowing letters, reading words, writing words). Teachers had to rate each child in their class on a 9-point semantic differential scale displayed by stick figures in a horizontal row. Lower values indicated a lower level of academic ability. The achievement measure used in this study therefore reflects a social reference standard, similar to grades ($M = 6.21$, $SD = 2.04$, Cronbach's $\alpha = 0.84$). The measure was part of a questionnaire assessing children's' ability self-concepts on the same scales (Cimeli et al., 2013).

Data Analysis

Analyses were conducted using IBM SPSS Statistics 25.0. Based on *a priori* analyses with the G*Power software package

(Faul et al., 2009), for linear multiple regression analyses with up to five predictors we targeted a minimum sample size of 92 children to achieve a power of 0.80 (fixed model, R-squared deviation from zero, alpha level = 0.05, effect size $f^2 = 0.15$). Since we allowed all children at the contacted schools to participate when they gave consent, the analyses were calculated with the complete sample of $N = 147$. To test whether willpower theories predicted behavioral self-regulation and whether this relationship was moderated by academic ability level, a three-stage hierarchical multiple regression was conducted with behavioral self-regulation as the dependent variable. Control variables were considered at stage one, willpower theories at stage two, academic ability level at stage three. Concerning the question as to whether the relation between willpower theories and behavioral self-regulation was mediated by children's learning goal orientation, a simple mediation analysis was carried out. As we estimated our models with no *a priori* constraints on direct effects and the modeling of latent variables would reduce the power for our sample size, an OLS regression approach for estimating mediation models (Hayes, 2018) was chosen over a maximum likelihood based SEM program. Further OLS regression is more appropriate in small samples than SEM due to the *p*-values derived from t distributions. Both mediation and moderation analyses were conducted with a regression-based approach in SPSS using the macro PROCESS with bias corrected and accelerated bootstrap intervals estimates (Hayes, 2018). Bootstrapping as a non-parametric resampling procedure seemed reasonable to test the significance of a mediation effect, as it does not rely on the assumption of normality and is adequate for small sample sizes. Following the recommendations of Hayes (2018) regression analyses which include a product of predictors in the model are reported and interpreted based on unstandardized coefficients. In regression models without a product term as a predictor (Hayes, 2018, p. 313), standardized regression coefficients were generated and can be interpreted accordingly. As the children were clustered in kindergartens, we checked whether the application of a multilevel model would be necessary, although this would hardly be methodologically applicable for our small sample of 19 kindergartens. Small ICCs for all main variables between $\rho = 0.002$ for willpower theories and $\rho = 0.111$ for behavioral self-regulation with non-significant Wald z values indicated that there were no significant differences in willpower theories, goal orientation, age, academic ability ratings, or behavioral self-regulation across kindergartens.

RESULTS

Table 1 shows means, standard deviations, and range of willpower theories, goal orientation, behavioral self-regulation measures, academic ability level, and the covariates as well as zero-order rank correlations among all constructs. Kindergarteners' willpower theories showed approximately the same medium correlation with teacher ratings of academic abilities ($r = 0.226$) and behavioral self-regulation ($r = 0.219$). As expected from previous research on the positive relation between self-regulation and academic ability level, results showed medium correlations of $r = 0.363$ between behavioral self-regulation assessed with the HTKS and academic ability level.

Structure of Willpower Theories

As we developed new items tailored to this age group to assess willpower theories, it is recommended that exploratory factor analysis (EFA) should precede CFA (Worthington and Whittaker, 2006). Both items to assess learning goal orientation and willpower refer to children's motivational beliefs about dealing with challenges and were assessed with the same instrument. Therefore, to clarify the data structure, we conducted a principal axis component analysis (PAF) on the 12 items with oblique rotation, as we expected the factors to be moderately correlated. The Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy to the analysis, KMO = 0.851. EFA yielded a 2-factor solution (43.14% EV), with a scree plot that justified two factors. Factor loadings after rotation showed reasonable item loadings from 0.416 to 0.814 on the two factors (Worthington and Whittaker, 2006). The two factors, learning goal orientation and willpower theories, showed a significant medium correlation of 0.302. To determine the theoretically assumed factor structure of the data, we applied CFA with MLM estimators that are robust to non-normality and skewed data, as is the case with goal orientation. A two-dimensional model with learning goal orientation and willpower theories computed as two related first-order latent factors immediately fit the data well [$\chi 2$ (53) = 50.108, $p = 0.588$; RMSEA = 0.000, 90% CI [0.000;0.049], TLI = 1.008, CFI = 1.000, SRMR = 0.052]. Given these findings, we constructed a willpower theories scale (Cronbach's $\alpha = 0.71$) and a learning goal orientation scale (Cronbach's $\alpha = 0.88$) for the two first-order factors.

TABLE 1 | Descriptives.

	N	Range	*M*	*SD*	SR	WT	GO	AAL	Gender	Age
Behavioral self-regulation (SR)	142	12–57	41.70	10.36	–	0.227**	0.223**	0.352**	−0.101	0.132
Willpower theories (WT)	138	1–5	2.89	1.05	0.219**	–	0.264**	0.246**	0.109	0.104
Learning goal orientation (GO)	138	1–5	3.66	1.18	0.227**	0.285**	–	0.288**	0.224**	0.136
Academic ability level (AAL)	142	1–9	6.21	2.04	0.363**	0.226**	0.269**	–	−0.010	0.165
Gender	147	1–2	1.48	0.50	−0.113	0.116	0.186*	−0.010	–	0.129
Age in months	143	65–86	77.21	4.67	0.118	0.176*	0.131	0.154	0.147	–

*Non-parametrical Spearman correlations above the diagonal, parametrical Pearson correlation below the diagonal. Gender (girls = 1, boys = 2), *p < 0.05, **p < 0.01 (two-tailed).*

Relation of Willpower Theories With Behavioral Self-Regulation

Our second research question addressed the relation between willpower theories and behavioral self-regulation. Because empirical studies reported inconclusive or culturally different results regarding age and gender differences in behavioral self-regulation (Gestsdottir et al., 2014; Montroy et al., 2016; Yamamoto and Imai-Matsumura, 2017) with no difference or better behavioral self-regulation in girls and older children, gender and age were included as covariates. Results from the hierarchical regression model (**Table 2**) revealed in step 1 that gender and age explained 2% of the variance in behavioral self-regulation, with girls regulating better than boys and older children better than younger ones, but on a non-significant alpha level ($p = 0.104$). Introducing willpower theories in step 2 led to a significant change in R^2 of additional 6% of explained variance in predicting behavioral self-regulation ($p = 0.005$) and established willpower theories as an important predictor of behavioral self-regulation ($\beta = 0.243$, $p = 0.005$). The more children thought of their willpower as non-limited, the better was their behavioral self-regulation. If academic ability level is included in step three, an additional 10% of the variance in behavioral self-regulation can be explained ($p = 0.000$). Regression coefficients in **Table 2** show that willpower theories still contributed significantly to explain the variance in behavioral self-regulation ($\beta = 0.175$, $p = 0.036$).

Moderation by Academic Ability Levels

Although the results showed that willpower theories are related to behavioral self-regulation, we hypothesized that the relation would be moderated by academic ability levels. **Table 3** shows results of a regression analysis examining the moderation of willpower theories to behavioral self-regulation by academic ability level, controlling for age and gender using PROCESS (Hayes, 2018). Results of the moderation analysis showed that 23% of the variance in behavioral self-regulation could be explained by willpower theories, academic ability level, gender, and age. The relation between willpower theories and behavioral self-regulation was significantly moderated by academic ability level [$F(1,129) = 7.801$, $p = 0.006$], with an effect size of 5% increase in variance ($\Delta R^2 = 0.046$). A graphical depiction of the interaction revealed that behavioral self-regulation was especially low among children with low academic abilities which tended toward a limited willpower theory (see **Figure 1**). The analyses showed that the conditional direct effect of willpower theories on self-regulation was significant in children with low academic ability levels ($M_{-1SD} = 4.149$, $b = 4.078$, $SE = 1.158$, $p = 0.001$, 95% CI [1.787, 6.368]) and in children with moderate academic ability levels ($M = 6.189$, $b = 2.014$, $SE = 0.811$, $p = 0.014$, 95% CI [0.409, 3.619]). In contrast, willpower theories were not significantly related to behavioral self-regulation of children with a high academic ability level ($M_{+1SD} = 8.229$, $b = -0.049$, $SE = 1.033$, $p = 0.962$, 95% CI [−2.093, 1.995]). To ensure that the results of the interaction analysis were not caused by a statistical artifact due to low variance of willpower theories in children with high academic abilities, the sample was divided into three groups (low achievement level, $n = 44$, $M = 2.63$, $SD = 0.94$, medium achievement level, $n = 47$, $M = 2.79$, $SD = 1.01$; high achievement level, $n = 47$, $M = 3.23$, $SD = 1.11$) and compared regarding their variance. All three groups showed a range from a limited (1) to a non-limited theory (5) and no difference in variance (Levene's test, $F(2,135) = 0.801$, $p = 0.451$. Conditional effects with 95% CI are displayed in the **Supplementary Material**. The Johnson-Neyman Technique revealed that the confidence interval was not completely above zero after an academic ability level of 6.60, which is the case for 44% of the children. Therefore, for the 56% children with lower ability levels, a more non-limited willpower theory was associated with better behavioral self-regulation than a more limited willpower theory was.

TABLE 2 | Hierarchical regression model for behavioral self-regulation.

Model		*B*	*SE B*	β	*p*	CI_{95} lower	CI_{95} upper	R^2	*p*
1	*Constant*	23.207	14.696		0.117	−5.862	52.277		
	Age	0.297	0.192	0.134	0.124	−0.082	0.677		
	Gender	−3.045	1.807	−0.146	0.094	−6.619	0.528		
								0.019	0.104
2	*Constant*	23.730	14.315		0.100	−4.588	52.049		
	Age	0.208	0.190	0.094	0.275	−0.167	0.583		
	Gender	−3.509	1.767	−0.168	0.049	−7.005	−0.013		
	Willpower theories	2.429	0.851	0.243	0.005	0.754	4.114		
								0.069	0.006
3	*Constant*	20.977	13.614		0.126	−5.956	47.910		
	Age	0.133	0.181	0.060	0.463	−0.225	0.491		
	Gender	−3.301	1.679	−0.158	0.051	−6.623	0.021		
	Willpower theories	1.756	0.827	0.175	0.036	0.120	3.392		
	Academic ability level	1.641	0.420	0.319	0.000	0.809	2.472		
								0.161	0.000

Model 1: $F(2, 132) = 2.302$, $\Delta R^2 = 0.034$, $\Delta p = 0.104$; Model 2: $F(3, 131) = 4.331$, $\Delta R^2 = 0.057$, $\Delta p = 0.005$; Model 3: $F(4, 130) = 7.409$, $\Delta R^2 = 0.095$, $\Delta p = 0.000$.

TABLE 3 | Model coefficients of the moderation of academic ability level on the relation between willpower theories and behavioral self-regulation, controlling for age, and gender.

		Coeff.	*SE*	*t*	*P*	CI_{95} lower	CI_{95} upper
Intercept		−1.237	15.472	−0.080	0.936	−31.848	29.375
Willpower theories (WT)	b_1	8.275	2.469	3.351	0.001	3.390	13.160
Academic ability level (AAL)	b_2	4.573	1.127	4.058	0.000	2.343	6.802
WT × AAL	b_3	−1.012	0.362	−2.793	0.006	−1.728	−0.295
Gender	b_4	−3.424	1.638	−2.091	0.038	−6.664	−0.184
Age	b_5	0.185	0.177	1.042	0.299	−0.166	0.536

$F(5, 129) = 7.798$, $p = 0.000$, Adjusted $R^2 = 0.202$; R-square increase due to interaction: $\Delta R^2 = 0.046$, $F(1,129) = 7.801$, $p = 0.006$.

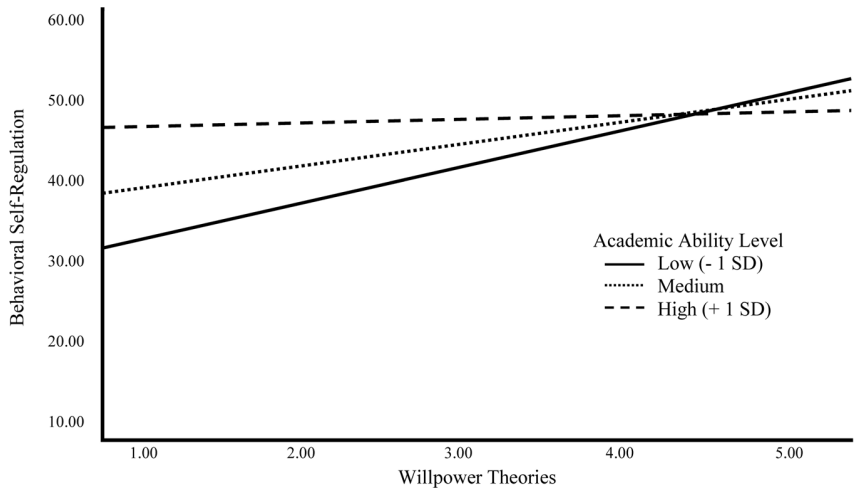

FIGURE 1 | Graphical depiction of the moderation of the effect of willpower theories on behavioral self-regulation by academic ability level using $M \mp 1$ *SD* to represent low, moderate and high values on the moderator.

Mediation Through Goal Orientation

The simple mediation analysis (Model 4 in PROCESS) conducted using ordinary least square path analysis showed that willpower theories directly and indirectly influenced behavioral self-regulation through its effect on learning goal orientation (**Figure 2**). As **Table 4** shows, children who thought of their willpower as non-limited were more learning oriented than children with limited theories were ($a = 0.280$, $p = 0.004$, 95% CI [0.093, 0.466]), and children who were more learning oriented showed better behavioral self-regulation than children who liked to do easy tasks that they had already mastered ($b = 1.909$, $p = 0.014$, 95% CI [0.391, 3.427]). The completely standardized regression coefficients are displayed in **Figure 2** and **Table 4**. A bootstrap confidence interval for the indirect effect ($ab = 0.534$) based on 10,000 bootstrap samples showed that this effect was statistically different from zero as revealed by the 95% bias-corrected bootstrap confidence interval entirely above zero (95% CI [0.100, 1.347]). A partially standardized indirect effect of 0.052, 95% CI [0.009, 0.124] and a completely standardized effect size of 0.053, 95% CI [0.010, 0.129]) revealed a small partial mediation with a significant ratio of indirect to total effect of willpower theories on behavioral self-regulation (0.220, 95% CI [0.038; 1.003]). The direct effect of willpower theories remained significant, indicating that they were related to behavioral self-regulation independent of their effect on learning goal orientation ($c' = 1.889$, $p = 0.029$, 95% CI [0.190, 3.588]).

DISCUSSION

This study is the first to demonstrate that kindergarteners already have distinct and varying ideas about the nature of their willpower that can be assessed reliably. Children's implicit willpower theories range from a non-limited to a limited theory in low and high achievers and are distinguishable from related concepts such as a learning goal orientation. Importantly, this study shows that kindergarteners' beliefs about the nature of willpower are related to behavioral self-regulation. Children who agreed more that they needed a break after strenuous tasks (limited theory) performed worse in the behavioral self-regulation task than children who rather agreed that exerting willpower is energizing (non-limited theory). Further, our results support the hypothesized moderation by academic ability levels: willpower theories are especially beneficial for children with a low ability level. We also found support for the hypothesized mediation: The more children endorsed a non-limited theory about their willpower the more they expressed a preference for challenging tasks in order to learn, which accounted for their

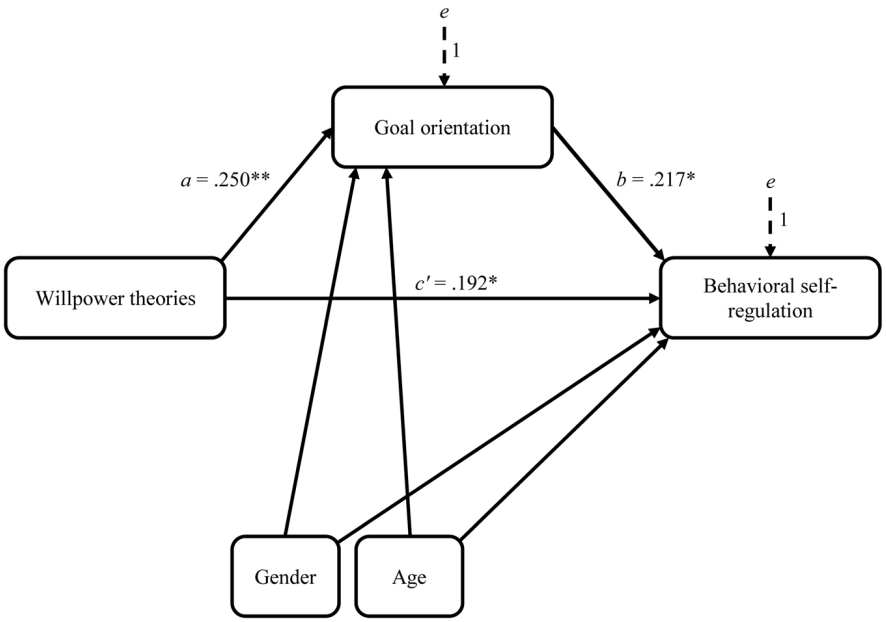

FIGURE 2 | Statistical diagram of the mediation model with standardized regression coefficients for presumed influence of willpower theories on behavioral self-regulation through goal orientation with statistical controls; $^{*}p < 0.05$, $^{**}p < 0.01$.

TABLE 4 | Model coefficients and completely standardized regression coefficients for the conditional direct and indirect effects of willpower theories on behavioral self-regulation, through goal orientation.

		Goal orientation					Behavioral SR			
		β	Coeff.	*SE*	*p*		β	Coeff.	*SE*	*p*
Willpower theories	*a*	0.250	0.280	0.094	0.004	*c′*	0.192	1.889	0.859	0.029
Goal orientation		–	–	–	–	*b*	0.217	1.909	0.767	0.014
Gender		0.133	0.313	0.195	0.111		−0.200	−4.136	1.737	0.019
Age		0.068	0.017	0.021	0.412		0.080	0.178	0.185	0.338
Constant	i_M		1.064	1.584	0.503	i_Y		21.537	13.988	0.126
			$R^2 = 0.102$					$R^2 = 0.132$		
			$F(3,132) = 4.972$, $p = 0.003$					$F(4,131) = 4.969$, $p = 0.001$		

better performance in behavioral self-regulation. These results support our assumption that a limited willpower theory in children is associated with a preference for easy tasks. We assume that Children with a limited theory avoid difficult tasks so as not to strain their willpower and therefore seldom train their behavioral self-regulation.

One of the main questions leading this research was why some children come to effectively regulate their behavior, which is related to better adaption and performance in school, while others struggle. The results highlight the possibility that behavioral self-regulation may not only depend on biological predisposition or develop as a result of repeated training, as examined in past research (Walk and Evers, 2013; Diamond and Ling, 2016). It might also develop through an implicit understanding of willpower as non-limited. Haimovitz et al. (2019) proposed that "if children learn to approach willpower as self-energizing, this could develop into a more general tendency to search for strategies and be resourceful across multiple novel self-regulatory situations" (p. 7). Besides this rather direct relationship to improved behavioral self-regulation in challenging situations, our results also highlight an indirect relationship. Viewing willpower as more of a limited resource is relates to a less pronounced learning goal orientation and therefore may lead to an avoidance of challenging, strenuous tasks. In turn, opportunities to train behavioral self-regulation in the face of difficulties get lost. If children continue to avoid challenging tasks, this may become a pronounced hindrance over time, since challenge is important for training self-regulation (Diamond and Lee, 2011). A non-limited theory therefore might be especially beneficial in the early childhood years. During this time autonomous play and learning environments are more common than later in primary school, where the selection of task difficulty becomes more externally controlled by teachers than by children's own motivational beliefs. Especially in newer adaptive teaching and learning concepts, which are based on the assumption of a self-regulated active individual,

willpower theories may play an important role for task selection, strategy use, and persistence. Swiss kindergartens emphasize open learning environments, and it may be that the interaction of willpower theories, academic ability level, and behavioral self-regulation is different in more structured environments, where there is less free play and free choice. On the other hand, the greater autonomy in kindergartens might foster a non-limited willpower theory. Sieber et al. (2019) showed that autonomous goal striving promotes the endorsement of non-limited theories mediated through vitality, the experience that tasks are energizing. However, autonomous task selection and pursuit might also be challenging and overtaxing for some children (Sieber et al., 2016). The change from strong external regulation by primary caregivers in early childhood to complete internalization of regulation is a central process in the development of self-regulatory competence (Kochanska et al., 2001). Therefore, support from teachers is crucial also in autonomous settings to enable children to experience tasks as not draining but stimulating.

Future research should look at the role willpower theories play in different teaching and learning settings. Especially longitudinal designs are important, with multiple variables to assess developmental patterns after the transition from kindergarten to primary school, where the educational setting often changes dramatically.

Various previous studies have shown that the behavioral self-regulation task used in this study is predictive of achievement later in school and that it measures children's performance in working memory, attention, and inhibition. This is what children need to successfully regulate themselves in classrooms, where they must actively remember instructions from the teacher, focus on the task at hand, and ignore distractions. Since the relation between a more non-limited willpower theory and behavioral self-regulation was especially pronounced in children with low academic ability levels, willpower theories may represent a resilience factor against poor performance. In this study, willpower theories did not seem to be related directly to behavioral self-regulation in children with high academic ability levels. We were able to rule out that the measurements for willpower theories and behavioral self-regulation were not sensitive enough in the upper ranges. But it might be that a non-limited theory has positive effects for children with high academic abilities in other areas of self-regulation, such as in the use of different or more effective learning strategies (Haimovitz et al., 2019).

In the present study we tested two distinct models (moderation by ability level and mediation through goal orientation) concerning the relation between willpower theories and self-regulation. An open question is, whether these two models can be combined within one more comprehensive model. It could be that academic ability level also influences the indirect effect between willpower theories and behavioral self-regulation, as ability level might moderate the relationship between willpower theories and goal orientation. Previous research suggests that learning goal orientations are independent from ability level (Dweck and Leggett, 1988). However, theoretical and empirical results on the topic are inconclusive. Children on low ability levels with a limited theory are possibly more prone than children on high ability levels to choose tasks they already master as their academic self-beliefs are lower (Marsh and Martin, 2011; Schloz and Dresel, 2011). On the other hand, high achieving children with a limited theory, who think that their resources become depleted might be just as interested in choosing tasks they already master to protect their higher self-concepts (Bouffard and Narciss, 2011; Butler, 2011). In order to generate first insights into that relationship, additional explorative moderated mediation analyses were conducted. However, in those analyses we found no evidence, that the indirect effect from willpower theories to behavioral self-regulation by goal orientation was moderated by academic ability level (see **Supplementary Material** for details on the moderated mediation, Model 7 in PROCESS).

A second possibility could be that ability level moderates the relationship between goal orientation and behavioral self-regulation. Previous research documents that interventions promoting a growth mindset, which is supposed to promote learning goal orientation, are specifically beneficial among lower achieving students (Paunesku et al., 2015; Yeager et al., 2019). Apparently, low ability students are the ones whose performance depends more heavily on their motivational orientation toward learning and effort engagement. High performing students might float through academic settings without high effort expenditure. Accordingly, we conducted a second explorative analysis (Model 14 in PROCESS). Again, we found no evidence, that the indirect effect from willpower theories to behavioral self-regulation by goal orientation was moderated by ability level (see **Supplementary Material** for details on the moderated mediation). Thus, future research should further investigate the relationship between willpower theories, learning goal orientation and self-regulation based on individual students' academic ability levels and may also include self-concepts and self-efficacy as mediators.

Our results highlight that willpower theories already vary widely in kindergarteners, and Dweck (2017) puts the formation of mindsets at the center of development from birth. This raises the important question about the origins of willpower theories. From a developmental and evolutionary psychological perspective, a strong orientation toward exerting willpower, effort, and persistence after failure may be expected in all young children, who face challenges almost on a daily basis when learning to walk, talk, or ride a bike. When and how do the two different mindsets start to develop? Haimovitz et al. (2019) see the development of mindsets as a result of socialization and changeable by various environmental influences. There is hardly any research on possible influencing factors during child development. Studies on implicit intelligence theories suggest that contextual factors, such as feedback from significant others, may have an impact (Gunderson et al., 2013, 2018). Model learning certainly also plays a central role in the development of implicit theories. If children see that significant others experience challenges as energizing, a non-limited mindset may be promoted (Haimovitz et al., 2019). Conceivably, parents or teachers who display depleted energy and a need for recreation after a challenging workday may set an example for a limited theory.

However, it should always be remembered that taking breaks, as a motivational strategy in the sense of a self-reward and not as cause of depleted resources, is a highly recommended self-regulatory strategy (Wolters, 2003). In a recent study, Bernecker and Becker (2020) emphasize that a balance between long-term goals (i.e., learning to read) and hedonic goals (i.e., pleasure) is paramount to adaptive self-regulation. It makes a difference whether children struggling with a task take a break because they believe their resources are depleted ("I'm exhausted") or take a break as a reward for a job well done ("I've earned a break!").

Therefore, teachers and parents may play a crucial role in the forming of willpower theories. Further, it is plausible that teachers' approaches to instruction may lead to differences in the associations between willpower theories and self-regulation in students. Interventions should look deeper into the assumed causal relation between self-regulation and willpower theories as well as possible mechanisms that affect kindergarteners' implicit theories. Classroom practices such as low autonomy during goal striving (Sieber et al., 2019) as well as innocuous advice from practitioners, such as "take a break after strenuous tasks," might promote a limited willpower theory. This would have possible negative consequences for behavioral self-regulation and subsequently hinder a child's academic development overall. As a consequence, teachers might be encouraged to be sensitive to subtle linguistic cues and to their own behavior as role models. As people with a limited theory are sensitive to the availability of mental resources (Haimovitz et al., 2019), teachers might possibly influence children's mindsets. Future research should explore the salience and effect of different cues and instructional practices that may foster a non-limited willpower theory in the school context.

Although this study expands previous findings, there are some limitations that should be addressed. First, the correlational nature of this study precludes any claims of causation. As previous studies with students (Job et al., 2010) and preschoolers (Haimovitz et al., 2019) showed that experimentally manipulated willpower theories caused a difference in self-control or delay of gratification, for example, we believe that the presented theoretical assumptions and previous empirical findings justify the assumption of a causal process. Nevertheless, it is possible that behavioral self-regulation and willpower theories influence each other and that the development of a person's willpower theories is partly a result of metacognitive experiences, knowledge, and skills during the self-regulation process. For example, if a child struggles with a challenging task and cannot successfully complete it, the attribution of the self-regulation failure to limited willpower that has to be replenished seems reasonable. A limited theory would therefore be the consequence of self-regulation failure and not the reason. As in the present study willpower theories and academic ability levels show a medium correlation, future intervention studies should look into academic achievement as an outcome. It might be assumed that the positive constellation of non-limited willpower theories, learning goal orientation, and behavioral self-regulation must be reflected in later achievement. Therefore, kindergarteners with low academic ability levels who adopt non-limited willpower theories and show high behavioral self-regulation may show a positive development trend of academic achievement during primary school. Non-limited willpower theories might act as a motivational precondition for positive academic development.

Second, further research should validate the newly developed instrument to assess willpower in children. The items that we developed for this study may not be feasible for other age groups (e.g., younger children might have only early forms of mindsets) and cultures, as research points out that there are differences in willpower theories across cultures (Savani and Job, 2017). As willpower theories in children in this age group had not been measured up to now, future studies could explore if the manipulation of children's beliefs (e.g., as in the study of Haimovitz et al., 2019) only affects short-term behavioral self-regulation in the experimental situation or if it also affects underlying beliefs about willpower.

Third, we assessed academic ability levels by teacher ratings of students' academic abilities, which has advantages and disadvantages. With no formal grades given in kindergarten, teachers' assessment of students' abilities are valid judgments, and the kindergarten group as social reference norm is an important indicator (Marsh et al., 2002). Social comparison processes are an important developmental process for the validation of self-perception in kindergarten. This approach leads to a small variance across kindergarten classes but represents more than a mere reflection of students' academic abilities, because teacher ratings also take motivational characteristics into account. Future research should consider the use of both achievement tests and teacher ratings but as separate latent constructs, since they have different psychological meanings (Pinxten et al., 2010).

Further, although the assessment of learning goal orientation as children's willingness to exert effort to learn something vs. choosing easy tasks that they already master on a unidimensional scale is acceptable for this age group (Gunderson et al., 2018; Compagnoni et al., 2019), future studies should try to capture differentiated goal orientations (e.g., performance/mastery, avoidance/approach) to fully address the correlates and relations between willpower theories, behavioral self-regulation, and goal orientation.

In sum, this study suggests that willpower theories in young children can be reliably assessed, which opens up exciting new avenues for theory and application of self-regulation research. The present research shows that kindergarteners who think that willpower is limited already self-regulate less well than their peers with a non-limited view, and they prefer to do easy tasks that they already master. This holds especially true for children with lower academic achievement levels. Early behavioral deficiencies are known to be problematic for school transitioning and future learning behavior (Blair and Raver, 2015). Therefore, research on motivational beliefs (e.g., willpower theories) in this young age group is required to better understand the processes involved in the development of self-regulation. Future research should investigate mechanisms that affect willpower theories of kindergarteners, to foster a view of their own willpower as energizing. This has the potential to promote behavioral self-regulation and possibly ensure long-term academic success.

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 human participants were reviewed and approved by Ethics Commitee, Faculty of Arts and Social Sciences, University of Zurich, Switzerland. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

MC conceived and designed the study, developed the new measure, collected and analyzed the data, and wrote a first version of the manuscript. VS verified the analyses. VS and VJ provided advise and discussed the results. All authors wrote the final manuscript.

SUPPLEMENTARY MATERIAL

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Do Only White or Asian Males Belong in Genius Organizations? How Academic Organizations' Fixed Theories of Excellence Help or Hinder Different Student Groups' Sense of Belonging

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High-profile organizations often emphasize fixed giftedness rather than malleable effort-based criteria as critical for excellent achievements. With giftedness being primarily associated with White or Asian males, such organizational implicit theories of excellence may shape individuals' sense of belonging depending on the extent to which they match the *gifted White/Asian male prototype*, i.e., the prototypical gifted person which is typically imagined to be a White or Asian male. Previous research has reported fixed excellence theories emphasizing giftedness (vs. malleable theories emphasizing effort) to impair the sense of belonging of females and negatively stereotyped ethnic minorities. We investigate the combined effects of gender and ethnicity. We predicted that, while individuals whose gender and ethnicity do not match the gifted prototype show a reduced sense of belonging in fixed organizations, White/Asian males who match the gifted prototype show the opposite effect, experiencing a *higher* sense of belonging in fixed (vs. malleable) organizations. In an experimental study (N = 663 students), we manipulated advertising material used by a highly selective academic institution in Germany and tested effects on students' belonging. Whereas the original material emphasized giftedness as essential for excelling (fixed excellence version), our manipulated version stressed effort (malleable version). As expected, females from stereotyped ethnic minority groups felt less belonging in the fixed (vs. malleable) organization, while White/Asian males anticipated stronger belonging in the fixed (vs. malleable) organization. Fixed views of excellence impair negatively stereotyped individuals' belonging but may even strengthen the belonging of prototypical academic elites.

Keywords: stereotypes, organizational implicit theories, gender, ethnicity, belonging, prototype

INTRODUCTION

> "*The [organization name] supports young people with a high scientific or artistic giftedness who, [. . .] successfully study [. . .] and from whom, according to their giftedness and personality, special achievements [. . .] are to be expected.*"

Selective organizations like the Ivy League, scholarship providers, or high profile companies are looking for individuals with excellent achievements. The above quote from the advertising material of a highly selective German scholarship provider (which we manipulated in the present study) illustrates how these organizations often inadvertently send messages about their implicit theories of excellence. The quote specifically exemplifies the common *fixed* view of excellence – i.e., the idea that excellent achievements are based on innate and stable personal characteristics, like giftedness or talent, rather than having to be developed through effort (malleable view of excellence). Implicit theories of excellence may, however, not only signal *how* one can reach excellent achievements within an organization, but also *which groups of people* may be likely to do so, thus differentially fostering individuals' sense of belonging.

Intellectual stereotypes associate giftedness with males rather than females and with White or Asian individuals rather than other non-Asian ethnic minorities (e.g., African or Middle Eastern individuals) who are negatively stereotyped (Fiske et al., 2002; Cuddy et al., 2009; Bian et al., 2017). Based on these stereotypes, fixed organizational excellence theories may not make all individuals belong equally. Indeed, previous research (Leslie et al., 2015; Bian et al., 2018) has found evidence that fixed organizational theories with their emphasis on giftedness may impair the sense of belonging of females and negatively stereotyped ethnic minorities who do not match the gifted White/Asian prototype, i.e., the prototypical gifted person which is typically imagined to be a White or Asian male. In these studies, no effects for Whites, Asians or males were reported. So far, however, research in this area has only considered one identity – i.e., either gender *or* ethnic identity – in isolation.

In the present research, we investigate the intersection of gender and ethnicity. We hypothesize that the combination of gender and ethnicity – and specifically the extent to which the combination of these group memberships match the gifted White/Asian male prototype (Niedenthal et al., 1985; Bian et al., 2018) – may be relevant in determining the extent to which organizational fixed excellence theories make individuals belong: Fixed theories emphasizing giftedness rather than effort may signal prototypical White/Asian males are most likely to succeed. Accordingly, we hypothesized that fixed theories impair the belonging of individuals who do not match the gifted White/Asian male prototype, i.e., females from intellectually stereotyped ethnic minority communities, but even increase the sense of belonging of White/Asian males matching the prototype of the gifted.

Individuals' Sense of Belonging

As "social animals," humans are driven by their need for belonging and social connection (Baumeister and Leary, 1995). Developing a strong sense of belonging in a given community can thus be seen as an important outcome in its own right. At the same time, individuals' subjective sense of belonging has also been shown to be a crucial determinant of other important outcomes, as diverse as individuals' engagement and performance in academic and professional settings, the formation of friendships and associated social capital, as well as mental and physical health (Walton and Cohen, 2007, 2011; Wilson et al., 2015; Yeager et al., 2016).

While the need for belonging seems to be largely universal (Baumeister and Leary, 1995; Walton et al., 2012), individuals seem to differ in the way they respond to different environmental factors regarding their sense of belonging. Overall, previous research suggests that maintaining a strong and stable sense of belonging seems to be more difficult for individuals who are negatively stereotyped in a given context. Negatively stereotyped individuals have been shown to experience higher fluctuations in their sense of (non)belonging in their daily lives and to doubt their belonging more readily when confronted with non-belonging cues, such as the experimentally induced perception that one might not have a lot of friends (Walton and Cohen, 2007; Yeager et al., 2016). Moreover, many public spaces seem to include cues that cater to the mainstream White male culture, but may impair the belonging of other individuals. Several studies (Fryberg, 2012; Fryberg et al., 2013; Brannon et al., 2015) have for example shown that universities primarily focus on independent values (e.g., stressing the importance of finding one's own individual path for students), which can create the sense of a "cultural mismatch" and non-belonging for non-White and female individuals, who are culturally more attuned to interdependent values. Understanding how different student groups' – and specifically negatively stereotyped individuals' – sense of belonging can be strengthened is thus a crucial task, which we aim to pursue in this research through the means of organizational implicit theories.

Organizational-Level Implicit Theories of Intelligence

Previous research on implicit theories has mostly focused on *individuals'* implicit theories or mindsets – i.e., the extent to which *a person* thinks that certain attributes like intelligence or skills are malleable (growth mindsets) or innate (fixed mindsets, Dweck, 2008). Building on this work, some recent research has begun to explore organization-level implicit theories – i.e., the extent to which *organizational* culture is broadly perceived to reflect a belief in the malleability or fixedness of certain attributes. Murphy and Dweck (2010) have highlighted the added value of organization-level implicit theories by showing how organizations – beyond their individual members' mindsets – may themselves maintain distinct implicit theories. Specifically, Murphy and Dweck showed that organizational implicit theories, communicated through, for instance, advertising material or statements of organization members, lead members to adapt to these theories, reproducing them in the ways they see and present themselves, how they judge others, and how they select new employees. Through these top-down adaptation and selection

processes, organizations may maintain distinct implicit theories on the long run.

A series of experiments by Emerson and Murphy (2015) has further shown organizational implicit theories to shape individuals' attitudes toward organizations. Specifically, organizations with a malleable (versus fixed) theory of intelligence led individuals to think they would be judged more positively, feel more accepted, and exhibit more trust as well as engagement. While effects tended to be more pronounced for women, who may be more sensitive to the possibility of being judged negatively in business contexts (Kray and Shirako, 2011), they largely held for males, too. In line with research showing that growth mindsets of intelligence helps individuals see failures as opportunities for growth rather than a lack of talent (Dweck and Leggett, 1988; Smiley et al., 2016), organization-level malleable theories of intelligence seem to signal the respective institution to be more accepting and less judgmental toward employees and their mistakes.

Beyond the question to what extent intelligence is malleable or not, an equally crucial matter may be to what extent individuals' excellent achievements – i.e., outstanding outcomes, rather than skills – are thought to be malleable: Excellent achievements can be thought of as being pre-determined and fixed by individuals' innate intellectual giftedness as an extraordinarily high form of intelligence (fixed theory of excellence), or as being malleable, having to be developed through hard work and effort (malleable theory of excellence). Both theories of excellence seem widespread in organizations: Investigating service organizations' online communication, Leung et al. (2020) found that around a quarter of investigated companies showed a pronounced fixed excellence theory, emphasizing giftedness, while another quarter showed a pronounced malleable focus, emphasizing effort; with the remaining organizations showing either a mixed theory (mentioning both talent and effort) or no indication of either theory.

Although innate giftedness is not commonly thought to be distributed differently in varying social groups (Steele and Aronson, 1995; Hyde, 2005; Penner, 2008), research suggests that the use of messages emphasizing the importance of giftedness may impair negatively stereotyped individuals' sense of belonging. Specifically, Leslie et al. (2015) found evidence that faculty members' domain-specific beliefs in the importance of giftedness were related to females' and African Americans' underrepresentation in the respective academic fields: The stronger faculty members endorsed that giftedness as an innate, fixed quality was the cornerstone of success, the fewer females and African Americans the respective domain seemed to attract.

Even more importantly, Bian et al. (2018) conducted several experimental studies in which success was portrayed as either requiring innate giftedness (corresponding to a fixed excellence view) or dedication and motivation (malleable view). They found that women's interest and anticipated sense of belonging in various educational and professional opportunities was lower in fixed excellence organizations emphasizing giftedness rather than malleable organizations focusing on motivation, while no significant difference was found for males. Bian and colleagues also provided evidence for the idea that individuals' match with prototypes may determine their sense of belonging: Specifically, they found effects on individuals' sense of belonging in the respective organization to be explained by their perceived similarity to the prototypical organization member. In contrast, stereotype threat, i.e., women's anticipation that they may be negatively stereotyped by others, did not mediate effects.

Relatedly, an experimental study by Rattan et al. (2018) showed that making individuals believe that only some people had what it takes to succeed negatively affected sense of belonging in females and negatively stereotyped ethnic minorities studying in science, technology, engineering, and math (STEM) fields. The view that only some individuals have the potential to succeed is implied in the fixed view of excellence, claiming that excellent achievements are innate and cannot be achieved by effort.

In sum, these findings suggest that compared to malleable theories of excellence, fixed theories have a negative effect on individuals whose gender or ethnicity does not match the gifted White/Asian male prototype, while no effects appear for individuals whose gender or ethnicity matches the gifted prototype.

This research has so far only investigated either gender *or* ethnicity, differentiating between individuals who match the gifted White/Asian male prototype with either their gender or ethnicity (i.e., males and White or Asian individuals) and individuals who do not match this prototype with their gender or ethnicity (i.e., females and negatively stereotyped ethnic minorities) only. However, every person carries both, a gender and an ethnic identity, at the same time. Accordingly, the gifted prototype is also characterized by both features, (male) gender and (White or Asian) ethnicity. Individuals' match with the gifted prototype can therefore vary between a full prototype match regarding both group memberships (i.e., White males or Asian males), no matching group memberships (females from negatively stereotyped ethnic groups); and a mixed match (i.e., White females, Asian females, males from negatively stereotyped ethnic minority groups). Investigating the combined effects of gender and ethnicity, we consider all three degrees of self-prototype match in our study.

Advantageous Effects of Fixed Implicit Theories in the Context of Positive Stereotypes

Despite the wide range of domains investigated, research on both individual mindsets and organizational-level implicit theories has so far focused on the *negative effects of fixed implicit theories or mindsets* on individuals (e.g., Chiu et al., 1997; Dweck, 2008; Murphy and Dweck, 2010; Emerson and Murphy, 2015; Yeager et al., 2019). Findings from two previous studies investigating how individuals' intelligence mindsets impact their performance after relevant stereotypes have been activated indicate, however, that fixed views may not always carry universally negative effects, but even show advantageous effects for some individuals: Froehlich et al. (2016) as well as Mendoza-Denton et al. (2008) found that fixed intelligence mindsets increased detrimental stereotype threat effects on negatively stereotyped individuals' performance,

but increased advantageous stereotype lift effects on positively stereotyped individuals' performance. It thus seems that fixed intelligence mindsets can function as moderators in context of stereotype-based effects, strengthening both, negative effects of negative stereotypes and positive effects of positive stereotypes.

Building on this line of work, we reasoned that previously found moderating effects of implicit theories may not be limited to individual-level implicit theories, but could extend to organizational implicit theories of excellence. We expected that students who do not match the gifted prototype with their gender and ethnicity (female ethnic minorities) experience impairments in their belonging by a fixed (vs. malleable) theory, while students with a full match (White/Asian males) benefit from a fixed versus malleable organizational-level implicit theory. Students with a mix of matching and non-matching group memberships (White/Asian females, males from negatively stereotyped ethnic minority groups) fall in between those two extremes and may thus show no overall effects. This latter assumption is supported by previous stereotype threat/lift research suggesting that, when no identity is experimentally activated, individuals with mixed prototype match may show no consistent stereotype-based effects: While individuals may suffer from the activation of a negatively stereotyped social identity (e.g., female gender), and profit from the activation of a positively stereotyped identity (e.g., Asian ethnicity; Shih et al., 1999), no consistent effects were found when both positive and negative identities were activated or when no identity was activated (Gonzales et al., 2002; Gresky et al., 2005; Rydell et al., 2009).

The Present Research

As outlined, the present research aims to investigate whether organizational implicit theories of excellence may differentially affect individuals' belonging depending on the extent to which they match the prototype of the gifted White/Asian male. We investigated this issue using the original advertising material obtained from Germany's biggest and most selective scholarship organization. This material is sent out to several thousand top performing university students each year (usually the top 2% of students, as assessed by their grades). We used the material in its original form for the fixed condition and constructed an analogous manipulated version for the malleable condition. All data and material can be found online: https://osf.io/r359f/?view_only=c7d654c2f5bf4953ad17954d5aa72244.

MATERIALS AND METHODS

Participants

Participants were recruited at a university in Germany as well as online through email lists for students and German-speaking student groups on the social media platform Facebook. The study was conducted online and was said to investigate the experiences of students at their university. Participants could win Amazon vouchers worth 200 Euros. In total, 663 students completed our online questionnaire. The mean age was $M = 24.27$, SD = 5.36.

Procedure

After giving informed consent, students were randomly assigned to one of two conditions (fixed or malleable) and subsequently provided with the respective version of scholarship advertising material. After reading the respective material, they completed a questionnaire with our outcome variable (the belonging measure) and demographic information.

Experimental Manipulation

The information material describes the services that the scholarship entailed (e.g., a 300 Euro monthly stipend, free seminars on diverse topics in- and outside of Germany, scholarships to study abroad) as well as information about requirements for successful applications.

The original version of the advertising material served as the fixed condition. With minor exceptions (we, e.g., changed the name of the scholarship organization to ensure that prior associations with the well-known organization would not affect results), no changes were made.

To create material for the malleable condition, we manipulated only the four expressions in the 225-word document which referred to implicit theories of excellence. Following previous implicit theory manipulations (e.g., Chiu et al., 1997; Mendoza-Denton et al., 2008; Yeager et al., 2019), the malleability condition emphasized that excellence must be developed through effort and diligence, while the fixed condition emphasized innate giftedness as the most important characteristic of their successful applicants. The crucial fixed (vs. malleable, in brackets) manipulation material reads as follows (manipulated parts are underlined):

"The Bahde Foundation offers one of the largest German giftedness scholarship programs (/scholarship programs). Requirement profile: Under the motto "Performance, Initiative, and Responsibility," the Bahde Foundation supports young people with high scientific or artistic talent (/high commitment) who, guided by curiosity and a passion for knowledge, successfully study and conduct research (/continuously advance in their studies and research through diligence), develop and implement ideas on their own initiative, actively engage themselves beyond their own concerns – and from whom special achievements in the service of the general public can therefore be expected according to their talent (/extraordinary willingness to work hard) and personality."

Measures

Prototype Match Regarding Group Membership

We assessed individuals' ethnicity and gender to determine the extent to which their group memberships matched the prototype of the gifted White/Asian male. Individuals were asked to indicate their gender, and whether their parents or grandparents came from a country other than Germany (a question commonly used in Germany as a replacement for more direct questions about ethnicity or race; e.g., German Federal Statistical Office, 2005). The degree of match with the gifted prototype was coded as the number of matching group memberships regarding gender

(male = fit, female = non-fit) and ethnicity (White or Asian = fit, non-Asian minority = non-fit), with White or Asian males showing the highest match (two matching group memberships) and females from negatively stereotyped ethnic minority groups showing the lowest match (0 matching group memberships).

Overall, 70% of participants (467) were female. Twenty-three% (153) were members of non-Asian ethnic minority groups. Of the remaining 77% (510) of participants, nine indicated being from an Asian background and 501 to be White. **Table 1** includes information on the number of participants by prototype match and condition. In sum, 21% of participants matched the gifted prototype with their gender and ethnicity (i.e., indicating male gender as well as White or Asian ethnicity), 64% held one matching identity (i.e., indicating either male gender or White/Asian ethnicity) and 15% held no matching group identities (i.e., indicating female gender and non-Asian ethnic minority status).

Manipulation Check

To check whether our manipulation successfully manipulated individuals' perception of the organization's implicit theories, participants were asked in how far the attributes "gifted" and "intelligent" ($\alpha = 0.71$) applied to a typical scholarship holder (1 = "does not apply at all," 7 = "fully applies").

Anticipated Belonging

To assess participants' anticipated belonging with the foundation, students were asked how much they agreed to the following two items modeled after existing scales (Walton and Cohen, 2007; Murphy and Zirkel, 2015): "I think I would feel like I belong at the Bahde Foundation" and "I think I am the kind of person the Bahde Foundation is looking for" (1 = "strongly disagree", 7 = "strongly agree"; $\alpha = 0.80$).

Prior Achievement

To control for individuals' prior achievement, we asked students to indicate the grades they received on their three last exams. These grades were than averaged to one prior-achievement score. In order to prevent the 22 students (3%) who did not complete this measure (possibly because they did not receive any grades yet) from being excluded, we imputed mean scores for these students. The mean GPA was $M = 1.93$ (corresponds to the letter B in the United States-American system).

TABLE 1 | Descriptive statistics of individuals' anticipated sense of belonging by condition and prototype match.

Condition	Prototype Match	*M*	*SD*	*N*
Fixed theory	No match	3.30	1.20	50
	Mixed match	3.34	1.33	216
	Match	3.78	1.23	73
Malleable theory	No match	4.04	1.45	49
	Mixed match	3.28	1.37	205
	Match	3.28	1.30	69

Prototype match = degree to which individuals' social identities (gender and ethnicity) match the gifted White/Asian male prototype (match = White/Asian males; no match = females from stereotyped ethnic minority groups; mixed match = White/Asian females and males from stereotyped ethnic minority groups).

RESULTS

Manipulation Check

We used an ANOVA to check, if our manipulation changed participants' perception of the organizations' implicit theories of excellence. Results revealed a significant condition effect, $F(1,661) = 20.47$, $p < 0.001$, $\eta^2 = 0.030$. Participants imagined a typical scholarship holder to be more gifted in the fixed condition ($M = 5.64$, $SD = 0.96$) than in the malleable condition ($M = 5.28$, $SD = 1.07$).

Anticipated Belonging

To check whether the effect of implicit theories would vary with individuals' degree of match with the prototype of the gifted White male student, we conducted several ANOVAs controlling for individuals' prior achievement. Means and standard deviations for participants' sense of belonging by prototype match and condition are reported in **Table 1**.

We first conducted a 2 (condition) × 3 (degree of prototype match) ANOVA. As expected, we found a prototype match × condition interaction on anticipated belonging, $F(2,655) = 6.10$, $p = 0.002$, $\eta^2 = 0.018$, suggesting that the effect of organizational implicit theories indeed varies with the extent to which individuals match the gifted prototype.

Post hoc ANOVAs testing the condition effect for the different subgroups further confirmed hypotheses, as illustrated in **Figure 1**: Individuals matching the gifted prototype – i.e., White/Asian males – anticipated higher belonging in the organization with a fixed view of excellence than in the organization with a malleable view, $F(1,139) = 4.64$, $p = 0.032$, $\eta^2 = 0.033$. Conversely, individuals whose personal group memberships did not match the gifted prototype – i.e., females from negatively stereotyped ethnic minority groups – anticipated higher belonging in the malleable organization than the fixed condition, $F(1,96) = 7.66$, $p = 0.007$, $\eta^2 = 0.074$. Groups of individuals with a mixed prototype match in group memberships – i.e., White/Asian females and males from stereotyped ethnic minority groups – showed no significant difference between fixed and malleable condition overall, $F(1,419) = 0.12$, $p = 0.732$, $\eta^2 < 0.001$ [$F(1,365) = 0.007$, $p = 0.934$, $\eta^2 < 0.001$ and $F(1,51) = 0.95$, $p = 0.334$, $\eta^2 = 0.018$, respectively].

Regarding main effects, we found a non-significant main effect of the experimental manipulation, $F(1,655) = 0.33$, $p = 0.57$, and a significant main effect of prototype match, $F(2,655) = 5.44$, $p = 0.005$, $\eta^2 = 0.016$. Exploratory *post hoc* analyses suggest that overall, individuals with a mixed prototype match exhibited lower levels of belonging than individuals with a full match, $p = 0.020$, and individuals with no match, $p = 0.005$. Individuals with a full and no match did not differ significantly, $p = 0.520$. While individuals with no

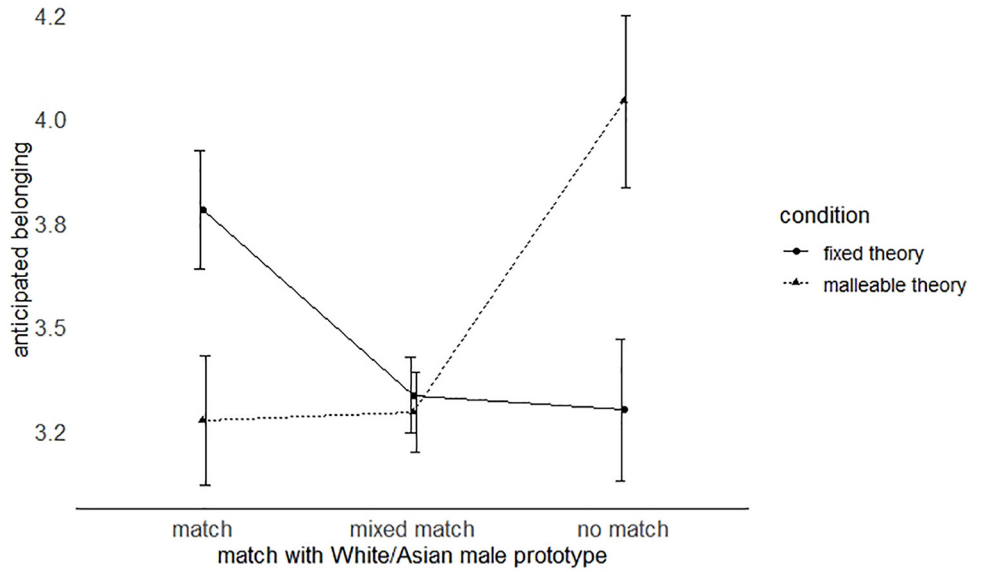

FIGURE 1 | Effects of fixed versus malleable theories of excellence on individuals' anticipated sense of belonging depending on the extent their social identities match the gifted prototype. Match = White or Asian males; no match = females from stereotyped ethnic minority groups; mixed match = White or Asian females and males from stereotyped ethnic minority groups. Error bars represent ±1 standard error.

match experienced an increase in belonging in the malleable condition, and individuals with a full match experienced an increase in belonging in the fixed condition, individuals with a mixed match showed similarly low levels of belonging in both conditions.

DISCUSSION

Selective academic organizations like the Ivy League or scholarship providers strive for individuals with excellent academic achievements – presumably independent of individuals' demographics. Yet, frequently used fixed messages of excellence, emphasizing innate giftedness as criterion for individuals' excelling in selective academic institutions may signal that only a certain group of people – specifically individuals who match the prototype of the gifted White/Asian male – can belong at the respective organization.

Previous research in this area has focused on either females or negatively stereotyped ethnic minorities, suggesting that fixed excellence messages may impair their belonging, while others (i.e., White/Asian students and males) may be unaffected. Investigating the combined effects of gender and ethnicity in a relatively large student sample, we expected the extent to which organizations' implicit theories of excellence make individuals feel they belong to depend on the degree to which individuals' gender and ethnicity match the gifted White/Asian male prototype. Consistent with our hypotheses we found that individuals who do not match that prototype – i.e., females from negatively stereotyped ethnic minority groups – showed a reduced sense of belonging in the organization conveying a fixed (vs. malleable) implicit theory of excellence. In contrast, White and Asian males, who fit the prototype of the gifted, benefited regarding their sense of belonging in the organization with a fixed view of excellence. Students with a mix of matching and non-matching group memberships (i.e., White or Asian females and males from stereotyped ethnic minorities) exhibited similar levels of belonging in both conditions in line with the idea that the opposing effects of the matching and mismatching identity may cancel each other out (Gonzales et al., 2002; Gresky et al., 2005; Rydell et al., 2009).

Contributions to Theory and Practice

This research makes important contributions to theory and practice. First, our results highlight how organizational fixed implicit theories may not always carry negative effects for all people, but may even serve certain groups in some specific contexts. Previous research has almost exclusively focused on the negative effects of fixed mindsets or implicit theories. Complementing two earlier studies about the advantageous effects of fixed intelligence *mindsets* on positively stereotyped individuals in stereotype lift paradigms (Mendoza-Denton et al., 2008; Froehlich et al., 2016), we show that fixed *organizational theories*, too, and can yield advantageous effects for individuals who match the gifted prototype. Overall, our results support the assumption that implicit theories can moderate effects of stereotypes, with fixed theories strengthening both negative effects of negative and positive effects of positive stereotypes. Importantly, this does not mean that fixed theories are always beneficial for positively stereotyped individuals. There is for example little reason to assume that the negative effects of fixed intelligence mindsets on individuals' response to failure (Dweck and Leggett, 1988; Smiley et al., 2016) would not also apply to positively stereotyped individuals. Only in specific

stereotype-relevant contexts, fixed theories may be beneficial to positively stereotyped individuals. We hope our results help develop a more nuanced understanding of the effects fixed and malleable theories may carry for diverse individuals and contexts.

Second, in examining the intersection of multiple social identities, our research highlights the usefulness of this approach when investigating organizational implicit theories. Many scholars in social psychology have called for research to study the interplay of different social identities (e.g., McCall, 2005; Purdie-Vaughns and Eibach, 2008; Cole, 2009), and emerging empirical results highlight the importance of such intersectional approaches, illustrating that the combined effects of two identities can play out in different ways which cannot be predicted from separate investigations into each identity – in some cases adding up, and in other cases showing interactive effects (Shih et al., 1999; Levin et al., 2006; Purdie-Vaughns and Eibach, 2008). Still, relatively little research has so far done so. With respect to organizational implicit theories, there is to our knowledge no research taking an intersectional approach. Compared to previous research on the effects of organizational excellence theories or similar constructs, which only investigated one social identity (gender or ethnicity) in isolation and has only found negative effects for negatively stereotyped individuals, the intersectional approach in the present research yielded a more nuanced picture of results for different subgroups depending on the degree to which their identities match the gifted prototype.

Third, our research highlights the practical importance of organizational implicit theories of excellence in shaping students' anticipated belonging to academic institutions. The present research used the original and a manipulated version of advertising material obtained from Germany's biggest and most selective scholarship organization and investigated a sample of relatively high performing students as a potential target group for the scholarship organization. In doing so, we highlight how currently used fixed excellence messages may impair the belonging of negatively stereotyped individuals in academic institutions and how conversely, the (tailored) use of a malleable view on excellence could help make underrepresented female ethnic minority students feel like they belong.

Questions for Future Research

Our research also raises exciting questions for future research to investigate. Firstly, future research should compare different operationalizations of malleable excellence theories as well as malleable intelligence theories. While our malleable excellence condition emphasized the importance of effort and hard work, other excellence theory research has previously used concepts more closely related to motivation and dedication in their malleability treatments (Bian et al., 2018). Emphasizing the importance of effort may imply that successful candidates have to be strongly motivated, too, but compared to a motivation focus it may go a step further in stressing that the implementation of motivation into goal-oriented behavior is also required. It is thus conceivable that the motivation-focus in malleable theories may be perceived as less demanding than the effort focus and thus elicit more positive responses. Similarly, malleable theories of *intelligence* conveying that every organization member can become smarter may signal a higher tolerance for mistakes (Smiley et al., 2016) and appear less demanding than malleable excellence theories stressing that a high degree of effort is required. This may explain why some studies have found positive effects of malleable excellence and intelligence theories on individuals' belonging more broadly, and not only for women from ethnic minority groups, as in our study (Emerson and Murphy, 2015; Bian et al., 2018).

Secondly, with regards to the mixed prototype match group (e.g., White males), future research should explore if the activation of individuals' positively versus negatively stereotyped identity moderates the effects of organizational excellence theories on their sense of belonging. In our study, we did not specifically activate any identity. With this approach, we did not find any condition effect for individuals with a mixed prototype match. Previous research on stereotype threat and stereotype lift effects suggests that a targeted activation of individuals' positive vs. negative identity can elicit positive stereotype lift vs. detrimental stereotype threat effects, respectively (Shih et al., 1999; Rydell et al., 2009). Accordingly, such a targeted identity activation (or even a chronic activation of a certain social identity which may be present in some populations) may also shape the effect of organizational implicit theories on belonging.

Thirdly, as a basis for deriving interventions to support organizations in developing a malleable culture of excellence, it would be interesting to explore how exactly implicit theories of excellence emerge. One possible explanation of how fixed theories arise would be that the people in power who create them are often White/Asian males, to whom the fixed messages may be more appealing than to other groups. Another possibility is that fixed messages may broadly, irrespective of individuals' gender or ethnicity, seem more exclusive and thus desirable for individuals who have already joined an organization. Being part of a group of naturally gifted individuals, born with innate talents, may seem to be more special and appealing than being part of a diligent, hardworking group. Understanding how implicit theories of excellence emerge in the first place may help develop targeted interventions that could optimize organization's implicit theories in the long run.

Furthermore, future research should explore consequences of organizational excellence theories on individuals beyond belonging. Previous research has associated individuals' sense of belonging in a given environment with diverse outcomes such as individuals' engagement, performance, and social integration (Walton and Cohen, 2007, 2011; Wilson et al., 2015; Yeager et al., 2016). Would fixed messages of excellence, in line with this research, undermine these outcomes for stereotyped individuals, leading them to, e.g., disengage in completing their application material, show worse performance in assessment center tests or being less sociable around members of the respective organization? Would adverse effects on negatively stereotyped individuals' belonging and related outcomes also show after individuals may have obtained a scholarship and thus impair their experience and engagement within the organization? And would the same effects show for White/Asian males receiving malleable messages of excellence or would their outcomes be buffered against such impairments by the previously reported heightened long-term stability in their sense of belonging (Walton and Cohen, 2007)?

Finally, it would be interesting to explore boundary conditions of our effects. Our findings emerged in cultures in which giftedness is strongly associated with White/Asian males rather than females or non-Asian ethnic minorities. While we are not aware of any (sub)cultures in which these associations are not common, it may be interesting to experimentally change individuals' associations between giftedness and different demographic groups and investigate, if a more inclusive sense of giftedness (i.e., giftedness being less strongly associated with White/Asian males) could reduce differential effects and make individuals feel they belong more equally irrespective of fixed vs malleable excellence messages.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in an online repository under the following link: https://osf.io/r359f/?view_only=c7d654c2f5bf4953ad17954d5aa72244.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethikkommission der Freien Universität Berlin. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

BH and CB designed and conducted the research and wrote the manuscript. CB conducted the analyses. Both authors contributed to the article and approved the submitted version.

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Implicit Theories of Intelligence and Achievement Goals: A Look at Students' Intrinsic Motivation and Achievement in Mathematics

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The present research seeks to utilize Implicit Theories of Intelligence (mindsets) and Achievement Goal Theory to understand students' intrinsic motivation and academic performance in mathematics in Singapore. 1,201 lower-progress stream students (596 males, 580 females, 25 missing data), ages ranged from 13 to 17 years (M = 14.68 years old, SD = 0.57), from 17 secondary schools in Singapore took part in the study. Using structural equation modeling, results confirmed hypotheses that incremental mindset predicted mastery-approach goals and, in turn, predicted intrinsic motivation and mathematics performance. Entity mindset predicted performance-approach and performance-avoidance goals. Performance-approach goal was positively linked to intrinsic motivation and mathematics performance; performance-avoidance goal, however, negatively predicted intrinsic motivation and mathematics performance. The model accounted for 35.9% of variance in intrinsic motivation and 13.8% in mathematics performance. These findings suggest that intrinsic motivation toward mathematics and achievement scores might be enhanced through interventions that focus on incremental mindset and mastery-approach goal. In addition, performance-approach goal may enhance intrinsic motivation and achievement as well, but to a lesser extent. Finally, the study adds to the literature done in the Asian context and lends support to the contention that culture may affect students' mindsets and adoption of achievement goals, and their associated impact on motivation and achievement outcomes.

Keywords: implicit theories, mindsets, achievement goals, interest, intrinsic motivation, mathematics achievement, Singapore, lower-progress students

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INTRODUCTION

Human behavior is complex, and no single psychological theory can explain all aspects of human motivation and achievement (Roberts, 1992). Nonetheless, several theories, for example, Implicit Theories of Intelligence (Dweck, 2000) and Achievement Goal Theory (Elliot, 1999), have revealed important determinants of motivation and achievement in education. The present study seeks to utilize these two theories to understand the learning engagement and academic performance in mathematics of lower-progress students in Singapore.

Singapore has an educational system where students are streamed nationally into different ability streams based on their academic performance in the Primary School Leaving Examination (PSLE) at the end of Year 6 (approximately 12 years old). The three streams are the Express stream, the Normal (Academic) stream, and the Normal (Technical) stream. The Express stream generally consists of students in the top 65% of the secondary school cohort, while the Normal (Academic) and Normal (Technical) streams consist of the remaining 35% who qualify for secondary school. As such, the Express stream is considered the higher-progress stream, while the Normal (Academic) and Normal (Technical) streams, collectively known as the Normal stream, are considered the lower-progress stream. By identifying the determinants of lower-progress students' motivation and achievement, this study hopes to offer suggestions for intervention that can help engage this group of students and promote learning engagement and academic performance in the classrooms.

Considering that socialization plays a role in shaping an individual's belief system, it is conceivable that students in Singapore and other Asian countries may view ability, learning, and achievement differently compared to their Western counterparts. There is evidence to suggest that more collectivist societies might encourage students to value the learning process over academic achievement and focus less on individual results (Costa and Faria, 2018). In contrast, a more academically competitive society in Europe might influence the students' perspectives of intelligence and lead them to prioritize individual outcomes and to value positive assessment over knowledge (Elliott and Dweck, 1988; Robins and Pals, 2002). With a lack of studies on mindsets and achievement goals in the Asian context, this study will also add to the literature and provide insights into Asian students' mindsets and adoption of achievement goals, and their associated impact on motivation and achievement outcomes.

Intrinsic Motivation

Intrinsic motivation is defined as activities done "for their own sake" or for their inherent interest and enjoyment (Deci and Ryan, 2000). It is deemed to be responsible for most of human learning across the life span, in contrast to externally mandated learning and instruction (Ryan and Deci, 2017). It is seen as an important consideration when examining participation in tasks that require perseverance and sustained levels of effort (e.g., Stanko-Kaczmarek, 2012). It has been found to play a significant role in student engagement (Froiland and Worrell, 2016) and school achievement (e.g., Taylor et al., 2014) and is frequently studied as an outcome of Achievement Goal Theory and Implicit theories (Cury et al., 2006). In Singapore, intrinsic motivation (or interest) is recognized as an important factor in enhancing lifelong learning in schools (Wang, 2017) and is included as a key outcome of the current study.

Implicit Theories of Intelligence

Implicit theories—or mindsets—about human abilities are important for academic learning. They form a belief system that triggers particular motivations, leads to different learning pathways, and shapes how individuals interpret and understand their learning experiences. Dweck and her colleagues (Dweck et al., 1995; Dweck, 2000) proposed the Implicit Theories of Intelligence to explain how individuals' implicit theories (mindsets) set up both a motivational and cognitive framework that colors the individuals' views of and responses to learning engagement and achievement.

According to Dweck and her colleagues (Dweck et al., 1995; Dweck, 2000), human mindsets can be categorized in two forms—incremental (growth) and entity (fixed) mindsets. Individuals with incremental mindsets—the incremental theorists—believe that intelligence is malleable and can be increased through effort. Incremental theorists are concerned with achieving mastery through learning. They tend to use performance outcomes as feedback to reflect on their task commitment and learning strategy. By contrast, individuals with entity mindsets—the entity theorists—believe that intelligence is fixed and cannot be changed. Entity theorists tend to judge their fixed level of intelligence based on performance feedback. They would conclude that they are smart if they perform well on academic tasks, and not smart if they perform poorly on these tasks. When entity theorists receive negative performance feedback, they tend to make sweeping generalizations about their lack of ability, give up prematurely, and show debilitation over time.

Research has provided evidence that mindsets predict achievement (e.g., Romero et al., 2014; Müllensiefen et al., 2015; Costa and Faria, 2018). Generally, research examining the different response patterns of students' mindsets had found that incremental mindsets, relative to entity mindsets, tended to be associated with better academic achievement (e.g., Blackwell et al., 2007; Burnette et al., 2013; Romero et al., 2014; Bostwick et al., 2017). Nonetheless, Costa and Faria (2018) found that culture was a moderator of the relationships. Using a meta-analytic approach, they established that incremental mindsets were associated with higher levels of students' achievement in Asia, Oceania (Australia), and at the limit of significance in North America but were not significant for Europe. In contrast, entity mindsets were not significantly associated with achievement in Asia but were negatively associated with student achievement in North America and positively associated with student achievement in Europe.

In addition, Dweck and her colleagues (Dweck and Leggett, 1988; Dweck, 2000) proposed that mindsets are the antecedents of achievement goals. This is because a mindset forms a belief system that triggers a particular achievement goal. In the next section, we will discuss the concept of achievement goals.

Achievement Goals

The achievement-goal approach has generated a huge amount of conceptual and empirical work over the last 40 years with different perspectives and positions on how to operationalize the construct (e.g., Korn and Elliot, 2016). Nevertheless, there is a general consensus that achievement goals are related to the reasons for behaviors in achievement situations (e.g., Dweck, 1989; Nicholls, 1989), and the standards of reference for evaluating one's competence and success (Elliot, 1997).

In the initial dichotomous model of achievement goals proposed in the 1980s, Nicholls (1984), among many others,

conceptualized achievement goals according to the *focus of competence*, and two ways of defining success—attainment of mastery (self-referenced success) and outperforming others (other-referenced success). Individuals who pursue the mastery goals are concerned with the development of ability. They are likely to seek achievement by developing competence and acquiring knowledge through effortful learning (Murphy and Alexander, 2000). These individuals define success in terms of the extent of mastery of the learning task (Pintrich, 2000). They are more likely to appreciate the intrinsic value of learning, see effort as the main factor defining their success, and evaluate their level of competence and learning based on self-established standards of achievement. In contrast, individuals who pursue performance goals seek "to gain favorable judgments and avoid negative judgments of one's competence, particularly if success is achieved through a minimum exertion of effort" (Murphy and Alexander, 2000, p. 28). These individuals define success in terms of their ability or performance relative to others (Pintrich, 2000). They judge their competence and sense of self-worth through whether they can outperform others or achieve their targets with less effort on norm-referenced standards set by external authorities. In general, mastery goals are associated with more adaptive outcomes, while performance goals are linked with less adaptive outcomes (see Elliot, 2005).

In the 1990s, achievement goal theorists began to include an additional component of competence, that is, the *valence of competence*, in their conceptual work (Elliot and Harackiewicz, 1996). This development kept mastery goals intact but divided performance-based goals into performance-approach and performance-avoidance, resulting in a three-goal trichotomy. A few years later, Elliot (1999) expanded the concept by proposing that both mastery and performance were fully crossed with approach and avoidance. In other words, individuals pursuing mastery goals may be motivated to approach mastery or to avoid lack of mastery. Likewise, individuals pursuing performance goals may be motivated to approach good performance or to avoid poor performance. This conceptualization yielded a 2 × 2 model featuring four types of achievement goals: mastery-approach, mastery-avoidance, performance-approach, and performance-avoidance goals (Elliot and McGregor, 2001). Subsequent research led to the differentiation of mastery goals into task-based and self-based standards (Elliot et al., 2011). With three different standards to evaluate competence, that is, task-based, self-based, and other-based, fully crossed with approach and avoidance, a 3 × 2 achievement goal model was obtained.

In this study, the 2 × 2 model featuring mastery-approach, mastery-avoidance, performance-approach, and performance-avoidance was adopted to draw comparisons to previous work exploring achievement goals of students in the Asian context. Using the 3 × 2 model will preclude any comparison to earlier studies.

Implicit Theories, Achievement Goals, Intrinsic Motivation, and Achievement

The four achievement goals of the 2 × 2 model are conceptually orthogonal and independent and are associated with different achievement and affective outcomes. Mastery-approach goals are largely linked to adaptive outcomes, such as intrinsic motivation and enjoyment (e.g., Fox et al., 1994; Biddle et al., 2003) and positive affect (e.g., Ntoumanis and Biddle, 1999). In comparison, the consequence of adopting performance-approach goals is more debatable (e.g., Midgley et al., 2001; Harackiewicz et al., 2002a). They are associated primarily with a positive but truncated set of positive outcomes (Elliot, 2005) and may be adaptive in the sense of promoting graded academic performance (e.g., Elliot and Church, 1997; Elliot and McGregor, 1999; Church et al., 2001; Harackiewicz et al., 2002b; Liu et al., 2009; Jang and Liu, 2012).

Although there was initial skepticism regarding mastery-avoidance goal, empirical evidence has supported the existence of this goal and suggested that mastery-avoidance goal is prevalent in achievement settings (e.g., Van Yperen, 2006; Liu et al., 2009; Jang and Liu, 2012). Specifically, mastery-avoidance and performance-avoidance goals are generally associated with less adaptive outcomes, such as low performance, low intrinsic motivation, disorganization, worry, and emotionality (e.g., Elliot and Church, 1997; Middleton and Midgley, 1997; Elliot and McGregor, 1999, 2001; Church et al., 2001; Wolters, 2004; Van Yperen et al., 2009).

In a meta-analysis of 98 papers with a sample size of 33,983 participants on achievement goals and achievements across work, sports, and education, Van Yperen et al. (2014) affirmed that both approach goals (mastery and performance) are related to positive performance attainment, whereas both avoidance goals (mastery and performance) are negatively associated with performance attainment. However, they found that nationality moderated the relationships between mastery-based goals and achievements. Most notably, mastery-approach goal seems to be more beneficial among Asian and "other" samples in comparison to US/Canadian and European samples, whereas mastery-avoidance goal seems to be more negatively related to achievement for Asian and US/Canadian samples in comparison to European and "other" samples. The finding underlined the importance of acknowledging the role of culture in motivational research (Pintrich, 2003). There are, nevertheless, limited studies that had interpreted their findings in light of the specific world region in which they had been derived (Bardach et al., 2019), and even fewer studies had been done in the Asian context or with Asian participants. For instance, Van Yperen and colleagues noted that the majority of the participants in the 98 studies were of US or Canadian nationality (59.0%), followed by European (23.0%), with only 10.8% Asian, and 7.2% other nationalities. Clearly, more research is needed in the Asian context to clarify or confirm the findings. It is too simplistic to assume that the findings for US/Canadian or European samples can be generalized to Asian participants.

In the Singapore context, using an intra-individual cluster-analytic approach to examine goal profiles, researchers established that students who were high in all four goals, that is, high in mastery-approach, mastery-avoidance, performance-approach, and performance-avoidance goals, and those who were only high in mastery-approach goals tended to be associated with positive psychological characteristics and outcomes (e.g., Liu and Wang, 2005; Wang et al., 2007; Liu et al., 2009). Additionally, Jang and Liu (2012) found that students who were high in all four goals had high mathematics performance but also

high anxiety and moderate boredom. In contrast, students who were only high in mastery-approach and low in mastery-avoidance profile reported high mathematics performance, high enjoyment, low anxiety, and low boredom. It is noteworthy that higher-progress students were overrepresented in the more adaptive clusters, whereas lower-progress students were overrepresented in the less adaptive clusters.

As mentioned earlier, the adoption of achievement goals may be related to the mindsets that individuals hold. Dweck and her colleagues (Dweck and Leggett, 1988; Dweck, 2000) proposed that mindsets form a belief system which may orient the individuals toward particular motivational goals which may in turn lead to different learning pathways. More specifically, mastery goal is associated with having an incremental view of intelligence, and performance goal is linked with an entity view of intelligence (Dweck and Leggett, 1988; Burnette et al., 2013). In addition to finding that incremental theorists have the tendency to adopt mastery goals and demonstrate mastery-oriented responses to academic setbacks, Dweck (2000) further found that for entity theorists with higher confidence in their intelligence, they were likely to adopt performance-approach goals, while those with lower confidence were likely to adopt performance-avoidance goals. Burnette et al. (2013) also revealed that the positive association between mindsets and mastery goals is stronger for mastery-approach goals than for mastery-avoidance goals. In comparison, the negative association between mindsets and performance goals is stronger for the performance-avoidance goal than for the performance-approach goal.

In the Singapore context, Liu and Wang (2005) found that students who were high in all four goals had a significantly higher entity mindset than students who were only high in mastery-approach goals, although both clusters tended to be associated with positive psychological characteristics and outcomes. In the domain of sports, studies (e.g., Wang and Biddle, 2001, 2007; Biddle et al., 2003) have shown that both the incremental mindset and mastery goals are linked to intrinsic motivation and adaptive motivational outcomes. In contrast, entity mindset and performance goals are associated with low intrinsic motivation, low perceived competence, and maladaptive learning outcomes. In line with Dweck's (2000) finding, Wang et al. (2009) established that perceived competence moderated the relationships between mindsets and avoidance goals in the domain of sports. Specifically, entity beliefs predicted performance-avoidance goals when perceived competence was moderately low but not when high. Likewise, incremental beliefs predicted mastery-avoidance goals when perceived competence was moderately low but not high.

Taken together, the findings from the abovementioned studies suggest that there is an association between mindsets and achievement goals. The two mindsets relate to the 2 × 2 achievement goals differently, and the two mindsets and the 2 × 2 achievement goals relate to learning outcomes differently, perhaps with different associations in different cultural contexts.

Rationale of Study and Hypotheses

The present study utilizes Implicit Theories of Intelligence (Dweck, 2000) and 2 × 2 Achievement Goal Theory (Elliot and McGregor, 2001) to understand the intrinsic motivation (interest) and academic performance (score) in mathematics of lower-progress students in Singapore.

This study focuses on lower-progress students because empirical studies have suggested that in general, lower-progress students relative to higher-progress have motivational related issues such as lower intrinsic motivation and self-determination (e.g., Chow and Yong, 2013; O'Shea et al., 2017), and lower self-esteem, more negative self-concepts, and poorer social adaptation (Safree et al., 2009). Studies in Singapore have indeed found that lower-progress students had significantly lower mathematics achievements and mathematics self-concept than higher-progress students (Liem et al., 2015). In addition, lower-progress students were overrepresented in more maladaptive clusters that had lower intrinsic motivation and mathematics performance and higher anxiety and boredom compared to higher-progress students (Jang and Liu, 2012).

It will be recalled that perceived competence can moderate the relationships between mindsets and goals (e.g., Dweck, 2000; Wang et al., 2009). Since stream membership is an explicit label of ability and a reflection of the students' academic competence, it is tenable that the relationships between mindsets, achievement goals, intrinsic motivation, and academic performance may not be the same for higher- and lower-progress students. As such, it is important that a theoretically driven research to examine lower-progress students' motivation be conducted to guide interventions.

Considering the scarcity of research in the Asian context as compared to research in the US, Canada, and Europe, this study will also be able to shed light on the relationships between the aforementioned constructs in a different cultural context and hence expand our knowledge base on the interaction between mindsets and achievement goals on learning outcomes.

Additionally, this study is premised on the learning of mathematics. This is because motivation is context-dependent. This means that individuals can have different types of mindsets and achievement goals depending on the contextual situation. For example, the same individual may have different mindsets and achievement goals in learning mathematics vs. participating in sports activities. Mathematics is chosen as the context in this study because there have been various reports on the motivational issues of lower-progress students in mathematics, a subject seen as cognitively demanding and anxiety-inducing for many students, in areas such as intrinsic motivation, mathematics value, mathematics enjoyment, and mathematics confidence (e.g., Herges et al., 2017; O'Shea et al., 2017). Research has highlighted that implicit theories of intelligence can have particular importance in challenging academic situations (Costa and Faria, 2018).

In summary, Implicit Theories of Intelligence (Dweck, 2000) and 2 × 2 Achievement Goal Theory (Elliot and McGregor, 2001) have provided insights into the nature and antecedents of motivation and achievement. Very few studies have examined the underlying mechanisms between mindsets, achievement goals, and outcomes. In the domain of sports, some researchers (Wang and Biddle, 2001, 2007; Biddle et al., 2003) have shown that incremental beliefs and mastery goals are linked to intrinsic motivation and adaptive motivational patterns. In contrast,

entity beliefs and performance goals are associated with low intrinsic motivation and maladaptive learning outcomes. Building on these findings, it was hypothesized that (H1) incremental beliefs would predict mastery-approach goals but not mastery-avoidance goals, (H2) entity beliefs would predict performance-approach goals but not performance-avoidance goals, (H3) mastery-approach and performance-approach goals would positively predict intrinsic interest and test scores, and (H4) mastery-avoidance and performance-avoidance goals would negatively predict intrinsic interest and test scores (see **Figure 1**).

Bearing in mind Van Yperen et al.'s (2014) finding on the moderation effect of nationality, we believe that in the current sample, mastery-approach goal would be a relatively strong positive predictor of performance (H3), while mastery-avoidance goal would be a relatively strong negative predictor of performance (H4). Considering that we are looking at lower-progress learners who may have low perceived competence, it is possible that incremental belief may predict mastery-avoidance goals (H1), while entity belief may predict performance-avoidance goals (H2).

MATERIALS AND METHODS

Participants and Procedure

In this study, a sample of 1,201 lower-progress students from 17 Singapore secondary schools responded to the survey. There were 596 males and 580 females, and 25 of them did not state their gender. The students' ages ranged from 13 to 17 years old (M = 14.68, SD = 0.57).

Prior to data collection, ethical approval was sought from the university's Institutional Review Board and permission to collect data from schools was obtained from the Ministry of Education (Singapore) and the respective school principals. The heads of mathematics department were then contacted to arrange a time slot for the administration of the questionnaire. Before responding to the questionnaire, students provided consent after having been informed of the nature of the research project, that participation in the study was voluntary, that they could withdraw at any time, and that their confidentiality would be maintained. The students took less than 15 min to complete the survey under classroom conditions.

Measures

Implicit Theories of Intelligence Scale

The six-item Implicit Theories of Intelligence Scale (Dweck, 2000) was used to assess students' mindsets. Three items each were used to measure entity mindset (e.g., "I have a certain amount of intelligence, and I really cannot do much to change it") and incremental mindset (e.g., "I can always greatly change how intelligent I am"). Responses were given on a 6-point Likert scale (1 = *Strongly agree*, 6 = *Strongly disagree*).

Achievement Goal Questionnaire

The Achievement Goal Questionnaire (Elliot and McGregor, 2001) was used to assess the four types of achievement goals with three items per subscale. In this study, the items were adapted

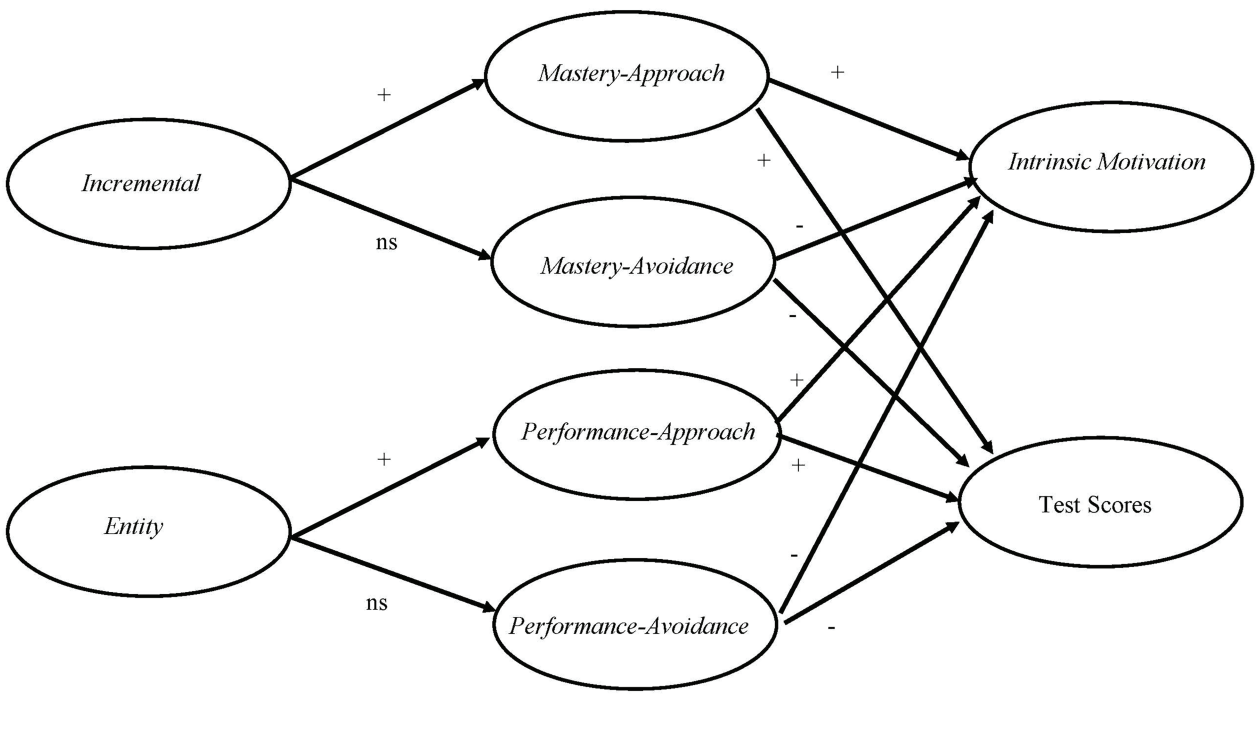

FIGURE 1 | Hypothesized model of the relationships between mindsets, achievement goals, intrinsic motivation, and test scores.

to reflect the context of mathematics learning. The four goals were mastery-approach (e.g., "I want to learn as much as possible from my mathematics class"), mastery-avoidance (e.g., "Sometimes I'm afraid that I may not understand the content of my mathematics class as thoroughly as I'd like"), performance-approach (e.g., "My goal in my mathematics class is to get a better grade than most students"), and performance-avoidance (e.g., "My goal in my mathematics class is to avoid performing poorly"). The items focused on the standard of competence per se, that is, task- and self-competence/incompetence for mastery-based goals and normative competence/incompetence for performance-based goals. Students indicated the extent to which they agreed that the statements were true in describing them on a 7-point Likert scale (1 = *Not true at all*, 7 = *Very true*).

Intrinsic Motivation Inventory

The interest subscale of the Intrinsic Motivation Inventory (IMI; McAuley et al., 1989) was adapted to assess students' interest in learning mathematics (three items; e.g., "I think mathematics is quite enjoyable"). It is considered the self-report measure of intrinsic motivation. The items were rated on a 7-point Likert scale (1 = *Not true at all*, 7 = *Very true*).

Mathematics Performance

The teachers provided the students' mathematics test scores as an outcome measure. The school-based tests were based on the national curriculum and were taken one to two months after completion of the survey. The possible test scores range from 0 to 100.

RESULTS

Confirmatory Factor Analysis (CFA)

CFA was conducted to examine the measurement model with all the constructs directly estimated based on their items. There were seven latent factors with its indicators, and the two beliefs, two mastery goals, and two performance goals were allowed to be correlated. EQS for Windows 6.3 (Bentler, 2006) was used as the analysis tool for CFA and SEM. Goodness-of-fits of the model were assessed with the robust χ^2 test statistics, the Bentler-Bonett normed fit index (NFI), the Bentler-Bonett non-normed fit index (NNFI), the comparative fit index (CFI), the mean square error of approximation (RMSEA), and its 90% confidence intervals. Typical cutoff scores taken to, respectively, indicate adequate and excellent fit to the data were used: (a) values greater than 0.90 and 0.95 for the NFI, NNFI, and CFI and (b) values smaller than 0.08 and 0.06 for the RMSEA (Hu and Bentler, 1999; Marsh et al., 2005). Results of the CFA showed an adequate fit for the measurement model (scaled χ^2 = 947.47, *df* = 178, NFI = 0.928, NNFI = 0.930, CFI = 0.941, RMSEA = 0.053, 90% CI of RMSEA = 0.049–0.056). This provided adequate factorial validity to the measurement model.

Descriptive Statistics

The means, standard deviations, internal reliabilities (rho; Fornell and Larcker, 1981), and latent correlations of the variables are presented in **Table 1**. The rho coefficients ranged from 0.73 to 0.92, indicating satisfactory internal reliabilities for all the subscales.

Essentially, the students had moderate incremental and entity beliefs (means = 3.67 and 3.61 respectively) (using means $\geq$ 4.5 on the seven-point scale as high, as suggested by Liu et al., 2009) and relatively high achievement goals (4.64 $\leq$ mean $\leq$ 5.33). They also reported moderate intrinsic motivation (interest) in mathematics (mean = 4.34). The mathematics test scores ranged from 3 to 97 marks with a mean of 52.21 and *SD* = 17.49 and were largely normally distributed (skewness = −0.18, *SE* = 0.07; kurtosis = − 0.43, *SE* = 0.14). The correlations among the measures indicate that all four achievement goals were positively associated (0.40 $\leq r \leq$ 0.59).

Structural Equation Modeling

Before conducting the SEM, the intraclass correlations (ICC) of the main variables with school as a grouping variable were computed. It was found that the mean ICC was 0.019, representing less than 2% of the variance which was attributed to the school membership; thus, multilevel analysis was not conducted. The results of the structural equation modeling with full latent model indicated a good fit of the model to the data (robust χ^2 = 1154.08, *df* = 196, NFI = 0.995, NNFI = 0.995, CFI = 0.996, and RMSEA = 0.066, 90% CI of RMSEA = 0.062, 0.070).

TABLE 1 | Means, standard deviations, and internal consistencies for all variables.

		Mean	SD	Range	Rho	1	2	3	4	5	6	7
1.	Incremental	3.67	1.14	1–6	0.84	1.00						
2.	Entity	3.61	1.13	1–6	0.84	−0.12**	1.00					
3.	Mastery-approach	5.31	1.25	1–7	0.84	0.18**	−0.01	1.00				
4.	Mastery-avoidance	5.08	1.22	1–7	0.75	0.06*	0.04	0.59**	1.00			
5.	Performance-approach	4.64	1.52	1–7	0.86	0.13**	0.09**	0.45**	0.40**	1.00		
6.	Performance-avoidance	5.33	1.33	1–7	0.73	0.04	0.08**	0.48**	0.59**	0.46**	1.00	
7.	Intrinsic motivation	4.34	1.57	1–7	0.92	0.19**	−0.04	0.55**	0.22**	0.31**	0.14**	1.00
8.	Test scores	52.21	17.49	3–97	---	0.11**	0.01	0.17**	−0.01	0.17**	−0.01	0.40**

*$p < 0.05$.
**$p < 0.01$.

Figure 2 shows the standardized solution of the hypothesized model. It can be seen that incremental mindset predicted mastery-approach goal and, in turn, predicted intrinsic motivation and mathematics test scores. Mastery-avoidance goal did not predict intrinsic motivation but was negatively associated with mathematics test scores. Entity mindset predicted performance-approach and performance-avoidance goals. Performance-approach goal was positively linked to intrinsic motivation and mathematics test scores; performance-avoidance goal, however, negatively predicted intrinsic motivation and mathematics test scores. The model accounted for 35.9% of variance in intrinsic motivation and 13.8% in mathematics test scores.

DISCUSSION

Motivation is every educator's business. It is of particular concern to educators of lower-progress students who often have to innovate on pedagogical practices and expend extra effort in engaging their students to learn. This study sought to identify the predictors of lower-progress students' intrinsic motivation (interest) and achievement in mathematics in Singapore. In doing so, this study hopes to offer suggestions for intervention that can promote learning engagement and academic performance in the classrooms of lower-progress students. More specifically, this study sought to examine the influence of mindsets (incremental and entity) and achievement goals (mastery-approach, mastery-avoidance, performance-approach, performance-avoidance) on lower-progress students' intrinsic motivation (interest) and academic performance (score).

The descriptive statistics showed that the scores for entity and incremental mindsets were moderate, that is, the students did not endorse any particular mindsets strongly, which is consistent with Burnette et al.'s (2013) observation. However, the two mindsets were barely correlated. This means that the two-belief system may lead to different processes.

Dweck and her colleagues (Dweck et al., 1995; Dweck, 2000) had postulated that mindsets play an important role in academic learning. Between the two mindsets—incremental vs. entity that individuals adopted—incremental mindset has been observed to be more adaptive. Relative to the entity mindset, the incremental mindset had consistently predicted higher interest (e.g., Dweck, 1986; Ng, 2018) and better academic achievement (e.g., Blackwell et al., 2007; Bostwick et al., 2017). Dweck and her colleagues (Dweck and Leggett, 1988; Dweck, 2000) also expounded that mindsets set up both a motivational and cognitive framework that affects individuals' beliefs in and responses to achievement situations. To this end, individuals with incremental mindset with its belief in the malleability of intelligence and the importance of effort and growth should facilitate the adoption of mastery goals. In contrast, individuals with entity mindset with its belief in a fixed level of intelligence and that it is innate talent and not effort that defines success should facilitate the adoption of performance goals. Insofar that mindsets (incremental and

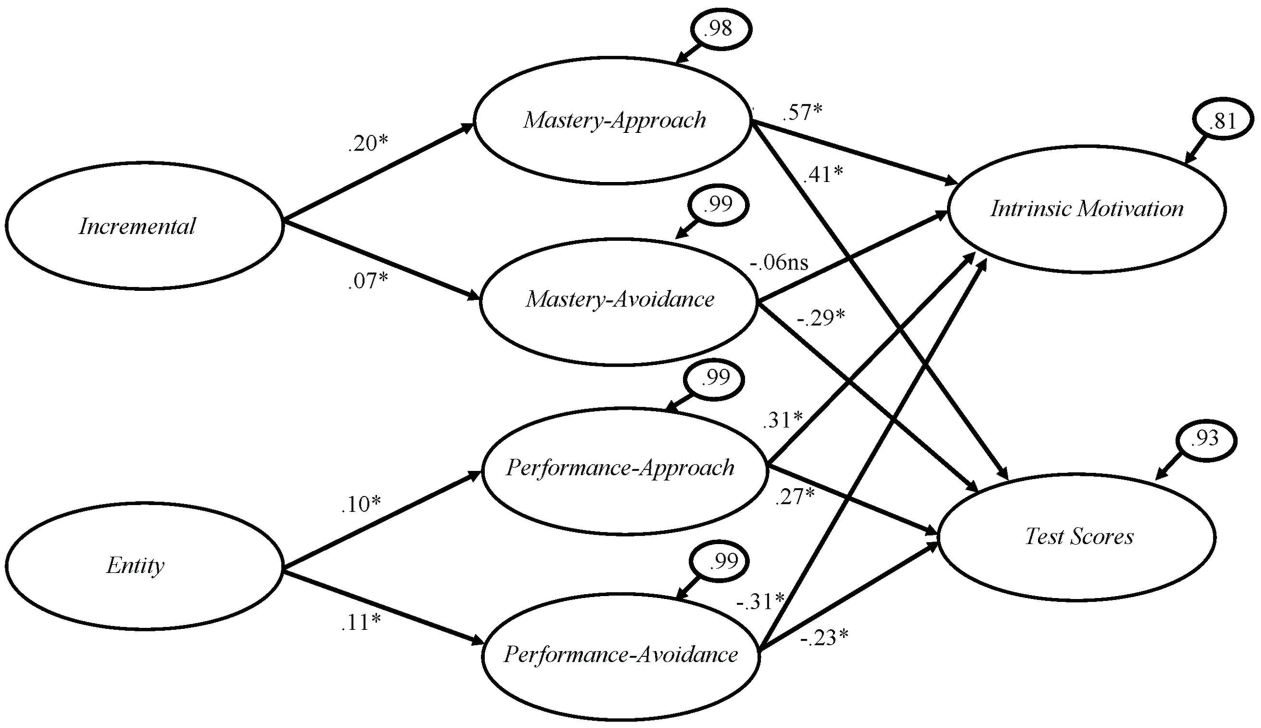

FIGURE 2 | Standardized solution of the hypothesized model. *$p < 0.05$.

entity) could trigger the adoption of different achievement goals (mastery-approach, mastery-avoidance, performance-approach, performance-avoidance), it would be reasonable to expect that the mindsets and achievement goals predict intrinsic motivation (interest) and academic performance (score) differently.

SEM was used to examine the relationships between mindsets, achievement goals, and outcomes in the current study. The results partially supported the first two hypotheses in that incremental mindset predicted mastery-approach goal and entity mindset predicted performance-approach goal. However, there were also significant positive relationships between incremental mindset and mastery-avoidance goal and between entity mindset and performance-avoidance goal. The findings could be due to the moderating effect of perceived competence suggested by Dweck (2000) and Wang et al. (2009). In essence, Wang et al. (2009) found that in the domain of sports, among students with high perceived competence, entity mindset did not lead to performance-avoidance goal, but when perceived competence was low, entity mindset positively predicted performance-avoidance goal. Similarly, when perceived competence was low, incremental mindset also predicted mastery-avoidance goal. Considering that the participants of the current study were lower-progress students who were likely to have low perceived competence, the rationalization seems logical. Nonetheless, there is a need for more empirical work with high-progress students as a comparison group to have a better understanding of the relationships between mindsets and achievement goals.

The results of the current study supported the third and fourth hypotheses in that mastery-approach and performance-approach goals positively predicted intrinsic motivation and test scores, while mastery-avoidance and performance-avoidance goals negatively predicted intrinsic motivation and test scores, albeit the path between mastery-avoidance and intrinsic motivation was not statistically significant. The findings are consistent with that of previous studies. For example, Biddle et al. (2003) reported that mastery-approach goals were positively related to enjoyment and intrinsic motivation, and Van Yperen et al.'s (2014) and Burnette et al.'s (2013) meta-analyses established that mastery-approach and performance-approach goals were related to positive performance attainment. Earlier research in the Singapore context found that students who were high in all four goals and those who were high only in mastery-approach goals tended to be associated with positive psychological characteristics and outcomes (e.g., Liu and Wang, 2005; Wang et al., 2007; Liu et al., 2009; Jang and Liu, 2012). In view of the current findings, it is tenable that although the students who were high in all four goals were already among the "top performers" in the earlier studies, their high avoidance goals could have held them back from achieving their potential. Researchers and educators in Singapore may want to work with their students who are high in all four goals and examine whether there is any merit in intervention to lower their avoidance goals.

Our results seem to be in line with Van Yperen et al.'s (2014) finding regarding the moderation effect of nationality. In essence, in the current sample, mastery-approach goal was indeed a relatively strong positive predictor of performance, while mastery-avoidance goal was a relatively strong negative predictor of performance.

The current study did not examine direct relationships between mindsets and learning outcomes. Nonetheless, the indirect relationships are consistent with studies that had reported that incremental mindset relative to entity mindset predicted higher interest (e.g., Dweck, 1986; Ng, 2018) and better academic achievement (e.g., Blackwell et al., 2007; Romero et al., 2014; Bostwick et al., 2017), and lend further support to Costa and Faria's (2018) meta-analysis finding that incremental mindsets are positively associated with students' achievement in Asia. Regarding entity mindsets, Costa and Faria's found that entity mindsets are not significantly associated with achievement in Asia, but we documented a small significant indirect relationship between entity mindset and achievement. Costa and Faria rationalized that the results obtained in Eastern continents might reflect cultural differences. They suggested that more collectivist societies might encourage students to value the learning process over academic achievement and focus less on individual results. In contrast, a "more academically and professionally competitive society in Europe" could influence the students' perspectives of intelligence and lead them to prioritize individual outcomes and to value positive assessment over knowledge (Elliott and Dweck, 1988; Robins and Pals, 2002). In the same vein, Kim and her colleagues noted that belief in incremental mindset is largely seen as a valued goal of child socialization in East Asian cultures (Kim et al., 2017) and is consistent with the teachings of many Asian cultures, e.g., Confucianism, that emphasize the responsibility of children to persevere and underscore the duty of parents to teach children the value of hard work (Kim and Wong, 2002; Park et al., 2014). There is also evidence to suggest that Asian American students more often attribute success and failure to effort compared to their European American counterparts (Mizokawa and Ryckman, 1990). Individuals of Asian descent are also more likely to have a self-improving orientation (i.e., focus on weaknesses to improve the self) rather than a self-enhancing orientation (i.e., focus on talents and successes) as compared to their European-American counterparts (Heine et al., 2001).

In the current study, the correlations among the four achievement goals indicate that they were moderately associated ($0.40 \leq r \leq 0.59$). Despite the inter-factor correlations, each goal had different associations with interest and mathematics scores, suggesting that all four goals were operative in the Singapore mathematics setting and were distinct. Our inter-factor correlations are comparable to those reported by Liu et al. (2009) with Singaporean youths in the academic setting. The finding is similar to Lau and Lee's (2008) observation that performance-approach and performance-avoidance goals are differentiable for their students in Hong Kong. However, Bong and colleagues (Bong, 2005; Bong et al., 2013) found that South Korean students were unable to reliably separate performance-approach and performance-avoidance goals. They rationalized that this might be due, in part, to the nature of South Korean schools, which strongly emphasize normative achievement and social comparison among students. They

posited that in such a learning context, the desire to do better than others might be indistinguishable from the desire not to perform worse than others (Bong et al., 2013). More extensive studies are needed to have a clearer understanding of students' ability to differentiate between different kinds of achievement goals in different cultural contexts and for lower- and higher-progress students.

The findings of this study have several implications and practical applications. Given that incremental mindset was a much stronger predictor of learning outcomes compared to entity mindset, pedagogical effort should focus on inculcating incremental mindset in our students. This means that educators should imbue in students the value that intelligence and abilities are malleable and can be developed through effort and hard work. By attributing intelligence and abilities to effort and hard work, educators are empowering the students and conveying a message of hope and potential for the low-progress students to succeed in tasks. This value should be instilled in the students at a tender age so that it can be integrated and internalized into the students' belief systems (Dweck, 2000).

For the older students, Dweck (2000) proposed the use of intervention to change mindset. In intervention, educators can explicitly teach students about incremental mindset, to attribute failure to a lack of effort rather than a lack of ability, to see failures as opportunities for self-reflection, self-improvement, and growth, and to embrace challenges. Educators can also provide more process praises (such as praises for effort or strategy) instead of praise for intelligence, give more encouragement and support (such as telling a student that he/she could improve with hard work), and suggest concrete strategies for improvement (such as telling a student that he/she needs to change his/her study strategies; Dweck, 2008). In addition, educators can share stories of mathematics greats as people who loved and devoted themselves to mathematics instead of being born geniuses (Good et al., 2007). In the same vein, educators can refrain from conveying the message of an entity mindset. This means to avoid telling students that talent alone leads to success, as doing so may discourage students from trying and may lead to learned helplessness and avoidance of challenges (Dweck, 2000). Empirically, studies have shown that such intervention studies are efficacious and that mindsets can be successfully primed to result in changes in the belief systems (e.g., Spray et al., 2006; Blackwell et al., 2007; Burnette and Finkel, 2012). Nonetheless, more empirical work needs to be done to understand the efficacy of such interventions, perhaps particularly in the Asian context.

From another perspective, educators may want to strive to increase students' perceived competence so that they are more likely to adopt approach goals, regardless of their mindsets and/or stream membership. Competence can be developed through the provision of support structure and success experience (Reeve, 2016). Educators can create opportunities for students to experience success through bite-size mathematics assessments which are manageable for the students.

Considering that mastery- and performance-approach goals significantly and positively predicted learning outcomes, pedagogical interventions can also target at developing approach goals. In nurturing mastery-approach goal, educators can encourage their students to work on mastering their knowledge and skills and to focus on learning and self-improvement (Elliot and McGregor, 2001). The TARGET framework originally proposed by Epstein (1988) and Ames (1992) is relevant in creating a mastery climate in the classroom. *TARGET* is the acronym for *T*ask, *A*uthority, *R*ecognition, *G*rouping, *E*valuation and *T*ime (see Deemer, 2004, for details). For example, to promote mastery-approach goals and develop competence, teachers should design mathematics tasks so that they are purposeful, challenging, and varied. They should respond to students' struggles with appropriate scaffolding and convey to them that learning requires effort and that mistakes are part of the experience. In addition, teachers can help students develop a sense of personal control and independence by giving them choices and involving them in decision-making when possible. When assessing and evaluating students' work, the emphasis should be self-referenced, rather than norm-referenced. It should focus on individual progress and improvement.

Interestingly, the sense of competition and a desire to do better than others, which is summarized as performance-approach goal (Elliot and McGregor, 2001), can also be a driving force to better learning outcomes. While the findings from this study suggest that performance-approach goal could be adaptive, it has to be noted that mastery-approach goal has stronger effects on learning outcomes in comparison with performance-approach goal. It is also important to be aware that performance-approach goal may trigger negative emotions such as anxiety, worry, and negative affect (e.g., Elliot and McGregor, 2001; Jang and Liu, 2012). Thus, while educators can consider instilling a sense of healthy competition among the students, they should also advise the students that outperforming others should not be the only emphasis when learning.

Lastly, in line with previous studies (e.g., Burnette et al., 2013; Van Yperen et al., 2014), mastery- and performance-avoidance goals significantly and negatively predicted learning outcomes. This means that the adoption of mastery-avoidance goal (which involves avoiding challenging tasks) and performance-avoidance goal (which involves avoiding failure in front of others) can be detrimental to intrinsic motivation and mathematics performance. Fortunately, avoidance goals can be changed or lessened. Research studies have suggested that avoidance goals can be significantly reduced *via* purposefully designed interventions (e.g., Schnelle et al., 2010; Wang et al., 2018). For example, Wang et al. (2018) reported that individuals' avoidance goals can be changed by directly targeting at participants' understanding of avoidance goals and their detrimental effects on learning outcomes, and the deliberate adoption of more adaptive goals and behaviors until they become second-nature. As another example, through experimental manipulations, Schnelle et al. (2010) showed that the availability of goal-relevant resources such as time for learning, family support, close friends, and self-confidence could lessen the adoption of avoidance goals and to promote the adoption of more approach goals. Of note, even the perception on the availability of resources could influence the students' goal adoption. Considering that some of the "top performers" in Singapore may be high in all four goals (e.g., Liu and Wang, 2005; Wang et al., 2007; Liu et al., 2009; Jang and Liu, 2012), which could be holding them back, more need

to be done to lower students' avoidance goals. Considering that students with low perceived competence have a higher tendency to adopt avoidance goals, such interventions may be more crucial for lower-progress learners as compared to their higher-progress counterparts.

In conclusion, using Implicit Theories of Intelligence (Dweck, 2000) and 2 × 2 Achievement Goal Theory (Elliot and McGregor, 2001), this study attempted to identity the predictors of intrinsic motivation (interest) and mathematics performance among a group of lower-progress students in Singapore. Findings from the present study suggest that the adoption of an incremental mindset and approach goals—mastery and performance—are beneficial for learning outcomes. For educators, a two-pronged approach—the nurturance of an incremental mindset and mastery- and performance-approach goals—would be useful for the promotion of intrinsic motivation and academic performance. Finally, the study adds to the literature done in the Asian context and lends support to the contention that culture may affect students' mindsets and adoption of achievement goals, and their associated impact on achievement outcomes.

LIMITATIONS OF STUDY

Despite the interesting findings, the present study has its limitations. First, the study is cross-sectional in design and thus causality cannot be inferred, unless a number of conditions are fulfilled (e.g., Pearl, 2009; Grosz et al., 2020, March 18). For instance, Grosz et al. (2020, March 18) mentioned the need to (i) articulate a clear causal question and state the precise definition of the causal effect of interest; (ii) think carefully about how other variables relate to the treatment variable and outcome variable to identify potential confounders, colliders, mediators, and instrumental variables; (iii) establish an identification strategy and estimate the causal effect; and (iv) test the identification strategy against violations of assumptions to see how much the effect estimate would change if certain assumptions were violated. Alternatively, an experimental study can be conducted to test the causal relationships. Taking inspiration from an experimental study conducted in the domain of sports, an experiment can be set up where students are randomly assigned to one of three groups: entity mindset manipulation, incremental mindset manipulation, or a control group with no mindset manipulation (Spray et al., 2006). By examining students' mindsets and achievement goals before and after the mindset manipulations, and their performance in a mathematics task, e.g., solving mathematics puzzles with increasing levels of difficulties, it will be possible to determine the causal relationships between mindsets, achievement goals, and performance.

Second, as with all self-report studies, the findings from this study might not be an accurate representation of the actual situations. Further studies using other research methodologies such as behavioral observations can be conducted to triangulate the findings. Third, this study was conducted with lower-progress stream students. Hence, the findings may not be generalized to students in the general population. It would be beneficial to replicate the study with students from different ability streams in Singapore or do a comparison study between higher- and lower-progress students to better understand the relationships between mindsets, achievement goals, and students' intrinsic motivation and achievement in mathematics.

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 human participants were reviewed and approved by Nanyang Technological University Institutional Review Board (NTU-IRB), Nanyang Technological University, Singapore (IRB-2013-01-009). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

WL carried out the research with the research team. She conceptualized and wrote the manuscript.

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Teachers' Implicit Theories of Professional Abilities in the Domain of School Improvement

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Numerous studies show positive effects of students' malleable implicit theories of their abilities on their self-regulated learning and learning achievements (Yeager and Dweck, 2012; Burnette et al., 2013), especially when domain-specific implicit theories are assessed (Costa and Faria, 2018). Thinking of school improvement as a collective learning process for the teaching staff, it is reasonable to assume that this relationship also exists on the teacher level. Hence, this study aims to provide answers to the following overarching question: What role do teachers' implicit theories of professional abilities play for school improvement? In a first step, a measurement instrument was developed to assess teachers' implicit theories of professional abilities in the domain of school improvement. In a second step, we explored the link between these implicit theories and collective teacher learning in the area of further developing the school's educational practices. In a sample of N = 1,483 Swiss primary school teachers at N = 59 schools, we analyzed how teachers' malleable (vs. fixed) implicit theories of professional abilities are related to collective metacognitive and emotional-motivational regulation activities and to the perception that the school is on the right track to improvement. Results show that teachers' implicit theories of professional abilities can be assessed reliably. Structural equation modeling analyses revealed that the more teachers view professional abilities as malleable and developable, the more positive their perceptions of the schools' improvement were. This relation was mediated by collective emotional-motivational regulation activities. However, no significant effect of a malleable implicit theory on collective metacognitive regulation was found. It can be concluded that teachers have varying beliefs about the malleability of teachers' professional abilities that are linked to their collective regulation. It therefore acknowledges the domain-specific effects of teachers' implicit theories in the area of school improvement.

Keywords: implicit theories of professional abilities, school improvement, teacher beliefs, self-regulated learning, motivation, metacognition, primary school

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INTRODUCTION

Whether people implicitly believe that their abilities are innate and unchangeable (fixed theory) or changeable through time and training (malleable theory) is related to various motivational and cognitive effects (Dweck, 2017). Numerous studies have found a correspondence between holding to a more malleable theory and better emotional, motivational, and metacognitive self-regulation (Dweck and Leggett, 1988; Hong et al., 1999; Molden and Dweck, 2006). Further, implicit theories

influence how people interpret and respond to challenges (Burnette et al., 2013) and thus play a central role in the adaptive management of challenges (Yeager and Dweck, 2012).

Challenges in further developing educational practice in schools can be seen as collective learning processes. Therefore, from a school improvement perspective, a teacher's implicit theory that 'being a good teacher' is something that can be changed and learned seems crucial for professional development and improvement of the school organization. This is especially true, as schools and their actors are faced with constantly changing requirements and must be able to react competently to various challenges (within and outside the classroom). To do so, professional abilities need to be acquired in teacher training programs and further developed in an ongoing learning process. In this study, a teacher's professional abilities are conceptualized broadly as a set of social and intellectual skills (e.g., different kinds of content and pedagogical knowledge or adaptive self-regulation strategies) that all have an impact on the teacher's competencies in teaching and working cooperatively with other staff members (Kunter et al., 2013).

Over the last decades, school improvement has shifted from a rather prescriptive (top-down) best practice approach to a professionalization approach (balancing bottom-up initiatives and top-down reforms), where teachers are required to develop professional abilities as well as organizational structures to improve their teaching practice and student learning (Emmerich and Maag Merki, 2014; Hopkins et al., 2014). Thus, teachers are more and more seen as crucial actors not only for their personal development but also for collective and organizational improvement. In the last 15 years, a fast-growing body of literature on distributed leadership (Spillane, 2005), middle leadership (Harris et al., 2019), and teacher leadership (Robinson et al., 2008) has reflected this shift toward a school improvement perspective, where not only policymakers and principals but also the teaching staff are seen as drivers of change. To understand different aspects of teachers as agents of change, teachers' professional capacity has been operationalized as a combination of abilities, beliefs, dispositions, and work arrangements (Bryk et al., 2010). Consequently, successful professional development activities should not be exclusively about improving teaching abilities or about changing organizational structures, such as work arrangements, but also need to consider teachers' underlying belief systems, including their implicit theories of teachers' professional abilities. The rationale behind this is that the normative belief system of individuals or groups guides their actions and discourse patterns in everyday educational practices—and changes in these practices as well (Mitchell and Sackney, 2011; Sherer and Spillane, 2011; Shirrell et al., 2019). Failed reforms, for instance, are often seen as a product of professional development activities that were too limited in scope (e.g., with a narrow focus on new instructional materials or settings) and did not address teachers' belief systems or underlying assumptions concerning a specific innovation or reform (Ladwig, 2010; Heitink et al., 2016; Weddle et al., 2019). Therefore, not only subject-related content and pedagogical knowledge but also teachers' professional beliefs play a crucial role when it comes to developing teachers' professional competencies (Calderhead, 1996; Kunter et al., 2013). To successfully improve educational practices through professional learning activities, the role of teachers' beliefs needs to be taken into consideration. Up to now, this has not been done in a differentiated manner.

The analyses of implicit theories of abilities as either fixed or malleable have proven their value in different educational contexts, especially in terms of student learning (for an overview see Dweck, 2017). There is a growing body of research emphasizing the more significant effects of mindsets assessed for specific domains (Costa and Faria, 2018). However, so far, research on teachers' implicit theories has focused on how teachers' beliefs about intelligence may foster a growth classroom mindset or influence students' motivation and mindset (Leroy et al., 2007; Rattan et al., 2012; Dickhäuser et al., 2017) and has neglected perspectives on teachers as members of a professional learning community (Louis et al., 1996; Mitchell and Sackney, 2011). As a consequence, there is no measurement instrument available to analyze teachers' implicit theory of professional abilities. Further, questions arise as to whether findings from research on implicit theories in the educational context of student learning can be transferred to the context of teachers' professional development in the domain of school improvement.

In this study, we focus on possible associations between teachers' malleable theory of professional abilities and their perceptions of school improvement. Further, as literature about student learning has shown, the mediating role of regulation activities will be analyzed. Implicit theories of teachers' professional abilities will therefore be considered from two perspectives: first, from existing theoretical and empirical frameworks on implicit theories and teachers' beliefs in general, and second from a school improvement perspective. Both perspectives are combined with a theoretical framework on self-regulated learning to better understand processes and dynamics of teachers' implicit theories and their role in the domain of school improvement.

Teachers' Implicit Theory of Professional Abilities as Part of Teachers' Beliefs

Beliefs are domain-specific psychological understandings, premises, or propositions that are felt to be true (Braten, 2010; Valcke et al., 2010). They function as personal guides for individuals to define and understand the world and themselves (Pajares, 1992) and function as a filter through which new knowledge and experiences are screened for meaning (Kagan and Tippins, 1991). Teachers' beliefs have been defined as beliefs "about processes, variables, and actors that are central to learning and instruction settings, such as educational beliefs, epistemological beliefs, beliefs about inclusive education, etc." (Valcke et al., 2010). In terms of school improvement, some researchers argue that teachers should have a socio-constructivist view of learning when it comes to the implementation of educational reforms (Birenbaum et al., 2011; Sach, 2015; Heitink et al., 2016). From a socio-constructivist standpoint,

learning is understood as an interactive and intersubjective process, where individuals actively and collectively construct, deconstruct, and reconstruct their knowledge (Vygotsky, 1978; Mitchell and Sackney, 2011). Following this argumentation, beliefs can be seen as a product and predictor of cognitive processes, such as perceptions of the social context and how other people think and behave within this context (Valcke et al., 2010).

Implicit theory of the nature of abilities is a particular set of beliefs held by the individual (Dweck, 1999). Without necessarily being aware (therefore, *implicit*), people differ in how they think personal abilities can be changed through time and training. As a consequence, they turn to different approaches when confronted with a challenge (for instance, in the process of learning): Whereas some people enjoy trying new strategies and change routines quite flexibly, others stick to a set of routines with which they are already familiar (Dweck and Leggett, 1988). Research on implicit theories aims to solve the puzzle of why people follow different patterns in the regulation processes when facing new challenges, and whether one or the other way is more beneficial for learning (Burnette et al., 2013). Therefore, the concept of implicit theory is highly related to and centrally important in the discourse on self-regulated learning.

Self-regulated learning is best defined as individuals taking consciously control over their learning by setting goals, making choices on how to reach these goals, and if necessary adjusting motivational states, cognition, or metacognition in the process of learning (Winne and Hadwin, 2008). In the context of self-regulated learning, two motivational belief systems have been highlighted: a malleable and a fixed implicit theory of personal abilities (Dweck and Leggett, 1988). These implicit theories of personal abilities can be seen as a particular set of beliefs that influence how challenges are interpreted and that set different motivational patterns in motion (Yeager and Dweck, 2012). A fixed implicit theory (also termed entity theory or fixed mindset) entails the belief that abilities are something more innate and unchangeable (Dweck and Leggett, 1988). In contrast, people with a malleable implicit theory (also termed incremental theory or growth mindset) believe that their abilities are changeable through time and training. A malleable implicit theory can be associated with the concept of brain plasticity (Yeager and Dweck, 2012), where the brain is described as similar to other muscles, capable of growing when given repeated practice in the face of challenges. Dweck and colleagues focused mainly on implicit theories of intelligence, as implicit views on the nature of intelligence are the root of motivational patterns such as goal setting, goal operating, and goal monitoring (Burnette et al., 2013). There is ample empirical evidence that supports the impact of implicit theory on different aspects of self-regulated learning (Dweck, 2017). A malleable implicit theory (vs. a fixed implicit theory) is associated with better resilience and learning (Yeager and Dweck, 2012), a mastery orientation (Dweck and Leggett, 1988; Burnette et al., 2013; Compagnoni et al., 2019), better metacognition (Burnette et al., 2013; Karlen and Compagnoni, 2016), better emotional-motivational regulation strategies (Nussbaum and Dweck, 2008), and higher achievement during transitions (Blackwell et al., 2007).

But although implicit theories have been assessed mostly in a domain-general way for attributes, such as intelligence (Spinath, 1998; Hong et al., 1999) or willpower (Job et al., 2015), individuals can hold differing implicit theories for specific domains such as health (Schroder et al., 2016), writing (Karlen and Compagnoni, 2016), romantic relations (Knee, 1998), or programming aptitude (Scott and Ghinea, 2014). It is assumed that domain-specific implicit theories set up a frame of reference for evaluating performance, abilities, and traits in a specific domain (Costa and Faria, 2018). It therefore seems reasonable to argue that teachers may also hold implicit theories of the malleability of teachers' professional abilities that influence their self-regulation but also their evaluation of performance, abilities, and traits as teachers. Further, studies have shown that implicit theories not only influence individual self-regulation but also self-regulation on an interpersonal level (Knee and Canevello, 2006). Knee and colleagues have found that a malleable view of relationships is associated with better coping strategies, an optimistic evaluation of a relationship's potential, and a general intention to work on relationships (Knee, 1998; Knee et al., 2003; Knee and Canevello, 2006). A belief in the malleability view of relationships was generally associated with relationship-maintenance strategies, an emphasis on relationship development, and "the belief that relationships grow not despite obstacles but in part because of them" (Knee and Canevello, 2006). Although Knee and colleagues focused on romantic relations, they are among the few researchers that have conducted research in the interpersonal domain and found that implicit theories on the individual level influence self-regulation on the interpersonal level.

Based on Dweck's, and Costa and Faria's work we therefore assume that a domain-specific implicit theory of professional abilities sets up a frame of reference for evaluating not only an individual teacher's traits and abilities but also the traits and abilities of other teachers at a school. Additionally, based on Knee's work, we assume that a malleable implicit theory of teachers' professional abilities is associated with an optimistic evaluation of the collective professional potential, development, and general intention to work toward improvement. The concept of implicit theories of professional abilities might therefore not only explain differences in the personal self-regulation of a teacher but also influence the collective regulation of teachers as part of school communities. To this end, in this study we explore whether the concept of implicit theories can be transferred to research on collective professional development, such as school improvement.

School Improvement and a Teacher's Implicit Theory of Professional Abilities

School improvement can be pictured as a school's journey (Jackson, 2000; Hallinger and Heck, 2011), where different actors get on and off the means of transport at different stages, equipped with various sets of skills, dispositions, experiences, expectations, and beliefs. In this picture, the teaching staff is a traveling group where the destination, itinerary, and means of transport are constantly objects of negotiation–without the group members necessarily coming to

an agreement or joint solution. As a result of this, different patterns of school-level growth in student learning and in the professionalization of the school staff, as the two main goals of school improvement (Emmerich and Maag Merki, 2014), can be seen (Hallinger and Heck, 2011). To better understand these micro-political negotiations on means and ends of school improvement (Altrichter and Moosbrugger, 2015) and the different patterns of organizational growth (Hallinger and Heck, 2011), we base our argumentation on the theoretical framework of a school improvement capacity (Mitchell and Sackney, 2011; Maag Merki, 2017), where the complex interplay of individual and collective capacities to change educational practices is heuristically elaborated.

Since schools are complex conflict systems with different actors pursuing ambiguous goals with unclear technology on how to reach these goals (Cohen et al., 2012), it is neither a single factor nor the sum of various factors but rather a complex interplay of multiple features that explains success or failure when improving schools (Bryk et al., 2010; Emmerich and Maag Merki, 2014). The concept of a school improvement capacity gives expression to these complex nested structures in terms of three interrelated capacity dimensions: From a socio-constructivist point of view, Mitchell and Sackney argue that improving educational practices in a school is about: (1) (de-/re-) constructing personal knowledge and beliefs (personal capacity), (2) creating collective meaning and ideas that pass not only an individual's test but also a social test (interpersonal capacity), and (3) building lasting organizational structures in the form of discourse patterns that foster school improvement (organizational capacity) (Mitchell and Sackney, 2011).

Several researchers argue that to develop a school's capacity to change there is a need to focus on how individual beliefs and collective sense-making processes are intertwined (Coburn, 2001; Sleegers et al., 2014). White's (1988) model of contextual rationality describes the organization as an important environment where meaning and order can be provided even when tasks and aims are ill-defined and sometimes contradicting—which is often the case in educational institutions (Cohen et al., 2012; Emmerich and Maag Merki, 2014). Therefore, in a process of collective sense-making, common ground is created within a specific context where questions and their answers are often vague and always a product of negotiation (Weick, 1995).

Following this argumentation, a teacher's implicit theory of professional abilities can be seen as an integral part of a teacher's personal capacity to change. Further, we assume that implicit theories of professional abilities influence how collaborative activities are performed and evaluated. However, the theoretical concept of school improvement capacity has been criticized as being still too vague to explain processes and dynamics between individuals' orientations and beliefs and their behavior as individuals or in a group (Maag Merki, 2017). Therefore, to better understand how individual beliefs and collective sense-making processes are actually intertwined, we argue that theoretical assumptions about self-regulated learning are helpful. To this end, the next section highlights collaborative regulation activities for further developing educational practices.

Collective Metacognitive and Emotional-Motivational Regulation in School Improvement

With the concept of self-regulated learning a second theoretical layer has been added to conceptualize the dynamics of individual and collaborative activities aiming to further develop educational practices. The literature on self-regulated learning focuses mostly on student learning and has neglected teachers, who can be seen as active and lifelong learners–in particular when it comes to professional development and school improvement. By framing teachers as learners aiming to further develop educational practices individually and collectively, it becomes possible to transfer theoretical and empirical assumptions in the field of self-regulated learning to the domain of school improvement.

Implicit theories of abilities are related to various aspects of self-regulated learning, especially the regulation of motivation and metacognition through goal setting and monitoring (Nussbaum and Dweck, 2008; Burnette et al., 2013). Thus, expert learners should display a more powerful repertoire of self-regulated learning strategies when facing challenges in further developing educational practices (Zimmerman, 2015; Panadero, 2017). Two sets of regulation strategies have been shown to be important in the context of learning: activities to regulate emotional and motivational states, and metacognitive strategies. Whereas emotional-motivational regulation activities aim to solve motivational and emotional problems by enhancing perseverance and self-reinforcement (Zimmerman, 2015), metacognitive regulation activities are defined as strategies for monitoring, analyzing, and adjusting the learning process (Winne and Hadwin, 2008).

Winne and Hadwin's recursive model of self-regulated learning (Winne and Hadwin, 2008; Panadero, 2017) illustrates a bridge between personal beliefs and self-regulation processes. According to the recursive model, a learner COPES with a task by relying on task and cognitive *conditions*, *operating* with different (more or less suitable) strategies at hand, which in turns ends up in a *product* (result) more or less satisfactory depending on the *evaluation* according to personal *standards* (Winne and Hadwin, 2008). Whenever the learner has to stop their routine and adjust certain aspects of the learning process, self-regulated learning is at work. These adjustments can be made either by changing conditions (task or cognitive), starting new operations, or by lowering or raising standards (Winne and Hadwin, 2008). According to this theoretical framework, emotional-motivational and metacognitive regulation activities are the means to successfully change conditions, operations, or standards.

Theories of self-regulated learning have been criticized as focusing too strongly on individual learning processes and consequently neglecting social aspects of learning (Hadwin et al., 2011). To expand Winne and Hadwin's theoretical framework from an exclusively individual perspective to collective regulation processes, the concept of socially shared

regulation of learning was introduced (Hadwin et al., 2011; Panadero and Järvelä, 2015). Socially shared regulation of learning is defined as "the interdependent or collectively shared regulatory processes, beliefs, and knowledge orchestrated in the service of a co-constructed or shared outcome" (Hadwin et al., 2011). According to that, successful collaboration in groups, which is conceptualized as a sense of higher self-efficacy for group work, emerges when individuals share the regulation of learning (Hadwin et al., 2011). This is done by co-constructing shared tasks representations, articulating shared goals, and through shared metacognitive monitoring and control of motivation. Several researchers have found evidence of shared regulation of emotions, motivations, and metacognition on a student level (i.e., Järvenoja and Järvelä, 2009).

When migrating these conceptual ideas to the research on school improvement, regulation activities in schools can be conceptualized as individual and collective processes of identification, analysis, and adaptation of conditions, operations, and standards by applying cognitive, metacognitive, and motivational and emotional strategies (Maag Merki et al., in press).

Following the argumentation of the recursive model of self-regulated learning (Winne and Hadwin, 2008), a teacher's implicit theory of professional abilities can therefore be understood as an integral part of the cognitive conditions. Hence, teachers' beliefs have an impact on operations such as emotional-motivational and metacognitive regulation strategies and therefore indirectly also on the product of these operations (e.g., perceiving the school's improvement) (Muis, 2007). This is in line with the argumentation in Weddle et al. (2019) study on teacher cooperation. Weddle et al. pointed out a need to further examine emotional and motivational aspects of how teachers perceive collaboration as a possible key to better understanding how capacity-building efforts work and how effective strategies can be fostered.

To sum up, we base our argumentation on three different theoretical anchors: first, the socio-cognitive framework by Dweck and Leggett (1988) to analyze the influence of self-theories (such as implicit theories about professional abilities) on regulation processes; second, the recursive model of self-regulated learning by Winne and Hadwin (2008) to obtain a more in-depth picture of these regulation processes (in this case emotional-motivational and metacognitive regulation activities involved in further developing educational practice); third, the socio-constructivist approach of Mitchell and Sackney (2011) to conceptualize the intertwined dimensions of individual and collective regulation activities to further develop educational practice.

Research Questions and Hypotheses

This study aims to provide answers to the following overarching question: What role do teachers' implicit theories of professional abilities play for school improvement? The following research questions are central for this article:

1. Do teachers have varying implicit theories of professional abilities, and can these theories be measured reliably?
2. What role do the implicit theories of professional abilities play for teachers' collective metacognitive and emotional-motivational regulation activities at their school?
3. How are implicit theories of professional abilities related to teachers' perceptions of their school's improvement?

First, we hypothesize that teachers have varying implicit theories of teachers' professional abilities, which can be measured reliably (H1) (Dweck, 1999). Second, since individual beliefs have been shown to affect not only perceptions of personal but also interpersonal strategies (Knee and Canevello, 2006), we hypothesize that a more malleable implicit theory of professional abilities is positively related to teachers' perception of collective regulation activities (metacognitive [H2a] and emotional-motivational regulation activities [H2b]) (Nussbaum and Dweck, 2008; Burnette et al., 2013). Although in reality a change in ability can be in a positive or negative direction, several researchers have indicated that the concept of a malleable implicit theory focuses on the phenomena of increasing abilities (Dweck, 1999; Dresel and Schloz, 2011). Therefore, third, we assume that a malleable implicit theory of teachers' professional abilities is associated with an optimistic evaluation of a general intention to work toward improvement (H3) (Knee and Canevello, 2006). Finally, we assume that this effect is mediated through collective emotional-motivational and metacognitive regulation activities (H4; Muis, 2007; Dweck, 2017).

MATERIALS AND METHODS

Study Design and Sample

To answer these research questions, we collected data from 1,625 teachers and principals at 59 primary schools in the German-speaking part of Switzerland. All of the participants took part in the study on a voluntary basis and actively gave informed consent to participate by completing an online questionnaire. Although the sample was not obtained through random sampling, it can be considered representative both on a school and teacher level for all primary schools in the German-speaking part of Switzerland, as outlined below.

First, a short overview of the primary schools in the German-speaking part of Switzerland: Almost 95% of Swiss pupils attend eight years of primary level schooling from pre-school to Grade 6 at a public school (FSO, 2019). There is no national curriculum, and traditionally, the primary responsibility for regulation and enforcement in these schools lies with the cantons and communes (Eurydice, 2020a). However, in 2006 the Federal Constitution and the Intercantonal Agreement on Harmonization of Compulsory Education (HarmoS Agreement) (EDK, 2011) obliged the cantons to coordinate and harmonize their educational systems with regard to structure and objectives (Eurydice, 2020b). This led to profound changes not only for the cantons and communes but also their schools. For instance, all schools had to undergo large-scale curriculum reform in the subsequent

TABLE 1 | Descriptive statistics of the sampled primary schools (N = 59).

	Mean (SD)	Median	Min	Max
Response rate (in %)	83.8 (10.7)	85.7	46.9	100
Size				
N_{staff}	28.9 (17.7)	23	6	74
$N_{student}$	226.7 (143.7)	184	34	593
SES[a]				
Taxable income	33,489 (10,390)	31,030	16,183	64,735
Social welfare	2.36 (1.66)	1.65	0.5	6.3
Regional context[b]	–	4	1	9

[a]*Socioeconomic background of the school's community (SES) was measured in terms of average taxable income (in Swiss francs, CHF) and social welfare ratio (in %)*
[b]*Regional context of a school is rated on an ordinal scale from 1 (rural) to 9 (urban).*

10 years (D-EDK, 2016). Further, through increased autonomy for every school, low-stake accountability structures in the form of school inspections were introduced to monitor and assess the quality of primary schools (Eurydice, 2020c). In addition, schools in the German-speaking part of Switzerland all face similar organizational challenges, at least to a certain degree, in terms of high turnover in teaching staff (Denzler, 2010; Sandmeier et al., 2018) and an increase in the heterogeneity of the students (FSO, 2018). Therefore, we assumed that these schools and their staff were most likely to have experienced similar school improvement issues, such as changing educational structures, articulating shared development goals for the school organization, experimenting with new teaching techniques, or developing enhanced collaborative work in teams.

Second, despite these similarities, we acknowledge that primary schools face different challenges depending on their context and organizational structures, such as the size of the primary schools, the regional context (e.g., urbanization), and the socioeconomic background of the community (Muijs et al., 2004; Bryk et al., 2010). Thus, the sampled schools, as well as all primary schools in the German-speaking part of Switzerland, varied greatly in size: Whereas some smalls schools had fewer than 10 teaching staff and only a few more than 30 students, other schools could be considered as large schools, with more than 70 teaching staff and almost 600 students. Further, the 59 schools in our sample were located in different regional contexts. The regional context was measured on a scale from 1 (*rural*) to 9 (*urban*). Most schools in German-speaking Switzerland and in our sample are located in small- to medium-sized agglomerations (from 3 to 6 on the scale). In terms of the social context, the schools' local communities differed not only in their social welfare ratio (from very low 0.5% to relatively high 6.3% of the population) but also in the average taxable income. In the sample there were richer and poorer communities, where a rich community had an average income about four times the average income of a poor community. In sum, the schools in our sample were confronted with very different situations and challenges in terms of context and organizational structures (see **Table 1**).

Third, as the school sample was quite heterogeneous in terms of context and organizational structures, the effects of teachers' implicit theories of professional development on collaborative activities and the school's improvement might be influenced by these differences on a school level. To take this into account, in the analyses described below we controlled for the nested structure in our data.

Fourth, all teachers and principals in the study filled out an online questionnaire at the beginning of the school year 2019/20. To investigate teachers' implicit theories of professional abilities, we relied on a subsample of teachers (N = 1,483; 88% women; aged 21–67 years [M = 43.31, SD = 11.37]), who had at least 1 year of experience teaching at their school. We therefore excluded all principals having no teaching duties (N = 40) and teachers with less than a year of work experience at their school (N = 105) from the sample. The survey response rate on an individual level was 83.1% (N = 1,232). On a school-level the response rate was slightly higher (N = 59; M = 83.8, SD = 10.7; Min = 46.9, Max = 100). The average years of total teaching experience was close to 18 (M = 17.64, SD = 10.92), and the average years of teaching experience at the current school was around 10 (M = 10.39, SD = 8.83). More than half of the teachers reported working part-time, with a worktime <75%.

Last, our data was diverse not only in terms of school characteristics but also in terms of teacher demographics. A possible sampling bias was analyzed by comparing teacher demographics (gender, age, seniority) and school characteristics (size, regional context, and socioeconomic background) with data on all Swiss primary schools provided by the Swiss Federal Statistical Office (FSO, 2020). Since no significant differences were found, a sampling bias could be excluded. Therefore, the database of the SIC study was a solid basis for examining our research questions.

Measures

Implicit Theories of Professional Abilities

Whether teachers believe that the ability to be a good teacher is predominantly given or something that can be cultivated was assessed by adapting an instrument that was developed to assess students' self-theories (Schöne et al., 2003). In a pilot study with 90 secondary school teachers, we adapted the original scale items to fit the context of staff members at schools in order to capture teachers' self-theories of the malleability of professional abilities. This resulted in a reliable measurement instrument based on 4 items (N = 90; M = 4.26, SD = 0.96; Cronbach's α = 0.81). The items covered different facets of teachers' implicit theories of professional abilities (see **Table 2**). For example, teachers were asked whether they thought that the ability to be a good teacher is predominantly given (= 1) or is something that can be changed (= 6) and whether teacher training programs or professional development activities cannot (= 1) or can improve (= 6) teaching abilities. With our main data from more than 1,000 primary teachers, the instrument to measure teachers' implicit theories of professional abilities showed an acceptable Cronbach's alpha value close to 0.70 (DeVellis, 2012) (N = 1,175; M = 4.45, SD = 0.81; Cronbach's α = 0.69). Factor structure and validity of the instrument are discussed in detail in the sections below.

Collective Regulation Activities

Two subscales were used to examine collective regulation activities (see **Table 3**). A first subscale to assess emotional and motivational regulation activities on a collective level was

TABLE 2 | Measurement instrument to assess teachers' implicit theories of professional abilities.

Item		*N*	*M*	SD	r^{it}	α-drop	*α*
1	The ability to be a good teacher is predominantly given (= 1) or is something that can be changed (= 6)	1,177	3.50	1.25	0.46	0.64	–
2	Through training, classroom teaching and teaching related skills cannot (= 1) or can be improved (= 6)	1,177	5.10	0.98	0.46	0.62	-
3	Teachers vary in their repertoire for facing challenges in classroom teaching and teaching related tasks. This repertoire cannot (= 1) or can be changed (= 6)	1,175	4.90	0.95	0.46	0.63	-
4	Teacher training programs or professional development activities cannot (= 1) or can improve (= 6) teaching abilities	1,177	4.40	1.31	0.51	0.59	–
Latent construct	Teachers' implicit theory of professional abilities (fixed = 1; growth = 6)	1,175	4.45	0.81	–	–	0.69

M = *mean and SD = standard deviation.* r^{it} *indicates item-total correlation coefficients. α-drop indicates Cronbach's alpha of latent construct if item is dropped. α indicates Cronbach's alpha of the latent construct.*

TABLE 3 | Measurement instruments to assess collective regulation activities and feeling of the school being on the right track, with example item and scale characteristics.

Latent construct	Example item	*N*	*M* (SD)	Items	Range	*α*	$ICC_1(ICC_2)$
1. Collective metacognitive regulation activities	We, as a school, often think about what works and what does not work in our teaching	1,157	4.60 (0.64)	6	1-6	0.87	0.040 (0.449)
2. Collective emotional-motivational regulation activities	We, as a school, find ways to deal with negative emotions in order to continue our work	1,161	4.69 (0.66)	6	1-6	0.88	0.056 (0.537)
3. Being on the right track to improving	We, as a school, think that our pedagogic repertoire is continuously improving	1,159	4.48 (0.66)	4	1.75-6	0.93	0.040 (0.449)

M = *mean and SD = standard deviation. α indicates Cronbach's alpha of the latent construct.* ICC_1 *and* ICC_2 *are the intraclass correlation coefficients.*

developed based on a valid measurement instrument to assess students' emotional and motivational regulation (Schwinger et al., 2007). For example, the teachers were asked whether they as a school found ways to deal with negative emotions in order to continue their work. Teachers responded to this and other five statements on a 6-point Likert scale from 1 (*strongly disagree*) to 6 (*strongly agree*). The items were first tested in our pilot study ($N = 90$; $M = 4.46$, SD = 0.58; Cronbach's $\alpha = 0.88$) and then applied to the main data ($N = 1{,}157$; $M = 4.60$, $SD = 0.64$; Cronbach's $\alpha = 0.87$; ICC1[2] = 0.040 [0.449]). Both results indicated a high reliability of the test instrument in terms of Cronbach's alpha values. As an additional reliability measure, we calculated intraclass correlation coefficients (ICCs). An ICC(1) describes the ratio of between-school to within-school variance and thus indicates the extent to which there is variance between or within schools (Lüdtke and Trautwein, 2007). Since in research ICCs on between-school differences are typically rather low (Kyriakides and Creemers, 2009; Brunner et al., 2018), values lower than 0.10 can still reveal substantial explanation. With an ICC(1) coefficient of 0.04, almost 5% of the variance in collective emotional-motivational regulation activities could be explained by differences between schools. The ICC(2) considered the number of teachers at a school completing the questionnaire. ICC(2) coefficients higher than 0.40 indicated fair reliability for the class mean ratings (LeBreton and Senter, 2008).

To capture teachers' perceptions of collective metacognitive regulation activities, teachers responded to six statements on a 6-point Likert scale (e.g., "In our school, we often think about what works and what does not work in our teaching," or "In our school, from time to time we check whether we need additional information or materials"). Results from both our pilot study ($N = 90$; $M = 4.83$, $SD = 0.60$; Cronbach's $\alpha = 0.89$) and our main sample ($N = 1{,}161$; $M = 4.69$, SD = 0.66; Cronbach's $\alpha = 0.88$; ICC1[2] = 0.056 [0.537]) showed a high reliability of the test instrument. Moderate ICCs indicated that the sampled schools differed in terms of their collective metacognitive regulation activities.

School on the Right Track to Improving

As a school improvement outcome variable, we assessed teachers' perceptions of their *school being on the right track to improving educational practices*. Research on the effects of an individual's perception of collective regulation activities and structures has been reported to provide insights concerning the basis upon which professional development activities may flourish (Moolenaar et al., 2014). Since individuals perceive and evaluate their organization based on what happens in their close social neighborhood (Meredith et al., 2017), analyzing how individuals apply regulation activities and see others applying such activities provides an opportunity to make sense-making processes visible and work out how individual beliefs are intertwined with collective interaction patterns (Sherer and Spillane, 2011). Returning to the analogy of school improvement as a journey, perceptions about being on track (whether right at the start of a journey or after having traveled quite far) is one way to take into consideration different school contexts and stages when it comes to school-level growth in student learning (Hallinger and Heck, 2011; Sleegers et al., 2014). Therefore, we created a measurement instrument to assess a collective sense of heading in the right direction when further developing the school (e.g., "In our school we think that our pedagogical repertoire is continuously improving"). Teachers responded to four statements on a 6-point Likert scale from 1 (*totally disagree*) to 6 (*totally agree*). The reliability scores were high both in the pilot study ($N = 90$; $M = 4.57$, SD = 0.57; Cronbach's $\alpha = 0.92$) and with the main data ($N = 1{,}159$; $M = 4.48$, SD = 0.66; Cronbach's $\alpha = 0.93$; $ICC_{1[2]} = 0.040$ [0.449]).

Moderate ICCs revealed that there was some between-school variance. This meant that to some degree, teachers at a specific school had similar perceptions of their school's improvement, but within-school variance was still remarkable (see **Table 3**).

Data Analysis

To assess all the measurement instruments used in this study and to test our first hypothesis (H1) about the reliability of our latent construct to assess teachers' implicit theories of professional development, confirmatory factor analyses (CFA) were computed using the *lavaan* package Version 0.6-6 (Rosseel, 2012) in R (RStudio-Team, 2020). Fit indices of the CFA models were estimated by applying a robust maximum likelihood estimator (MLR) for the correction of data that is not normally distributed (Satorra and Bentler, 1994). Additionally, missing data was estimated with the full-information maximum likelihood method (Arbuckle et al., 1996). Further, as the assumption of non-independence of the observations was violated, due to a complex nested data structure, we applied a survey design approach (Muthen and Satorra, 1995). In this way, unbiased estimators were calculated by introducing the cluster variable 'school.'

The other hypotheses (H2, H3, and H4) about the direct and indirect relations of teachers' implicit theories of professional development were tested by applying a structural equation modeling technique using Mplus Version 8.3 (Muthén and Muthen, 2017). Again, due to the nested structure of our data, we estimated the standard errors in consideration of the violation of the assumption of non-independence of observations. Applying the COMPLEX function with the cluster variable 'school' delivered unbiased parameter estimates (Muthen and Satorra, 1995). Missing values were estimated with the full information maximum likelihood method. To test significance of direct and indirect effects, confidence intervals were calculated by the bootstrap function in Mplus (using 1,000 bootstrap samples), as bootstrapping does not rely on the assumption of normality (Bollen and Stine, 1992).

RESULTS

Teachers' Implicit Theories of Professional Abilities

CFA including all the latent constructs used in the statistical model revealed a good model fit and decent factoring structure (χ^2 (164) = 515.04, $p < 0.001$, Scaling correction factor Yuan-Bentler correction (Mplus variant) = 1.306, robust CFI =.96, robust TLI = 0.95; robust RMSEA [90% CI] = 0.049 [0.045–0.054], SRMR = 0.033). Standardized factor loadings for the latent construct of teachers' implicit theories of professional abilities ranged from 0.57 to 0.64, indicating that the factor substantially influenced the variables. Communalities higher than 0.30 but lower 0.45 indicated a modest but acceptable explanation of the items' total variance by the latent factor (36% of the total variance was explained by the factor). A composite measure based on the four items had a modest but acceptable internal consistency. Hence, a reliable test instrument based on four items to assess teachers' implicit theory of professional abilities was developed (see **Table 2**).

Implicit Theories and Collective Regulation Activities

As a second research question, we investigated the role of implicit theories of professional abilities when it comes to collective metacognitive and emotional-motivational regulation activities at the school. We hypothesized that teachers' implicit theories are directly related to their perceptions of collective regulation activities (metacognitive [H2a] and emotional-motivational regulation activities [H2b]) to improve educational practices. The results of the multilevel structural equation modeling in **Figure 1** showed how teachers' implicit theories of professional abilities are related to collective regulation activities (see **Table 4**). A standardized coefficient of 0.177 (SE = 0.047, $p < 0.05$, CI = [0.085–0.270]) revealed that a malleable theory is moderately positive associated with collective emotional-motivational regulation activities (H2a). Positive upper and lower boundary of the confidence interval indicated that this relation was significant. Implicit theories and collective metacognitive regulation activities were not significantly associated with each other (beta = 0.080, SE = 0.047, $p > 0.05$, CI = [−0.012–0.172]) (H2b).

Teachers' Implicit Theories and the School Being on the Right Track to Improvement

Our third research question concerned the role of implicit theories of professional abilities on teachers' perception about their schools being on the right track to improvement. We hypothesized that teachers with a malleable theory (vs. fixed theory) have a more positive perception of the school's improvement (H3). Implicit theories of professional abilities were positively correlated to the perception of the school's improvement (Pearson's $r = 0.13$, $p < 0.01$). However, there was no significant direct association of holding a more malleable theory and teachers' perceptions of their own school being on the right track to improving (see **Figure 1**) when we controlled for collective regulation (H4). But with a standardized coefficient of 0.058 (SE = 0.035, $p < 0.10$) and a lower boundary of the confidence interval only marginally negative (CI = [−0.001–0.117]) there was a tendency toward a positive association between a malleable theory and perception that their own school was on the right track to school improvement (see **Table 4**). A malleable theory was significantly related to a more positive perception of the school's improvement through collective regulation strategies: for one, mediated through emotional–motivational regulation activities ($\beta = 0.059$, SE = 0.017, $p < 0.05$, CI = [0.026–0.093]) and for another, through emotional-motivational regulation activities via metacognitive regulation activities (beta = 0.035, SE = 0.010, $p < 0.05$, CI = [0.014–0.055]). Teachers' implicit theories were not significantly associated with the feeling of being on the right track through metacognitive regulation activities (beta = 0.025, SE = 0.015, $p < 0.10$, CI = [−0.004–0.054]) or through metacognitive regulation activities via emotional–motivational regulation activities (beta = 0.017, SE = 0.010, $p < 0.10$, CI = [−0.003–0.037]). For both indirect effects, there was a tendency toward a positive relation. The total effect of the model was significant (beta = 0.149, SE = 0.056, $p < 0.05$, CI = [0.084–0.303]).

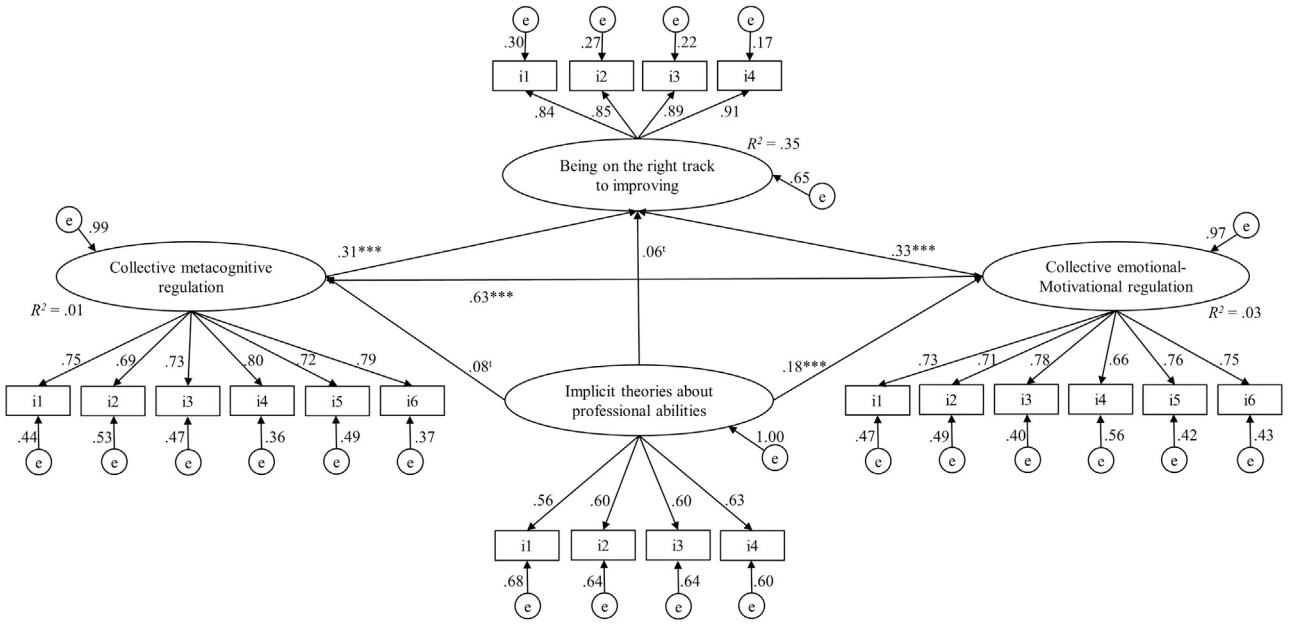

FIGURE 1 | Results of the structural equation model of teachers' implicit theories of professional abilities in school improvement (type = COMPLEX; cluster = school). $\chi^2(164) = 524.93$, $p < 0.001$, scaling correction factor Yuan-Bentler correction (Mplus variant) = 1.269: robust CFI =.96, robust TLI = 0.95; robust RMSEA [90% CI] = 0.043 [0.039–0.047], SRMR = 0.033. *e* = error. $^{t}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

TABLE 4 | Standardized coefficients, standard errors, and confidence intervals for direct, indirect, and total effects for structural equation model.

Effects	β (SE)	CI_{95}	
		LL	UL
Direct effects			
IT → MR	0.080(0.047)	−0.012	0.172
IT → EMR	0.177(0.047)	0.085	0.270
IT → BoT	0.058(0.030)	−0.001	0.117
MR → BoT	0.311(0.032)	0.247	0.374
EMR → BoT	0.334(0.037)	0.262	0.405
Indirect effects			
IT → MR → BoT	0.025(0.015)	−0.004	0.054
IT → EMR → BoT	0.059(0.017)	0.026	0.093
IT → EMR → MR → BoT	0.035(0.010)	0.014	0.055
IT → MR → EMR → BoT	0.017(0.010)	−0.003	0.037
Total effect	0.149(0.056)	0.084	0.303

IT = Teachers' implicit theories of teachers' professional abilities, MR = collective metacognitive regulation activities, EMR = collective emotional-motivational regulation activities, BoT = being on the right track to improving. β *= beta (standardized coefficient), SE = standard error,* CI_{95} *= 95% confidence interval, LL = lower level, UL = upper level. Confidence intervals were calculated using 1,000 bootstraps.*

DISCUSSION

This study aimed to analyze the role that teachers' implicit theories of professional abilities play for school improvement. With the development of a reliable test instrument to assess teachers' implicit theories of professional abilities an important first step to understand teacher beliefs about professional development and school improvement has been undertaken. Applying the test instrument revealed that primary teachers do vary in their implicit theories of the malleability of teacher abilities. Low ICC coefficients do not reveal any patterns indicating that malleable or fixed implicit theories can be explained by school affiliation. With a mean higher than 4 [on a 6-point Likert scale from 1 (*not changeable*) to 6 (*changeable*)] the majority of primary teachers in our sample tend to believe that professional abilities are changeable and developable. Nevertheless, with a minimum score of 1.5 to a maximum of 6 there is a range from rather fixed to malleable implicit theories of professional abilities. About 15% of the teachers reported to have a moderate to strong fixed implicit theory, answering the items on average between 1 and 3.5. More than every fourth teacher (27.6%) had an average score between 3 and 4, indicating that a substantial percentage of primary teachers are quite undecided concerning whether teaching abilities can actually be learned or not. These initial results reveal that our first hypothesis—that teachers vary in their implicit theories of professional abilities (H1)—can be accepted.

Based on our results, implicit theories of the malleability of teachers' abilities do indeed have an impact on perceptions of collective regulation activities and assessment of the school's recent development: First, teachers believing in the malleability of professional abilities evaluate the use of collective emotional-motivational regulation strategies more positively than teachers with more fixed theories (H2a) do. Whether this is because teachers with a malleable perspective on professional abilities embrace rather than avoid challenging situations (Dweck and Leggett, 1988) and therefore have more experience in applying emotional-motivational regulation strategies still needs to be assessed. Since there is no such effect in terms of

metacognitive regulation activities (H2b), previous research on students' implicit theories and the use of regulation strategies can only be transferred to some extent (Nussbaum and Dweck, 2008). Our second hypothesis—that there is a direct impact of different implicit theories of professional abilities on collective regulation activities (H2)—was therefore only partially fulfilled.

A possible interpretation of why collective metacognitive regulation activities were not found to be related to implicit theories of professional abilities is that the measurement instrument applied in this study might not have been suited to making differences in the metacognitive regulation of teachers in a group visible. This might be due to the fact that teachers are possibly used to reflecting upon and monitoring their work on a collective level informally rather than systematically (Mandinach and Schildkamp, 2020). Teachers might generally agree to collectively reflect on their educational work; however, this reflection might be largely superficial and based on informal exchange, without teachers necessarily analyzing in depth and sustainably adjusting their educational practices (Ehlert et al., 2009; Drossel et al., 2019). Therefore, these reflective activities might have limited impact on substantially further developing educational practices as a team. In this study, metacognitive regulation activities were assessed with a measurement instrument focused solely on teachers' collective monitoring and evaluating their work without explicitly mentioning the more complex facets of metacognitive activities, such as analyzing and adjusting cognitive or task conditions, operations, or standards (Winne and Hadwin, 2008). Whereas reflection in the tradition of Dewey has been conceptualized as a distinct form of thinking, where thoughts and actions are attentively and critically explored and framed by an individual's underlying belief system and the social context, it has been argued that practitioners often use *reflecting* synonymously with all kinds of *thinking processes* (Nguyen et al., 2014). This might relate to our finding that teachers, no matter what their implicit theory of professional abilities, report that they apply metacognitive regulation activities to collectively improve educational practices.

We assumed, in line with research on relationships (Knee and Canevello, 2006), that teachers who believe in change have more positive perceptions of collective regulation activities. But since everyone seems to exchange information on and experiences in their teaching with peers at least to a certain extent, no such effect could have been shown. Therefore, future research might address the question as to what teachers think of when it comes to collective metacognitive activities to further develop educational practices and whether there are differences in the quality of these activities by referring to theoretical concepts about metacognition and reflection (Livingston, 2003; Nguyen et al., 2014).

Further, implicit theories of professional abilities indeed shape the way that teachers perceive the success of their school's improvement. However, our results indicate that this effect is fully mediated by collective regulation activities. Therefore, we must reject our third hypothesis—that teachers' beliefs about the malleability of professional abilities is directly associated with their perceptions that the school is on the right track (H3).

Our fourth and last hypothesis about the mediating role of collective regulation activities can, again, only be accepted partially (H4).Whereas studies on students' implicit theories of personal abilities revealed indirect effects of a malleable theory on learning both through emotional–motivational regulation activities and metacognitive regulation activities (Muis, 2007; Dweck, 2017), on a teacher level there is no such relation straight from implicit theories through metacognitive regulation activities. However, there is an indirect path from implicit theories to school improvement through emotional–motivational regulation activities via collective metacognitive regulation activities. Thus, it seems that collective emotional–motivational regulation activities are of crucial importance and might function as door opener when it comes to associations between an individual's beliefs about the malleability of professional abilities and collective school improvement efforts.

Since teachers believing that professional abilities can be changed not only report experiencing better emotional-motivational regulation activities on the school level but also are more optimistic that their school is on the right track to improvement, one might wonder whether fostering a malleable implicit theory in the entire school staff might actually lead to a better pattern when it comes to school-level growth in terms of student learning (Hallinger and Heck, 2011). To this end, future studies need to address research questions on the impact of teachers' implicit theories of professional abilities with longitudinal designs and by measuring changes in teachers' and students' learning more objectively (i.e., learning achievements). Further, longitudinal data would allow analysis of a feedback loop from the evaluation of collective regulation activities back to the teachers' beliefs about the malleability of professional abilities. Another central limitation of this study is the self-report nature of the survey. Future research might need to assess collective regulation activities more directly through more fine-grained approaches (e.g., logfile, or group interview techniques).

Some additional limitations should be noted. In this study covariates such as age, gender, workload, and the teachers' formal roles were not included in the theoretical assumptions and the statistical modeling. To gain a more in-depth picture of implicit theories of professional abilities, some of these covariates might need to be addressed theoretically and empirically. In addition, studies on academic underachievers have revealed that the associations between implicit theories, self-regulated learning, and achievement are stronger for individuals with lower levels of performance (Paunesku et al., 2012; Job et al., 2015). It might be of interest to analyze such differentiated effects for teachers' implicit theories of professional abilities on a personal and school level. On a school level, the same argumentation might hold true when it comes to differences in the school's stage of the journey to school improvement. Fostering a malleable implicit theory of professional abilities might be particularly important for schools with challenging circumstances (i.e., high turnover rates or a problematic school climate). To this end, not only visible school

structures, such as school size or students' socioeconomic background, but also school differences in organizational deep structures, such as school climate (i.e., treatment of error, knowledge sharing (Staples and Webster, 2008)), openness to experimenting with new teaching ideas (Sleegers et al., 2014), or task cohesion (Brawley et al., 1987), and leadership issues might need to be addressed as well.

Further, although the internal consistency of the test instrument is acceptable, the instrument's reliability might be increased if one and the same items did not focus on both 'classroom teaching' and 'teaching related skills.' As teaching related skills is a wider concept subsuming various aspects of a teacher's professional competencies and can go beyond classroom teaching skills (aspects such as cooperating with colleagues, maintaining parental and community ties), a teacher might think of classroom teaching skills as fixed and at the same time teaching related skills as rather malleable or the other way around. Therefore, future research might further develop our test instrument to assess teachers' implicit theories of professional abilities by modifying the items such that they focus on the malleability of either classroom teaching or teaching related skills. In addition, as a next step in the development of a stable measurement instrument to assess teachers' implicit theories of professional abilities, test-retest reliability of the latent construct needs to be analyzed in other samples and educational contexts (Guttman, 1945).

Another limitation of this study is that the content validity of the measurement instrument used to assess collective metacognitive regulation activities is not entirely satisfactory. For future research the measurement instrument needs further development to adequately assess collective reflection as an in-depth inquiry process. In general, since most of the applied measurement instruments in this study are self-developed or have been migrated from research focused mainly on individual learning processes on a student level to research about collective learning processes on a teacher level, content validity of these instruments needs further verification. However, there is support for the validity of these instruments, as theoretical assumptions have been confirmed, for instance in terms of correlations between the applied measurement instruments.

Two interesting practical implications can be derived from our results that need to be interpreted within the cultural context of teachers in the German-speaking part of Switzerland: First, despite the fact that in recent years a large-scale curriculum reform has urged schools and their staff to change educational practice, by far not every teacher is fully convinced that professional abilities can actually be changed. This insight might be crucial for various stakeholders in the educational system, especially those in leading positions, such as policymakers, educational administrators, and principals, to better understand why implementing new policies, innovative teaching ideas, or working practices is sometimes a challenge equivalent to squaring a circle and does not always succeed in changing educational practice. Second, as the relatively low-stake accountability system of school inspections in Switzerland aims to further develop educational practice by giving teachers and schools as much autonomy as possible, teachers are requested to constantly further develop their professional abilities not only individually but also collectively. These high expectations of teachers to be self-directed learners in collaborative contexts (Slavit and Roth McDuffie, 2013) cannot be met if a substantial part of teachers do not fully belief in the malleability of professional abilities. Teacher educators might be of crucial importance in scaffolding and supporting teachers' learning processes and in addressing the impact of implicit theories on professional abilities in basic teacher education programs or in professional development programs.

To conclude, the promotion of malleable theories of professional abilities—the notion that 'good teachers' are not born but that good teaching is something that can be cultivated—may be used as a starting point not only for individual professional development but also for changing collective regulation strategies to foster personal, interpersonal, and organizational capacities for school improvement (Mitchell and Sackney, 2011; Maag Merki, 2017). Ultimately, changing educational practices may only work if teachers set their minds to it. Or in other words: Changing educational practices sometimes needs, for a start, some change in thinking.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors as soon as the research project is finished, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethikkommission der Philosophischen Fakultät (University of Zurich). The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors contributed to conception and design of this study. KM, AW and BR organized the database. We acknowledge the work of further members of the research team in collecting the data. BR and MC wrote the first draft of the manuscript with input from all authors. BR, MC and KM developed the theoretical assumptions in the introduction. BR wrote the section about Materials and Methods, and performed the statistical analysis. MC and KM verified the analytical methods. All authors discussed the results and contributed to the final manuscript. KM and AW supervised the project.

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Effect of Intelligence Mindsets on Math Achievement for Chinese Primary School Students: Math Self-Efficacy and Failure Beliefs as Mediators

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This study examined the relationship of intelligence mindsets to math achievement for primary school students in the Chinese educational context, as well as the mediating function of math self-efficacy and failure beliefs in this relationship. Participants included 466 fifth graders (231 boys and 235 girls) from two Chinese primary schools. Results indicated that boys had significantly higher mean levels of growth mindsets and math self-efficacy than girls, whereas boys had no statistically significant differences to girls on failure beliefs and math grade. Further, intelligence mindsets had a significant positive effect on math achievement, and failure beliefs and math self-efficacy played a full mediating role in the relationship between intelligence mindsets and math achievement. Moreover, intelligence mindsets affected math achievement through the chain mediating role of failure beliefs and math self-efficacy. These above findings contribute to advance our knowledge about the underlying mechanisms through which intelligence mindsets affect math achievement, which are of great significance to students' growth and current educational practice.

Keywords: math achievement, Chinese student, intelligence mindsets, failure beliefs, math self-efficacy

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INTRODUCTION

Mathematics is a very important tool subject, which occupies students' learning life from kindergarten to university and even higher level. Studies have established that a solid foundation of mathematics is essential to the professionalization of all professions. If you are not good at mathematics, it is difficult to engage in activities related to STEM (Science, Technology, Engineering, and Math), let alone engage in STEM careers (Wang and Degol, 2017).

However, the idea that math is only for some people has deep roots in the field of mathematics. Researchers surveyed scholars in various disciplines at US universities and found that among all STEM fields, math scholars were the most extreme in emphasizing fixed, innate abilities (Leslie et al., 2015). The single belief—that math is a "gift" that some people have and others do not—is responsible for much of the widespread math failure and underachievement in the word (Boaler and Dweck, 2016).

In fact, almost all students have the ability to learn math well and enjoy it, which depends on the individual's mindset. Everyone has a intelligence mindset (also called implicit theory of

intelligence), a basic belief about whether intelligence is fixed or malleable (Dweck, 2006). Two different types of intelligence mindsets can be distinguished: growth mindset and fixed mindset. A growth mindset believes that intelligence or ability can be constantly developed and changed with people's experience and learning. Correspondingly, a fixed mindset, believes that intelligence is predetermined, limited and unchangeable. General beliefs about intelligence across domains have also been expended to the incremental or entity views of particular domains like STEM or stereotypically masculine tasks (Moè et al., 2009; Patterson et al., 2016).

Intelligence mindsets would be a major influence on individual's academic and emotional experience, leading to different cognition—emotion—behavior responses in the face of academic success, failure and challenge, which in turn affect an individual's learning behavior, academic achievement, learning motivation, and psychological health status. Research has indicated that individuals with different intelligence mindsets have differences in achievement goals, especially in their responses to failures. A fixed mindset orientation is more concerned about performance goals and focuses more on score, ranking, and grade. On the contrary, a growth mindset orientation values mastery goals and focuses more on the mastery of knowledge and the improvement of ability. In addition, in the face of difficult tasks, a growth mindset orientation with mastery goals shows more resilience and makes more efforts to analyze their "not yet acquired" abilities and methods to overcome the difficulties. However, a fixed mindset orientation with performance goals will shrink back when they encounter challenges and difficulties, and they will be more likely to believe that the difficulties are due to the limitation of their own abilities. Therefore, individuals with growth mindsets have stronger learning motivation and self-efficiency, become more actively involved in learning, and improve their grades faster (Dweck, 2006).

Intelligence Mindsets and Academic Achievement

Students' intelligence mindsets have an essential role in their academic achievement. A review of findings based on the relevant articles published from 1998 to 2017 illustrated that intelligence mindsets served to affect academic achievement in most studies (Zhang et al., 2017). Similar results were found in the Programme for International Student Assessment (PISA). For example, data analysis results of PISA 2012 showed that, on average across OECD countries, the highest achieving mathematics students were those with a growth mindset, and they outranked their counterparts by the equivalent of more than a year of mathematics (Boaler and Dweck, 2016). Also in PISA 2018, students with a growth mindset scored 32 points higher in reading than those with a fixed mindset, after accounting for the socio-economic profile of students and schools (Schleicher, 2019).

However, the impact of intelligence mindsets on academic achievement is not stable and regional and cultural differences might exist. Students from Asia, Oceania, and North America were reported to have a positive correlation between growth mindset and academic achievement, while students from Europe showed a positive correlation between fixed mindset and academic achievement (Costa and Faria, 2018). Fixed-oriented individuals are eager to get good grades to prove their own ability. However, growth-oriented individuals do not attach great importance to achievements; vs. the belief that good achievements are a byproduct of their love for learning (Dweck, 2006). Therefore, the effect of intelligence mindsets on academic achievement may have complex psychological mechanisms, which have received only little attention.

Academic Self-Efficacy and Failure Beliefs as Mediators

Academic Self-Efficacy as a Mediator

Academic self-efficacy refers to the belief in one's capabilities to master new skills and tasks in a specific academic domain such as mathematics (Bandura, 1997). Previous studies have reached a consensus that academic self-efficacy was an important construct to explain students' achievement-related behaviors related to learning and performance (Schunk, 1989; Pajares, 1996; Chemers et al., 2001; Choi, 2005; Komarraju and Nadler, 2013; Macphee et al., 2013). Self-efficacy beliefs can not only predict a student's performance in mathematics such as the accuracy of mathematical operations and the ability of mathematic problem-solving (Schunk and Hanson, 1985; Pajares and Miller, 1994), but also can decrease mathematics anxiety (Samuel and Warner, 2019). Also, it has demonstrated that students with a stronger self-efficacy showed greater persistence on difficult math items than those with lower self-efficacy (Collins, 1982).

Students' intelligence mindsets may play a role through the stable academic self-efficacy within individuals. Martocchio (1994) found that self-efficacy increased for students with a growth mindset vs. decreased for those with a fixed mindset in the face of a challenging computers course. Samuel and Warner (2019) found that college students' self-efficacy in math was increased through a combination intervention of mindfulness and intelligence mindsets. Mcwilliams (2014) found that students with a growth mindset tend to make internal attributions and have a strong sense of academic self-efficacy. Additionally, results of PISA 2018 also indicated that a growth mindset was positively correlated with students' general self-efficacy.

However, students from grade 6 to 8 who received special education due to reading disabilities were investigated, and an intelligence mindsets intervention was conducted on the experimental group. Results showed that this intervention could significantly improve the learning motivation level of the experimental group, but there was no significant difference in self-efficacy and academic achievement between the experimental group and control group (Rhew et al., 2018).

The inconsistent results of previous studies may be due to the fact that the role of academic self-efficacy has not been fully explored and needs to be further investigated.

Failure Beliefs as a Mediator

Failure beliefs (Nishimura et al., 2017; Stern and Hertel, 2020) are a way of thinking that views failures as either an enhancing

or debilitating experience. Different failure beliefs would lead to different characteristic response patterns to academic difficulties. A failure-is-enhancing belief views failure as an enhancing experience that promotes learning. In the face of academic failures, individuals with this kind belief are more likely to adopt effort-based attributions and then would to engage in positive, effort-based coping strategies. In contrast, a failure-is debilitating belief views failure as an impairing experience that inhibits learning. Those students tend to adopt ability-based attributions and then would engage in negative, effort-avoidant coping strategies when encountering academic difficulties (Haimovitz and Dweck, 2016).

Different failure beliefs could lead to different learning outcomes. Dweck and Gilliard (1975) found that altering attributions for failures from low-ability to low-effort would enable learned helpless children to improve their problem-solving ability. Blackwell et al. (2007) established that students who make fewer ability-based helpless attributions would choose more positive, effort-based strategies to copy with failures, improving their math scores.

Different intelligence mindsets would set up different patterns of response to the threat of failures (Dweck et al., 1995b; Robins and Pals, 2002; Whittington et al., 2017). Relative to those with a fixed mindset, students with a growth mindset have been found to express less fear of failure and set up a more mastery-oriented pattern rather than a helpless response pattern in the face of academic setbacks. Specifically, they were more likely to make low-effort instead of low-ability attributions for failures and apt to employ positive strategies, such as the development of better strategies and work harder under failure, rather than negative strategies, such as an avoidance of challenge and effort withdrawal.

Students' intelligence mindsets may have few effects on academic achievement until challenges or setbacks or failures are present (Dweck, 2002, 2008; Grant and Dweck, 2003). In other words, the effect of intelligence mindsets on achievement becomes stronger in the face of failure. Therefore, the effect of intelligence mindsets on math achievement in challenging and demanding situations should be further examined.

Academic Self-Efficacy and Failure Beliefs as a Chain Mediator

Academic self-efficacy and failure beliefs were associated with one another. Effort attribution feedback on success or failure can increase students' academic self-efficacy (Schunk, 1989). Conversely, the more individuals attribute failure to ability and task difficulties, the lower their expectations of future success (Weiner, 1986). Attribution style was also found as the strongest predictor of self-confidence in math (Kloosterman, 1988). Moreover, the ways educators discuss success, failure, and challenges with students can also have a strong impact on improving academic self-efficacy. Educators can help students build self-efficacy by portraying failure as a positive aspect of learning while emphasizing the importance of persisting in overcoming these challenges (Rhew, 2017).

At the same time, academic self-efficacy has been revealed to play important roles in shaping people's attributions for failures and in their behavioral responses to attributions for failures (Dixon and Schertzer, 2013). Students with low self-efficacy may avoid accomplishing a task, whereas those who believe in their abilities should participate more eagerly. Especially in the face of setbacks and failures, a confident person ought to work harder and persist longer than those who doubt their abilities (Schunk, 1989). Similarly, in the face of failures, students with high self-efficacy would make low-effort attributions, while those with low self-efficacy would make low-ability attributions (Ganguly et al., 2017; Song et al., 2020).

Influence of Gender

For a long time, traditional math-gender stereotypes were very popular. Mathematics was considered as a "male subject," that is, males are good at math and perform better in math than females (Cvencek et al., 2011; Moè, 2018). In contrast, traditional math-gender stereotypes were rejected in some studies, where girls are believed to be as good as boys in math or even perform better in math than boys (Passolunghi et al., 2014). Based on the analysis of empirical data, it is also found that contradictory results often occur in the gender difference in math achievement. For example, in PISA 2012, out of 72 participating countries (regions or economies), boys' math scores were statistically significantly higher than girls' in 28 countries (regions or economies), while girls' math scores were significantly higher than boys' in 7 countries.

Math-gender stereotypes were found to affect both boys' and girls' self-perception of math ability. Therefore, the gender difference in math self-efficacy is also inconsistent. Several findings have indicated that girls had lower levels of math self-efficacy than boys (Middleton, 1999; Diseth et al., 2014). In contrast, other studies have observed the opposite, that is, girls were more self-efficacious in math than boys (Guvercin, 2008). Also, the well-established gender difference in math self-efficacy was not observed in some studies, that is, gender had no significant effect on math self-efficacy (Passolunghi et al., 2014).

Regarding gender differences in intelligence mindsets, few studies have been conducted. Findings obtained by Spinath et al. (2003) suggested a significant positive correlation with growth mindset for women. While Diseth et al. (2014) found that girls had weaker growth mindsets than boys. Gender was also found to be unrelated to intelligence mindset in other studies (Burnette, 2013).

Concerning gender differences in failure beliefs, compared to boys, girls (especially high-achieving girls) were reported to have a lower tendency for new and challenging tasks and tend to endorse ability-based attributions (Chen, 2012). Whereas some studies reported that very small differences in failure or success attribution exist among boys and girls no matter they are advantaged or disadvantaged SES (Bar-Tal et al., 1984).

Overall, previous studies represent high inconsistency and more studies are needed to illuminate the influence of gender.

The Present Study

These previous findings summarized above show that intelligence mindsets, failure beliefs, math self-efficacy and math achievement do correlate with each other, and it is very important and

meaningful to understand the influencing mechanism between these variables. However, based on these prior findings, there are still some questions that need to be further investigated. First, the inconsistent results of previous studies as mentioned above call for further investigation of the relationship between these variables. These inconsistent results may be related to cultural background. For example, the theory of intelligence mindsets has been found to be culturally shaped in previous studies (Stevenson et al., 1990; Morris and Peng, 1994; Dweck et al., 1995b; Costa and Faria, 2018). However, at present, few researches have been conduct with Eastern cultures, such as Chinese culture (Zeng et al., 2016; Zhao et al., 2018). As far as we know, no empirical research has been conducted to exam the effect of intelligence mindsets on academic achievement in the context of Chinese education. Therefore, this study investigated, for the first time, the relationship of intelligence mindsets to math achievement for Chinese students.

Second, why is intelligence mindset related to math achievement? Although many researches have indicated that mindsets play important roles in math achievement, few studies have investigated the underlying mechanisms through which mindsets correlate with achievement (Blackwell et al., 2007). As far as we know, our full model of the relationships between intelligence mindsets, failure beliefs, math self-efficacy, and math achievement has never been investigated before. Therefore, this study would contribute to advance our knowledge about the underlying mechanisms through which intelligence mindsets affect math achievement.

Based on previous research findings and our theoretical model, the following hypotheses are proposed:

- Hypothesis 1: boys have higher levels of growth mindset, math self-efficacy, failure beliefs and math achievement than girls;
- Hypothesis 2: growth mindset is positively related to math achievement;
- Hypothesis 3: growth mindset can positively predict math self-efficacy, and math self-efficacy can positively predict math achievement, as well as playing a mediation role between intelligence mindsets and math achievement;
- Hypothesis 4: growth mindset can positively predict failure beliefs, and failure beliefs can positively predict math achievement, as well as playing a mediation role between intelligence mindsets and math achievement.
- Hypothesis 5: math self-efficacy can positively predict failure beliefs, as well as math self-efficacy and failure beliefs sequentially mediate the relationship between intelligence mindsets and math achievement.

MATERIALS AND METHODS

Participants

We gathered convenient samples from two public primary schools in Urumqi, the capital city of Xinjiang Uygur Autonomous Region located in the northwest border of China. These two participating schools are located in the urban areas of Urumqi city, with various educational indicators that near the average education level of China. All fifth grade classes in each participated school, a total of eight classes, participated in this study.

Four hundred and sixty six fifth graders (ages ranging from 10 to 12 years) were recruited in total, which consisted of 231 (49.6%) boys and 235 (50.4%) girls. Participants were varied in ethnicity, among which 355 (76.2%) were Han, 45 (9.7%) were Uighurs, 43 (9.2%) were Hui, 10 (2.1%) were Kazak, and 13 (2.8%) were other nationalities.

A questionnaire survey was carried out in the classroom, taking a class as a unit, and within 15 min. One of the research assistants informed all participants that all of their responses would only be used for research purposes and encouraged them to provide honest answers in the questionnaire.

Measures

All scale items were rated on a six-point Likert scale from 1 (*strongly agree*) to 6 (*strongly disagree*). Items were reverse-scored if necessary.

Intelligence Mindsets Scale

Three items (Dweck, 2006) were adopted to measure participants' fixed mindset, e.g., "you can't really change how intelligent you are." Fixed mindset items rather than growth mindset items were chosen because growth items sometimes create an acquiescence bias (Claro et al., 2016). As two items in the scale were tautology after being translated into Chinese, only two items were retained in the final survey. These items were reverse-scored and then mean score of these two items was calculated as intelligence mindsets score, with a higher score indicating a stronger growth mindset ($M = 4.53$, SD $= 1.35$). The Cronbach's α coefficient for intelligence mindsets scale was 0.81.

Math Self-Efficacy Scale

Three items were selected from the PALS (Midgley et al., 2000) to measure participants' confidence in their ability to master math skills, e.g., "I am good at math." The mean score of these three items was calculated as the math self-efficacy score, with a higher score indicating a higher confidence in their math ability ($M = 5.14$, SD $= 0.75$). The Cronbach's α coefficient for math self-efficacy scale was 0.73.

Failure Beliefs Scale

The failure beliefs scale consisted of failure attributions and coping strategies subscales. Four items were used to measure participants' characteristic response patterns to mathematical difficulties (Blackwell et al., 2007). Among these items, two were used to measure students' failure attributions, that is, students rated the extent to which they believed their abilities or other factors contributed to the failure, e.g., "if I failed to pass my math test, it's because I'm not smart enough." The remaining two items were used to measure students' coping strategies for failures, that is, students rated how likely they were to adopt positive strategies, e.g., "if I failed to pass my math test, I would spend more time studying before the exam." Some of the items were negative statements and therefore were reverse-scored before data analysis. Then mean score of these four items was calculated as failure beliefs score, with a higher score

indicating a more positive response to failures ($M = 5.37$, SD = 0.7). The Cronbach's α coefficient for failure beliefs scale was 0.69.

Math Achievement

For many students, mathematics is a challenging subject that can trigger the distinctive motivational patterns associated with intelligence mindsets, which may not manifest themselves in low-challenge situations (Blackwell et al., 2007). Thus, math scores on the Urumqi's assessment of education quality in the spring term of fifth grade served as the measure of math achievement ($M = 89.58$, SD = 17.09, range = 0–100). Test questions of this assessment were mainly those that reflected the basic requirements of National Mathematics Curriculum for primary students. All fifth graders in Urumqi studied under the same mathematics curriculum and took the same exam.

Data Analytic Procedures

Data analysis subsequently included the following steps. First, analysis of statistical description and correlations of all study measures were calculated with SPSS21.0 software. Second, independent sample *t*-tests were performed to test the mean differences between boys and girls regarding all the study measures. Third, structural equation modeling (SEM) was conducted to examine the relationships between all study measures using M-plus7.0 software. Fourth, a bootstrapping method was used to test the mediating effect of math self-efficacy and failure beliefs. Lastly, multi-group analysis was conducted to test the structural differences of the full model by genders.

RESULTS

Common Method Bias Test

Common method biases may happen due to self-report methods, so Harman's single factor analysis was carried out to test the common method biases. Results showed that a total of four factors were extracted and the first factor explained 31.76% of the variance variation, which was less than the critical standard 40%, indicating that common method bias in this study was not obvious.

Descriptive Analysis and Intercorrelations

Students were classified into three different mindset categories according to their average intelligence mindsets score (Claro et al., 2016): students who scored from 1 to 2 points were categorized as "fixed mindsets;" those who scored from 5 to 6 points were categorized as "growth mindsets;" and those who scored from 2.1 to 4.9 points were categorized as "mixed mindsets," with 9.0, 58.2, and 32.8% falling into each category, respectively. Apparently, those participants were, more likely to have a growth mindset, which is consistent with previous research results under the same cultural background (Stevenson et al., 1990; Dweck et al., 1995a).

The distribution of math grades showed that 94% of the students scored above 60 and reached the basic requirements of the curriculum standard, which was in line with the results of national mathematics large-scale assessments for compulsory education (Liu et al., 2014). Chinese students have been outstanding in mastering basic math knowledge and basic skills for a long time and have excelled in international assessments of mathematics achievement (Ni et al., 2011). The present assessment, which focused on students' mastery of basic knowledge and basic skills, got an average score of 89.58 as expected. At the same time, the standard deviation was 17.09 and the minimum score was as low as 20, indicating a tendency toward polarization on math grade.

Correlation analysis results (see **Table 1**) showed that intelligence mindsets, math self-efficacy, failure beliefs, and math grade formed a network of interrelated variables as expected. Specifically, intelligence mindsets was significantly positively correlated with math self-efficacy ($r = 0.126$, $p < 0.01$), failure beliefs ($r = 0.214$, $p < 0.01$), and math grade ($r = 0.166$, $p < 0.01$). Math self-efficacy was significantly correlated with failure beliefs ($r = 0.443$, $p < 0.01$). Moreover, both math self-efficacy and failure beliefs were positively related to math grade ($r = 0.319$, $p < 0.01$; $r = 0.301$, $p < 0.01$).

Mean Differences

Independent sample *t*-tests were conducted to examine mean level differences of these variables regarding gender. As shown in **Table 2**, on average, boys had higher mean level scores on all the variables. However, statistically significant differences were found only on two variables. Compared to girls, boys have significantly higher mean levels of growth mindsets and math self-efficacy ($p < 0.05$). While no statistically significant differences were found between boys and girls on failure beliefs ($p = 0.165$) and math grade ($p = 0.258$).

Structural Equation Modeling

Structural equation modeling (SEM) was used to further examine the relationship between all study measures. First, measurement models were examined. Intelligence mindsets were indexed by two items; math self-efficacy was indexed by three items; failure

TABLE 1 | Descriptive analysis and intercorrelations.

Measures	Range	*M* ± *SD*	1	2	3	4
1. Intelligence mindsets	1–6	4.53 ± 1.35	-			
2. Math self-efficacy	1–6	5.14 ± 0.75	0.126**	-		
3. Failure beliefs	1–6	5.37 ± 0.70	0.214**	0.443**	-	
4. Math grade	0–100	89.58 ± 17.09	0.166**	0.319**	0.301**	-

*N = 466, **p < 0.01.*

TABLE 2 | Mean differences by gender and *t*-test results.

Measures	Range	Boys *M* ± *SD*	Girls *M* ± *SD*	*t*
Intelligence mindsets	1–6	4.68 ± 1.32	4.37 ± 1.36	2.49*
Math self-efficacy	1–6	5.21 ± 0.78	5.07 ± 0.73	2.05*
Failure beliefs	1–6	5.42 ± 0.71	5.33 ± 0.69	1.39
Math grade	0–100	90.49 ± 17.60	88.69 ± 16.55	1.13

*N = 231 for boys, N = 235 for girls, *p < 0.05.*

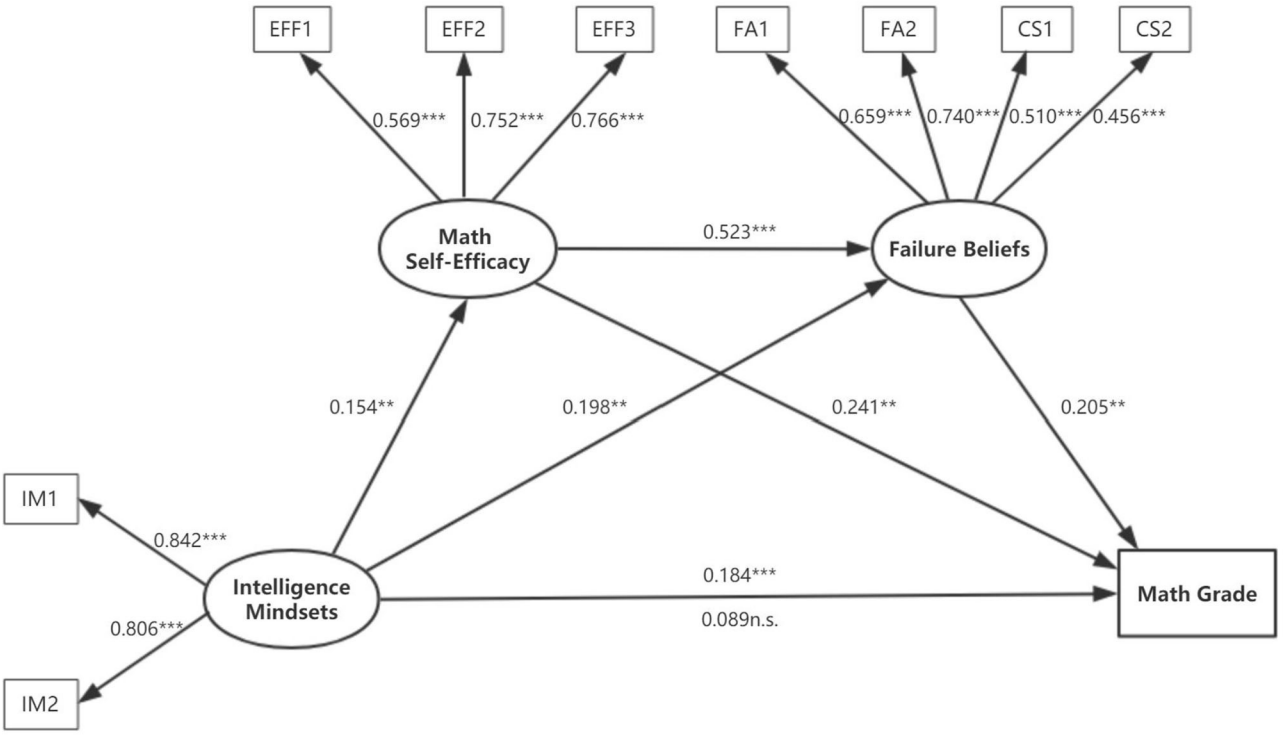

FIGURE 1 | Full model. Along the bottom path, the coefficient above the arrow indicates the direct effect, and the coefficient below the arrow indicates the effect with mediators. $^{**}p < 0.01$, $^{***}p < 0.001$.

beliefs were indexed by four items. Math grade was used as the outcome variable. All the factor loadings ranged from 0.456 to 0.842 and were significant, indicating that all the measurement indicators could be well-explained by the latent variables. Next, a structural model was conducted to establish the structural relationship between latent variables.

Results showed that the full model (see **Figure 1**) was well-supported by the data ($CFI = 0.943 > 0.9$, $TLI = 0.915 > 0.9$, $SRMR = 0.049 < 0.08$, $RMSEA = 0.067 < 0.08$) (Hu and Bentler, 1999), and all proposed paths were significant. Growth mindset can directly predict students' math achievement, as well as indirectly predict students' math achievement through math self-efficacy and failure beliefs. To be specific, growth mindset significantly predicted math achievement ($\beta = 0.184$, $p < 0.001$), math self-efficacy ($\beta = 0.154$, $p < 0.01$), and failure beliefs ($\beta = 0.198$, $p < 0.01$); math self-efficacy significantly predicted math achievement ($\beta = 0.241$, $p < 0.01$) and failure beliefs ($\beta = 0.523$, $p < 0.001$); and failure beliefs significantly predicted math achievement ($\beta = 0.205$, $p < 0.01$).

Mediating Modeling Analyses

The full model suggests that (a) failure beliefs mediate the relationship between intelligence mindsets and math grade, (b) math self-efficacy mediates the relationship between intelligence mindsets and math grade, and (c) failure beliefs and math self-efficacy chain mediate the relationship between intelligence mindsets and math grade. To further test whether the mediating effect was significant, a bootstrapping procedure with 10,000 bootstrap samples was used. If the bias-corrected (BC) 95% confidence interval (CI) for the path coefficient does not include 0, the mediating effect is significant.

As shown in **Table 3**, the direct relationship of intelligence mindsets and math grade ($\beta = 0.184$, $p < 0.001$) was found to be mediated by math self-efficacy [$\beta = 0.037$, $p < 0.01$, 95% $CI = (0.007, 0.089)$], failure beliefs [$\beta = 0.041$, $p < 0.01$, 95% $CI = (0.005, 0.108)$], and math self-efficacy to failure beliefs [$\beta = 0.017$, $p < 0.01$, 95% $CI = (0.002, 0.054)$]. The fact that the direct effect of intelligence mindsets on math grades was no longer significant after the model controlled for math self-efficacy and failure beliefs ($\beta = 0.089$, $p > 0.05$), which indicated a full mediation. The students with a growth mindset predicted a higher sense of math self-efficacy, and then predicted a more positive failure belief, which in turn contributed to students' math achievement.

Multigroup Analysis of the Full Model

In order to explore whether the full model depicted in **Figure 1** is equally valid across genders, a multi-group analysis was conducted (Vandenberg and Lance, 2000; Yao and Yang, 2017). As shown in **Table 4**, Model 1 (unconstrained model) has the restriction that all coefficients allowed to vary across genders; Model 2 restricted the measurement weights to be equal; Model 3 restricted the measurement weights and structural weights to be equal; In Model 4 (constrained model), all coefficients,

including measurement weights, structural weights, structural covariances, structural residuals, and measurement residuals, were set invariant across genders. The χ^2 differences among these four models were not significant (all *p*s > 0.05), indicating that the structural relationships shown in **Figure 1** were not found to have a significant difference for boys and girls. The generalizability of the full model was preliminarily supported.

DISCUSSION

This study aimed to explore the influencing mechanism of intelligence mindsets on math achievement for Chinese primary school students. SEM suggested that intelligence mindsets, math self-efficacy, and failure beliefs could all predict math achievement. Moreover, mediating modeling analyses further suggested that the association of intelligence mindsets and math achievement could be fully explained by math self-efficacy and failure beliefs. So we conclude that math self-efficacy and failure beliefs are meaningful concepts for understanding the mechanism of intelligence mindsets on math achievement. Specifically, the results revealed that having a growth mindset predicted a higher sense of math self-efficacy as well as more positive failure beliefs, and also having a higher sense of math self-efficacy predicted more positive failure beliefs, which both in turn positively influenced students' math achievement. Regarding the gender difference, our findings showed that boys had significantly higher mean levels of growth mindsets and math self-efficacy than girls, while boys and girls had no statistically significant differences on failure beliefs and math grade. In addition, the full model was proved to be equally valid across genders and the generalizability of the full model was preliminarily supported by the multi-group analysis. In summary, hypotheses 2, 3, 4, and 5 are all supported while hypothesis 1 is partially confirmed.

TABLE 3 | Bootstrapping analysis of the mediating effect.

			95%BC *CI*	
Mediator	**Parameter estimate**	**SE**	**Lower**	**Upper**
Math self-efficacy	0.037	0.021	0.007	0.089
Failure beliefs	0.041	0.025	0.005	0.108
Math self-efficacy → Failure beliefs	0.017	0.013	0.002	0.054

In the previous literatures, several paths have been examined separately. Our findings are in line with previous studies on the following: (a) intelligence mindset, math self-efficacy and failure beliefs could contribute to one's math achievement (Dweck and Gilliard, 1975; Dweck and Leggett, 1988; Schunk, 1989; Chemers et al., 2001; Blackwell et al., 2007; Boaler and Dweck, 2016; Claro et al., 2016); (b) growth mindset predicts math self-efficacy (Martocchio, 1994; Samuel and Warner, 2019); (c) growth mindset is positively related with failure beliefs (Dweck et al., 1995b; Robins and Pals, 2002; Whittington et al., 2017); and (d) math self-efficacy and failure beliefs are positively correlated (Schunk, 1989; Dixon and Schertzer, 2013; Ganguly et al., 2017). However, as far as we know, the full paths of the relationships among intelligence mindset, math self-efficacy, failure beliefs, and math achievement in our mediating model have not been tested simultaneously before in other research.

Most importantly, this study highlights the critical mediating roles of failure beliefs in the relationship between intelligence mindsets and math achievement. That is, intelligence mindsets can play a more important role in students' math achievement when faced with challenges, setbacks, or failures. For students with a growth mindset, a failure indicates that more effort needs to be put into the task in order to improve their intelligence or basic ability to do the task well, so they are more likely to attribute the failure to insufficient effort. In turn, these students with a belief of positive effort will tend to adopt positive strategies, such as persistence on the tasks and invest efforts to solve these problems in the face of challenges, setbacks, and failures, thereby improving math grades. By comparison, for students with a fixed mindset, a failure represents low intelligence or ability that cannot be developed through effort and hard work, so they are more likely to attribute their failure to their ability. In turn, those students with ability beliefs apt to employ negative strategies, such as an avoidance of study challenges and effort withdrawal in face of setbacks, which leaded to flat or even falling math grades over time.

Likewise, this study also highlights the critical mediating roles of math self-efficacy as well as the chain mediating roles of math self-efficacy and failure beliefs in the relationship between intelligence mindsets and math achievement. Students holding a growth mindset or fixed mindset have very different perspectives in views of math self-efficacy. Students with a growth mindset believe that their intelligence and ability can be improved over time. Thus, they have a higher belief in their own capabilities and participate more eagerly for accomplishing a task than students

TABLE 4 | Results of multi-group analysis: boys vs. girls.

Model	**Specifications**	χ^2	***df***	**CFI**	**RMSEA**	**Model comparison**	χ^2 **diff.**	**df diff.**	***p***
1	Unconstrained	134.018	60	0.934	0.052				
2	Measurement weights equal	146.117	69	0.931	0.049	1 vs.2	12.099	9	0.208
3	Structural weights equal	149.403	72	0.931	0.048	2 vs.3	3.286	3	0.350
4	Constrained	170.153	85	0.924	0.046	3 vs.4	20.75	13	0.078

who thought their intelligence and ability was fixed. Especially when facing failures, individuals who feel efficacious ought to make effort attributions and then work hard. Therefore, they were outperforming those who held more fixed mindsets and following low self-efficacy in mathematics.

A series of studies have proved that intelligence mindsets can be cultivated and a fixed mindset can also be transformed into a growth mindset by interventions (Blackwell et al., 2007). For example, students can be taught about the new science of brain plasticity and the new view of talent and giftedness as dynamic attributes that can be developed. At the same time, students can be guided to focus on effort and process through process praise and feedback by parents and teachers. Especially for the females and minority students, such messages should be conveyed that their underachievement has its roots in environmental rather than intelligence factors, and can be overcome through the improvement of the education environment and individual efforts (Blackwell et al., 2007; Dweck, 2008). Most importantly, our findings further demonstrated that in order to play a stable role on math achievement, intelligence mindsets need to be applied with the help of positive academic self-efficacy and failure beliefs. Therefore, parents and teachers should train students to develop self-motivated and self-directed growth orientations, give positive feedback to students when they face challenges and setbacks, and encourage them to meet challenges, persist, and become more confident. At the same time, parents and teachers should guide students to establish a correct view of mistakes, let them know the value of failures, realize that making mistakes is the best time to learn and a key time for brain growth, then let students learn from mistakes, and thus achieve the goal of improving academic achievement.

Limitations

This present research has demonstrated that math self-efficacy and failure beliefs are meaningful concepts for understanding the mechanism of intelligence mindsets on math achievement for the first time. However, this study also has some limitations. First, the study was conducted in two schools in Urumqi. It provided a window for relevant researchers to understand the underlying mechanisms through which intelligence mindsets are related to math achievement in the context of Chinese education. Although the educational indicators of these two schools were close to Chinese average education level, the samples were not gathered based on the probability sampling method, which may raise the question of generalization. Further studies should be conducted in larger samples to assess whether the findings of this study are still valid. Second, cross-sectional data was collected in this study, which is insufficient to understand how the positive role of intelligence mindsets is played vertically. Longitudinal approaches should be conducted in future studies to examine the vertically positive role. Finally, this study only used self-reports of primary school students, and future studies should combine perspectives of parents and teachers to further explore the influence of external environment on individual's intelligence mindsets.

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 human participants were reviewed and approved by Ethics Review Committee at College of Scinece, Minzu University of China. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

AS: research design, data collection, manuscript draft, and revision work. SW: literature search and data interpretation. WH: data collection and revision work. LD: data collection. All authors contributed to the article and approved the submitted version.

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Who Is Part of the "Mindset Context"? The Unique Roles of Perceived Professor and Peer Mindsets in Undergraduate Engineering Students' Motivation and Belonging

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In the current study, we explore the unique roles that perceived professor and peer beliefs play in creating a mindset context for undergraduate engineering students. We found that students (N = 304) perceived their peers, as compared to their professors, to endorse stronger fixed beliefs about intelligence and more negative beliefs about effort and failure, what we refer to as "unproductive mindsets". Students' perceptions of their professors' unproductive mindsets negatively predicted their motivation (utility, attainment, and intrinsic value of engineering) and sense of belonging, even controlling for students' own mindsets. Further, students' perceptions of their peers' unproductive mindsets negatively predicted their motivation (intrinsic value and mastery goals), sense of belonging, and choice of a difficult assignment, even controlling for students' own mindsets and their perceptions of their professors' unproductive mindsets. These results suggest that when considering the mindsets that permeate academic contexts, it is important to consider the unique role of perceptions of both teachers (professors) and peers.

Keywords: mindset beliefs, peers, professors, motivation, belonging

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INTRODUCTION

In Science, Technology, Engineering, and Mathematics (STEM) fields, students' motivational beliefs, values, goals, and sense of belonging are critical influences on their academic performance and retention (e.g., Wang, 2013; Wang and Degol, 2013; Perez et al., 2014; Wilson et al., 2015; Cromley et al., 2016). Thus, it is important to determine what kinds of academic contexts promote higher motivation and sense of belonging in students (e.g., Hilts et al., 2018; Murdock-Perriera et al., 2019). Some of the literature on academic contexts has focused on objective contextual features, such as class size or instructional characteristics (e.g., Ehrenberg et al., 2001; Corkin et al., 2017). However, a large portion of the research has focused on *perceived* contexts, highlighting the importance of how one's surroundings (physical and social environments) are psychologically experienced by the individual learner (e.g., Muenks et al., 2020; Starr et al., 2020). For example, one body of research has explored how students' perceptions of their teachers' mastery-oriented vs. performance-oriented instructional practices predict their motivation and achievement (e.g., Meece et al., 2006). Building on this work, the present study explores how perceived mindset contexts (e.g., Murphy and Dweck,

2010)—defined here as the perceived unproductive mindsets of teachers and peers around intelligence, effort, and failure—are associated with undergraduate engineering students' motivation and belonging. Though prior research has demonstrated that the unproductive mindsets of college professors—both self-reported (e.g., Canning et al., 2019) and perceived by students (e.g., Rattan et al., 2018; LaCosse et al., 2020; Muenks et al., 2020)—negatively predict students' motivation and belonging in those professors' classes, no studies to our knowledge have examined students' perceptions of their peers' unproductive mindsets. However, it is reasonable to assume that peers are also an important part of the perceived mindset context of a classroom (e.g., Yeager et al., 2019), particularly in a highly competitive field such as engineering (e.g., Goubeaud, 2010). Thus, in the present exploratory study, we examine the unique role of undergraduate engineering students' perceptions of their professors' and peers' mindsets about intelligence, effort, and failure on their motivation and belonging in engineering.

The Important Role of Students' Motivation and Belonging in STEM

A major focus of educational funding agencies across the world is encouraging more students to pursue and retain careers in STEM that contribute to the development and growth of industrialized societies (e.g., Atkinson and Mayo, 2010; UK Commission for Employment and Skills, 2015). To this end, researchers have explored what factors predict students' performance in undergraduate STEM classes and their persistence in STEM fields more broadly. Much of this work has focused on students' motivational beliefs, values, goals, and sense of belonging as predictors of their performance and retention in STEM (e.g., Bong, 2001; Wang and Degol, 2013; Cromley et al., 2016; Watt et al., 2017; Lazarides and Lauermann, 2019).

According to situated expectancy-value theory (Eccles and Wigfield, 2020), students' expectancies and subjective task values within specific domains, such as STEM, are key indicators of their motivation and predict their performance and choices in those domains. Expectancies refer to students' beliefs about their capabilities to accomplish certain tasks, and are highly related to students' self-efficacy beliefs, or their beliefs about their competence in a specific domain. Subjective task values are separated into utility value, defined as the usefulness of a task or domain; attainment value, defined as the importance of a task or domain; and intrinsic value, defined as one's interest in a task or domain (Eccles and Wigfield, 2020). Both expectancies and values have been shown to predict students' STEM outcomes across many studies (e.g., Andersen and Ward, 2013; Perez et al., 2014; Canning et al., 2018; Gaspard et al., 2019).

Within another theoretical framework, goal orientation theory, students' broad purposes for engaging in academic tasks are important indicators of their motivation (Urdan and Kaplan, 2020). Specifically, students can be oriented toward mastery goals (i.e., goals focused on mastery of concepts or skills) or performance goals (i.e., goals focused on performance; Dweck and Leggett, 1988). Performance goals are further separated into performance-approach goals (i.e., goals focused on performing well or doing better than others) and performance-avoidance goals (i.e., goals focused on avoiding performing poorly or doing worse than others; Elliot and Harackiewicz, 1996). In general, research demonstrates the beneficial effects of mastery goals and, to a somewhat lesser extent, performance-approach goals; and the maladaptive effects of performance-avoidance goals (e.g., Wolters, 2004; Chouinard et al., 2007; Hernandez et al., 2013), for students' STEM performance and retention. Relatedly, students' choices about what tasks they will pursue, such as whether they are willing to choose a difficult class or assignment in which they may learn a lot over an easy class or assignment in which they will learn very little, are likely to impact their ultimate performance and success in STEM fields (e.g., Hong et al., 1999).

Finally, students' sense of belonging is also a key predictor of their performance and retention in STEM fields (e.g., Strayhorn, 2012; Rainey et al., 2019). If students do not feel secure, comfortable, or that they "fit in" with others around them, they are likely to experience decreased motivation and are more at risk of dropping out of STEM (e.g., Thoman et al., 2014; Wilson et al., 2015).

In sum, students' motivational beliefs, values, goals, sense of belonging, and academic choices are critically important to their performance and retention in STEM. So, what predicts students' motivation and belonging in STEM? We turn next to the role of mindset contexts.

What Predicts Students' Motivation and Belonging? The Role of Mindset Contexts

According to Dweck, 1999 mindset theory, people hold different implicit beliefs about intelligence, also known as intelligence mindsets. A growth mindset is characterized by the belief that intelligence is malleable, whereas a fixed mindset is characterized by the belief that intelligence is fixed. Further, people's intelligence mindsets are strongly linked to other implicit beliefs they hold about effort and failure, and create a broader meanings system (e.g., Dweck, 1999; Molden and Dweck, 2006; Blackwell et al., 2007; Dweck and Yeager, 2019). Specifically, a fixed mindset about intelligence is thought to be closely tied with the belief that effort is a sign of low ability (e.g., Blackwell et al., 2007) and that failure is debilitating (e.g., Haimovitz and Dweck, 2016). In the present study, we will refer to this constellation of beliefs as "unproductive mindsets."

Researchers have found that students' own growth mindsets positively predict their motivation and belonging (e.g., Dweck and Leggett, 1988; Hong et al., 1999; Tabernero and Wood, 1999; Robins and Pals, 2002; Bråten and Strømsø, 2006; Blackwell et al., 2007; Payne et al., 2007; Nussbaum and Dweck, 2008; Chen and Pajares, 2010; Burnette et al., 2013; Degol et al., 2018; Lee and Seo, 2019; Bai and Wang, 2020; Lytle and Shin, 2020); most of this work has focused on intelligence mindsets. However, building off of earlier work on mastery vs. performance goal structures within a classroom (e.g., Ames, 1992; Meece et al., 2006; Patrick and Ryan, 2008; Murayama and Elliot, 2009), recent work by has

shifted away from focusing on mindsets at an individual level and has instead examined the motivational effects of different mindset *contexts* (Murphy and Dweck, 2010; Gasiewski et al., 2012; Schmidt et al., 2015; Canning et al., 2019; Fuesting et al., 2019; LaCosse et al., 2020; Muenks et al., 2020). Thus far, mindset contexts have been conceptualized and operationalized as the fixed vs. growth mindset values espoused by an organization (e.g., Murphy and Dweck, 2010; Canning et al., 2020) or by the actual or perceived fixed vs. growth mindsets of powerful people within those contexts, such as employers in a workplace or teachers in a classroom or school (e.g., Canning et al., 2019; LaCosse et al., 2020; Muenks et al., 2020).

The actual or perceived mindsets of teachers have been found to predict students' motivation and belonging. Schmidt et al. (2015) found that when middle school teachers emphasized growth intelligence mindsets in their teaching, their students benefited more from a student-centered growth mindset intervention, reporting sustained growth mindsets and mastery goal orientations over time. In a college STEM context, Canning et al. (2019) found that when professors reported more fixed intelligence mindsets, their students were less motivated in their classes, as measured by course evaluation items (e.g., "How much did your instructor motivate you to do your best work?"). Muenks et al. (2020) found that when undergraduate students *perceived* their professor to have stronger fixed intelligence mindsets, they reported more psychological vulnerability (including decreased belonging), and less interest and engagement in that professor's class throughout the semester (see also LaCosse et al., 2020). These results held when controlling for students' own intelligence mindsets, suggesting a unique effect of the perceived mindset context (here, operationalized as students' perceptions of their professors' intelligence mindsets) on students' outcomes. Similarly, Rattan et al. (2018) found that when students perceived STEM professors to believe that only *certain* students (rather than all students) could succeed, they experienced lower belonging in STEM.

In sum, recent research suggests that, above and beyond students' own intelligence mindsets, the perceived mindset contexts that surround students also affect their motivation and sense of belonging. However, in most of these studies, motivation was operationalized somewhat broadly (e.g., by course evaluation items; Canning et al., 2019; or by interest and engagement in a STEM class; Muenks et al., 2020). Only Schmidt et al. (2015) examined students' goal orientations, and this study focused on middle school students. No studies to our knowledge have examined how undergraduate students' perceptions of their professors' intelligence mindsets predict specific aspects of their motivation (self-efficacy, value, goal orientations), belonging, or their choices to pursue difficult tasks. Additionally, research thus far has focused on professors' intelligence mindsets, without examining students' perceptions of their professors' effort or failure mindsets, which may be more visible or salient to students in actual classroom contexts (e.g., Haimovitz and Dweck, 2016). Finally, research has thus far operationalized mindset contexts as the actual or perceived mindsets of professors, while neglecting the role of peers.

The Unique Role of Peers

In addition to teachers, peers are an integral and influential part of students' academic contexts and are critically important to students' motivation and belonging (e.g., Urdan and Schoenfelder, 2006; Song et al., 2015; King, 2016; Wentzel, 2017). Peers can create a positive motivational context by providing companionship, help, and emotional support (e.g., Riegle-Crumb and Morton, 2017; Wentzel, 2017; Zander et al., 2018), but can also create a negative motivational context by increasing competition and social comparison among classmates (e.g., Marsh, 1987; Fischer, 2017; Covarrubias et al., 2019; von Keyserlingk et al., 2020). Peer beliefs and norms can also spread quickly among students; in one study, Paluck et al., 2016 found that training just a few highly connected, "social referent" students on conflict reduction resulted in a spread of new anti-conflict norms throughout the student network. Examining mindsets specifically, King (2020) found that intelligence mindsets were socially contagious among classmates, such that students who were in classrooms in which their peers had stronger fixed intelligence mindsets were more likely to develop stronger intelligence fixed mindsets themselves over time. Peer mindsets have also been demonstrated to be impactful for students' outcomes: in a recent field experiment in the United States with a nationally representative sample, Yeager et al. (2019) found that an intervention aimed at changing students' own intelligence mindsets toward a growth mindset was most effective at increasing students' grades in schools where peer norms were also supportive of growth intelligence mindsets.

In sum, many studies have found that peers are important to students' motivation, and a few studies have specifically examined how peers' intelligence mindsets relate to students' own intelligence mindsets and performance outcomes. Thus, it may be particularly important to examine how peers play a unique role, above and beyond teachers or professors, in the perceived mindset contexts that permeate classrooms. That is, even if the teacher or professor espouses productive mindsets about intelligence, effort, or failure, students may still remain unmotivated or feel a lower sense of belonging if they perceived their peers to espouse unproductive mindsets. This may especially be the case in competitive undergraduate engineering contexts (e.g., Goubeaud, 2010; Covarrubias et al., 2019) such as the one used in the present study.

The Present Study

The broad purpose of the present study is to explore the role of undergraduate engineering students' perceptions of their professors' and peers' unproductive mindsets about intelligence, effort, and failure on their motivation and belonging. We seek to extend prior research in three key ways. First, though previous work has examined how students' perceptions of their professors' mindsets influence students' motivation and belonging (e.g., Canning et al., 2019; Muenks et al., 2020), "motivation" has often been broadly defined and has not been examined with respect to specific motivational beliefs, values, and goals. In the present study we will be able to examine more specific associations among

students' perceptions of their professors' mindsets and their motivation. Although the present study is exploratory in that we do not have specific hypotheses about which aspects of students' motivation would be most strongly related to their perceptions of their professors' and peers' unproductive mindsets, there are reasons to believe that these perceptions would be related to students' motivational beliefs, values, and goals. If students perceive an unproductive mindset context around them—that others in their field believe that their intelligence is fixed, that effort is a sign of low intelligence, and that failure is debilitating—they may become more worried about making a mistake or trying something new, which may lower their confidence and cause them to focus more on performing well (or on *not* performing poorly) rather than mastering the content (Schmidt et al., 2015) in that field. They may even decide to make choices that will make them look smart (such as choosing an easier assignment or to take a class with a professor who is known for giving easy grades) over choices that will help them learn more. They also may experience lower belonging in that field and start to value the field less—to feel that it is less useful, important, and/or interesting to them (LaCosse et al., 2020; Muenks et al., 2020).

Second, we examine the unique role of students' perceptions of their peers' unproductive mindsets in their motivation and belonging, which no previous studies have done. Thus, we will examine whether, above and beyond students' perceptions of their professors' unproductive mindsets, their perceptions of their *peers'* unproductive mindsets negatively predict their motivation and belonging. Third, we go beyond intelligence mindsets to explore other kinds of unproductive mindsets, including unproductive mindsets about effort (i.e., believing that effort is negatively associated with one's ability or intelligence; Blackwell et al., 2007) and unproductive mindsets about failure (i.e., believing that failure is debilitating; Haimovitz and Dweck, 2016). Given that other people's mindsets about effort and failure may be more salient or visible to students, because they are more proximal to the learning context, than intelligence mindsets (e.g., Haimovitz and Dweck, 2016), we sought to explore all three of these mindsets in the present study.

Although the central purpose of our study is to examine how professors' and peers' unproductive mindsets predict students' motivation and belonging, we start by simply examining the mean-level differences between students' perceptions of their professors' and peers' mindsets—that is, do students perceive that their professors or peers have more unproductive mindsets? Thus, we explore two research questions:

(1) What are the mean-level differences in students' perceptions of their and professors' and peers' unproductive mindsets about intelligence, effort, and failure?
(2) How do students' perceptions of their professors' and peers' unproductive mindsets about intelligence, effort, and failure predict students' motivation (self-efficacy, value, goal orientations), belonging, and academic choices, above and beyond their own mindsets?

MATERIALS AND METHODS

Participants

Participants were 304 undergraduate students majoring in Electrical and Computer Engineering at a large, public southwestern university (78.6% male, 21.4% female, 51.8% Asian, 28.1% White, 9.6% Hispanic/Latino, 7.4% Biracial or Multiracial, 2.3% Black, 0.3% Native Hawaiian or Pacific Islander, 0.7% Prefer not to say; Mean age = 19.56 years).[1] The sample consisted of 29.3% freshmen, 28% sophomores, 21.4% juniors, and 21.4% seniors.

Measures

Student mindsets. Participants responded to two items each measuring their intelligence mindsets (sample item: "You can learn new things, but you can't really change your basic intelligence"; α = 0.90; Dweck, 1999) and failure mindsets (sample item: "Experiencing failure inhibits my learning and growth"; α = 0.72; Haimovitz and Dweck, 2016), which were averaged to form composite scores. Participants also responded to two items measuring their effort mindsets ("To tell the truth, when I work hard at my schoolwork, it makes me feel like I'm not very smart" and "If you're not good at a subject, working hard won't make you good at it") taken from Blackwell et al., (2007); however, the two items had low internal consistency (α = 0.52). Thus, for the purposes of the present study, we only used the second item ("If you're not good at a subject, working hard won't make you good at it") as a measure of participants' effort mindsets. All items had a response scale of 1 = Strongly disagree to 6 = Strongly agree, where higher scores indicated stronger unproductive mindsets about intelligence, effort, and failure.

Perceptions of professors' mindsets. Participants responded to two items each measuring their perceptions of their professors' intelligence mindsets (sample item: "My ECE professors seem to believe that students have a certain amount of intelligence, and they really can't do much to change it"; α = 0.91; adapted from Dweck (1999)), effort mindsets (sample item: "My ECE professors seem to believe that if students are not good at a subject, working hard won't make them good at it"; α = 0.85; adapted from Blackwell et al. (2007)), and failure mindsets (sample item: "My ECE professors seem to believe that failure inhibits students' learning and growth"; α = 0.76; adapted from Haimovitz and Dweck (2016)) on a scale from 1 = Strongly disagree to 6 = Strongly agree. Higher scores indicated stronger perceived unproductive mindsets about intelligence, effort, and failure. Items were averaged to form composite scores.

Perceptions of peers' mindsets. Participants responded to two items each measuring their perceptions of their peers' intelligence mindsets (sample item: "My ECE peers seem to believe that people have a certain amount of intelligence, and they really can't do much to change it"; α = 0.95; adapted from

[1]Women were slightly overrepresented in this sample compared to the undergraduate population (18.9% women) and faculty (12.2% women) in the Electrical and Computer Engineering department.

Dweck (1999)), effort mindsets (sample item: "My ECE peers seem to believe that if people are not good at a subject, working hard won't make them good at it"; α = 0.85; adapted from Blackwell et al. (2007)), and failure mindsets (sample item: "My ECE peers seem to believe that failure is bad and should be avoided"; α = 0.79; adapted from Haimovitz and Dweck (2016)) on a scale from 1 = Strongly disagree to 6 = Strongly agree. Higher scores indicated stronger perceived unproductive mindsets about intelligence, effort, and failure. Items were averaged to form composite scores.

Motivation. Participants responded to two items measuring their self-efficacy ("How good at electrical and computer engineering are you?" on a scale from 1 = Not very good to 7 = Very good and "If you were to list all of the students from best to worst in electrical and computer engineering, where are you?" from 1 = One of the worst to 7 = One of the best; adapted from Jacobs et al. (2002)), which were averaged to form a composite score (α = 0.79). Participants also responded to one item each measuring their utility value ("How useful is what you learn in electrical and computer engineering?" from 1 = Not at all useful to 7 = Very useful), attainment value ("For me being good in electrical and computer engineering is . . . " from 1 = Unimportant to 7 = Important), and interest value ("I find working on electrical and computer engineering assignments . . . " from 1 = Boring to 7 = Interesting), all adapted from Jacobs et al. (2002). Finally, participants responded to one item each measuring their mastery goals ("In my ECE classes, I want to learn as much as possible"), performance-approach goals ("In my ECE classes, my goal is to get a better grade than most of the other students"), and performance-avoidance goals ("In my ECE classes, my goal is to avoid performing poorly"), on a scale from 1 = Not at all true of me to 6 = Very true of me, all adapted from Elliot and McGregor (2001).

Belonging. Participants responded to three items measuring their sense of belonging (sample item: "How much do you feel like you belong as a student in electrical and computer engineering (ECE)?") on a scale from 1 = Not at all to 7 = Completely, adapted from Murphy and Zirkel (2015). Items were averaged to form a composite score (α = 0.91).

Academic choices. Participants were asked two forced-choice questions. The first question was: "For one of your required courses, you have the option of two different instructors. Who would you choose?" with the response options: Instructor A, who is known to create challenging assignments and gives out few A-grades, but who students learn a lot from; or Instructor B, who is known to have easier assignments and give out more A-grades, but students learn less from. The second question was: "If you had a choice between one of two assignments, which would you choose?" with the response options: one that was harder and would probably lead to a lower grade, but where you would learn more; or one that was easier and would probably lead to a higher grade, but where you would learn less. Both items were coded such that 0 = choice of the easier instructor/assignment, whereas 1 = choice of the harder instructor/assignment.

SAT scores. We asked participants to report either their SAT or ACT scores. If they took the SAT, we also asked them whether their score was out of 1,600 or 2,400. We then converted all scores to an SAT score between 0 and 1,600.

Demographics. Participants reported their age, sex (coded 0 = male, 1 = female), race/ethnicity, and year in college.

Procedure

In Fall 2019 and Spring 2020, all Electrical and Computer Engineering undergraduate students at a large, public southwestern university in the United States were sent an email inviting them to participate in a 15 min survey from a faculty member in their department, in exchange for being entered into a raffle to win $25 or $50 Amazon gift cards. The sample reported in the present study (N = 304) includes participants from both waves of data collection (N = 242 from Fall 2019 and N = 62 from Spring 2020); because of this, wave (coded 0 = Fall 2019, 1 = Spring 2020) was included as a control variable in all analyses. Sixty-six participants completed the survey at both waves, but only their data from wave 1 (Fall 2019) was included.

Analysis Plan

To answer Research Question 1 (What are the mean-level differences in students' perceptions of their and professors' and peers' unproductive mindsets about intelligence, effort, and failure?), we conducted three paired samples t-tests using SPSS Version 25.

To answer Research Question 2 (How do students' perceptions of their professors' and peers' unproductive mindsets about intelligence, effort, and failure predict students' motivation (self-efficacy, value, goal orientations), belonging, and academic choices, above and beyond their own mindsets?), we conducted hierarchical regression analyses using SPSS Version 25. For all continuous outcome variables (self-efficacy, utility value, attainment value, intrinsic value, mastery goals, performance-approach goals, performance-avoidance goals, and belonging), we conducted hierarchical linear regression analyses. In Step 1, we entered in our three control variables, gender (coded 0 = male, 1 = female) SAT scores (which were z-scored), and wave (coded 0 = Fall 2019, 1 = Spring 2020). In Step 2, we entered students' own mindsets about intelligence, effort, and failure. In Step 3, we entered students' perceptions of their professors' mindsets about intelligence, effort, and failure. Finally, in Step 4, we entered students' perceptions of their peers' mindsets about intelligence, effort, and failure. We then examined the change in R^2 at each step to determine whether each set of variables explained a significant amount of variance in the outcome, above and beyond the variables included in the previous steps. Specifically, the change in R^2 at Step 2 allowed us to determine whether students' own mindsets predicted their motivation and belonging above and beyond the control variables (gender, SAT scores, and wave), the change in R^2 at Step 3 allowed us to determine whether students' perceptions of their professors' mindsets predicted their motivation and belonging above and beyond their own implicit beliefs, and the change in R^2 at Step 4 allowed us to determine whether students' perceptions of their peers' mindsets predicted their motivation and belonging above

TABLE 1 | Descriptives and correlations of all variables.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1. Self-intelligence																					
2. Self-effort	0.47**																				
3. Self-failure	0.25**	0.37**																			
4. Prof-intelligence	0.45**	0.35**	0.20**																		
5. Prof-effort	0.33**	0.50**	0.29**	0.66**																	
6. Prof-failure	0.23**	0.26**	0.35**	0.34**	0.51**																
7. Peer-intelligence	0.25**	0.24**	0.20**	0.43**	0.35**	0.09															
8. Peer-effort	0.16**	0.34**	0.23**	0.42**	0.55**	0.18**	0.61**														
9. Peer-failure	0.07	0.13*	0.26**	0.21**	0.21**	0.17**	0.51**	0.51**													
10. Self-efficacy	−0.06	−0.09	−0.20**	−0.10	−0.12*	−0.07	−0.12*	−0.14*	−0.12*												
11. Utility value	−0.08	−0.22**	−0.14*	−0.23**	−0.25**	−0.10	−0.12*	−0.20**	−0.12*	0.20**											
12. Attainment value	−0.04	−0.07	−0.07	−0.22**	−0.20**	−0.05	−0.05	−0.13*	−0.10	0.26**	0.51**										
13. Intrinsic value	−0.11*	−0.14*	−0.21**	−0.26**	−0.15**	−0.01	−0.23**	−0.25**	−0.31**	0.31**	0.61**	0.46**									
14. Mastery	−0.04	−0.15*	−0.20**	−0.15*	−0.14*	−0.03	−0.19**	−0.17**	−0.26**	0.18**	0.47**	0.42**	0.47**								
15. Perf approach	0.13*	0.13*	0.06	0.03	0.07	0.09	0.02	0.09	0.06	0.34**	0.05	0.23**	0.12*	0.14*							
16. Perf avoidance	0.04	0.03	0.17**	0.07	0.06	0.12*	−0.01	0.10	0.07	−0.16**	−0.01	0.11	−0.17**	0.10	0.09						
17. Belonging	−0.07	−0.14*	−0.32**	−0.28**	−0.27**	−0.14*	−0.28**	−0.39**	−0.28**	0.47**	0.41**	0.29**	0.48**	0.33*	0.09	−0.13*					
18. Choice-instructor	−0.06	−0.08	−0.16**	−0.06	−0.04	−0.08	−0.07	−0.03	−0.11	0.12	0.21**	0.13*	0.25**	0.39**	−0.07	−0.06	0.17**				
19. Choice-assignment	−0.11	−0.17**	−0.15**	−0.04	0.001	−0.003	−0.04	−0.04	−0.18**	0.10	0.12*	0.09	0.21**	0.30**	−0.05	−0.04	0.08	0.48**			
20. SAT	0.01	0.04	−0.05	−0.04	0.09	−0.08	−0.01	0.03	−0.08	0.24**	−0.07	−0.04	−0.003	−0.03	0.22**	−0.11*	0.10	−0.04	0.03		
21. Female	−0.07	−0.11	−0.03	0.01	0.02	−0.06	0.09	0.12*	0.03	−0.18**	−0.01	0.001	0.03	0.01	−0.07	0.06	−0.22**	0.01	0.09	−0.07	
Mean	2.83	2.23	3.05	2.43	1.89	2.14	3.35	2.83	3.79	4.46	5.55	6.03	5.13	5.02	4.09	4.83	4.80	N/A	N/A	1,466.91	N/A
SD	1.27	1.17	1.12	1.06	0.89	0.94	1.31	1.24	1.22	1.22	1.40	1.19	1.46	1.16	1.53	1.31	1.51	N/A	N/A	86.38	N/A
Range	1–6	1–6	1–6	1–6	1–6	1–6	1–6	1–6	1–6	1–6	1–7	1–7	1–7	1–6	1–6	1–6	1–7	0–1	0–1	0–1,600	0–1

*Note. N = 304. *p < 0.05, **p < 0.01. All variables that begin with "self" are students' own mindsets; all variables that begin with "prof" are students' perceptions of their professors' mindsets; and all variables that begin with "peer" are students' perceptions of their peers' mindsets. Mindsets about intelligence, effort, and failure and coded such that high licate more unproductive mindsets (or perceived mindsets). Choice variables are coded 0 = easier instructor/assignment, 1 = harder instructor/assignment. Female is coded 0 = male, 1 = female. Perf = performance.*

TABLE 2 | Perceived professor and peer mindsets predicting motivation and belonging: R-square change at each step.

	Self-efficacy	Utility value	Attainment value	Intrinsic value	Mastery goals	Performance approach goals	Performance avoidance goals	Belonging
Step 1: Controls	0.08***	0.01	0.01	0.001	0.001	0.05**	0.02	0.06**
Step 2: Self mindsets	0.04**	0.05**	0.01	0.05**	0.05**	0.02	0.03*	0.11***
Step 3: Perceived professor mindsets	0.01	0.04*	0.06**	0.06***	0.02	0.01	0.01	0.05***
Step 4: Perceived peer mindsets	0.003	0.01	0.01	0.06***	0.05**	0.01	0.02	0.05***

Note. *p < *0.05*, **p < *0.01*, ***p < *0.001*.

TABLE 3 | Perceived professor and peer mindsets predicting student choices: Nagelkerke R square at each step.

	Choice of more difficult instructor	Choice of more difficult assignment
Step 1: Controls	0.01	0.02
Step 2: Self mindsets	0.04*	0.06*
Step 3: Perceived professor mindsets	0.05	0.08
Step 4: Perceived peer mindsets	0.06	0.13*

Note. *p < *0.05*, **p < *0.01*, ***p < *0.001*. p-*values correspond to the chi-square test of model coefficients at each step.*

and beyond their own mindsets and their perceptions of their professors' mindsets.

For the two dichotomous outcome variables (choice of professor and choice of assignment), we conducted hierarchical logistic regression analyses. We followed the same procedure as with the continuous outcome variables, but examined the Nagelkerke R^2 and the chi-square value at each step of the model in order to examine whether each set of variables explained a significant amount of variance in the outcome, above and beyond the variables included in the previous steps.

RESULTS

Descriptives and Correlations

See **Table 1** for descriptives (means, standard deviations, ranges) and correlations for all variables.

Research Question 1: What are the mean-level differences in students' perceptions of their and professors' and peers' unproductive mindsets about intelligence, effort, and failure?

We found that participants perceived their peers to have significantly stronger fixed mindset beliefs (M = 3.34) than their professors (M = 2.43), t (302) = −12.41, p < 0.001, Cohen's d = 0.71, significantly more negative beliefs about effort (M = 2.83) than their professors (M = 1.89), t (303) = −15.42, p < 0.001, Cohen's d = 0.86, and significantly more negative beliefs about failure (M = 3.79) than their professors (M = 2.14), t (303) = −20.44, p < 0.001, Cohen's d = 1.18. That is, students perceived their peers to have more unproductive mindsets than their professors.

Research Question 2: How do students' perceptions of their professors' and peers' unproductive mindsets about intelligence, effort, and failure predict students' motivation (self-efficacy, value, goal orientations), belonging, and academic choices, above and beyond their own mindsets?

See **Table 2** for a summary of results of R^2 change from the motivation (self-efficacy, values, and goals) and belonging outcomes, and **Table 3** for a summary of results of chi-square at each step from the choice outcomes. See **Supplementary Tables S1–S10** in the Supplemental Materials for all individual models including coefficients for each variable at each step.

Motivation

We explored three broad categories of motivation: self-efficacy, value, and achievement goal orientation.

Self-Efficacy. For self-efficacy, the change in R^2 was only significant at Step 2, F (3, 296) = 4.35, p = 0.005, indicating that students' own mindsets predicted their self-efficacy above and beyond the control variables (gender, SAT score, and wave). The change in R^2 was not significant at Step 3 or Step 4, indicating that students' perceptions of their professors' and peers' mindsets did not predict their self-efficacy above and beyond their own mindsets.

Value. For utility value, the change in R^2 was significant at Step 2, F (3, 296) = 5.43, p = 0.001, and Step 3, F (3, 293) = 3.75, p = 0.01, indicating that students' own mindsets predicted their utility value above and beyond the control variables, and students' perceptions of their professors' mindsets predicted their utility value above and beyond their own mindsets.

For attainment value, the change in R^2 was only significant at Step 3, F (3, 293) = 5.95, p = 0.001, indicating that students' perceptions of their professors' mindsets predicted their attainment value above and beyond their own mindsets.

For intrinsic value, the change in R^2 was significant at Step 2, F (3, 296) = 5.06, p = 0.002, Step 3, F (3, 293) = 7.02, p < 0.001, and Step 4, F (3, 290) = 6.89, p < 0.001, indicating that students' own mindsets predicted intrinsic value above and beyond the control variables, students' perceptions of their professors' mindsets predicted their intrinsic value above and beyond their own mindsets, and students' perceptions of their peers' mindsets predicted their intrinsic value above and beyond their own mindsets and their perceptions of their professors' mindsets.

Goal orientation. For mastery goals, the change in R^2 was significant at Step 2, F (3, 296) = 4.76, p = 0.003, and Step 4, F (3, 290) = 4.85, p = 0.003, indicating that students' own mindsets predicted their mastery goals above and beyond the control variables, and students' perceptions of their peers' mindsets

predicted their mastery goals above and beyond their own mindsets and their perceptions of their professors' mindsets.

For performance-approach goals, the change in R^2 was only significant at Step 1, F (3, 299) = 5.41, p = 0.001, indicating that none of the mindset or perceived mindset variables predicted students' performance-approach goals above and beyond the control variables.

For performance-avoidance goals, the change in R^2 was only significant at Step 2, F (3, 296) = 2.93, p = 0.03, indicating that students' own mindsets predicted their performance-avoidance goals above and beyond the control variables. The change in R^2 was not significant at Step 3 or Step 4, indicating that students' perceptions of their professors' and peers' mindsets did not predict their performance-avoidance goals above and beyond their own mindsets.

Belonging

For students' sense of belonging, the change in R^2 was significant at Step 1, F (3, 299) = 5.91, p = 0.001, Step 2, F (3, 296) = 12.38, p < 0.001, Step 3, F (3, 293) = 6.76, p < 0.001, and Step 4, F (3, 290) = 6.91, p < 0.001. That is, each set of variables at each step predicted students' sense of belonging above and beyond the sets of variables at the lower steps. Of particular interest to the present study, students' perceptions of their professors' mindsets predicted students' sense of belonging above and beyond their own mindsets, and students' perceptions of their peers' mindsets predicted students' sense of belonging above and beyond their own mindsets and their perceptions of their professors' mindsets.

Choices

For choice of a more difficult instructor who students learn more from (over an easier instructor who students learn less from), the Nagelkerke R^2 was only significant at Step 2, χ^2 = 8.26, p = 0.04, indicating that students' own mindsets predicted their choice of instructor above and beyond the control variables (gender and SAT score). The Nagelkerke R^2 was not significant at Step 3 or Step 4, indicating that students' perceptions of their professors' and peers' mindsets did not predict their choice of instructor above and beyond their own mindsets.

For choice of a more difficult assignment that students get a worse grade on but learn more from (over an assignment that students get a better grade on but learn less from), the Nagelkerke R^2 was significant at Step 2, χ^2 = 10.20, p = 0.02, and Step 4, χ^2 = 10.89, p = 0.01. That is, students' own mindsets predicted their choice of a more difficult assignment above and beyond the control variables, and students' perceptions of their peers' mindsets predicted their choice of a more difficult assignment above and beyond their own mindsets and their perceptions of their professors' mindsets.[2]

[2]In exploratory analyses, we also examined whether gender moderated the association between students' perceptions of their professors' and peers' implicit beliefs and students' motivation, belonging, and choices. We only found one gender x perceived peer beliefs interaction effect on performance-approach goals, such that the more women (but not men) perceived their peers to have fixed beliefs, the more likely they were to report performance-approach goals (see **Supplementary Table S11** in the Supplemental Materials).

DISCUSSION

The overall purpose of the present study was to examine how undergraduate engineering students' perceptions of their professors' and peers' mindsets predicted their motivation, belonging, and academic choices in engineering. We found, consistent with prior research (e.g., Tabernero and Wood, 1999; Robins and Pals, 2002; Bråten and Strømsø, 2006; Payne et al., 2007; Chen and Pajares, 2010; Degol et al., 2018; Lee and Seo, 2019; Bai and Wang, 2020; Lytle and Shin, 2020), that students' own mindsets predicted their motivation (self-efficacy, utility value, intrinsic value, mastery goals, performance-avoidance goals), belonging, and choices of difficult (over easy) tasks, even controlling for gender and prior achievement (i.e., SAT scores). Specifically, students' unproductive mindsets were negatively associated with students' self-efficacy, utility value, intrinsic value, and mastery goals, and positively associated with their performance-avoidance goals. However, extending this research and consistent with other recent work (e.g., Rattan et al., 2018; LaCosse et al., 2020; Muenks et al., 2020), we found that the perceived mindset *context* of the classroom, as operationalized by students' perceptions of their professors' and peers' mindsets, also predicted their motivation, belonging, and academic choices. Specifically, students who perceived their engineering professors to have more *unproductive mindsets* about intelligence, effort, and failure—that is, perceived their professors to believe that intelligence is fixed, effort is a sign of low ability, and failure is debilitating—reported less utility value, attainment value, and intrinsic value, and lower belonging in engineering. Further, students who perceived their engineering peers to have more unproductive mindsets reported lower intrinsic value, mastery goals, and belonging in engineering, and were less likely to choose a difficult engineering assignment where they would learn a lot over an easy assignment where they would learn very little.

Our findings regarding students' perceptions of their professors' mindsets predicting their motivation and belonging are consistent with prior research (e.g., Rattan et al., 2018; LaCosse et al., 2020; Muenks et al., 2020). In our study, just as in these previous studies, we controlled for students' own mindsets, demonstrating that perceived mindset *contexts* (here, operationalized as students' perceptions of their professors' mindsets) predict students' psychological and motivational outcomes above and beyond students' own mindsets (e.g., Murphy and Dweck, 2010). We note, however, that it would be interesting to further explore (perhaps with qualitative methods) the extent to which students' own mindsets shape how they interpret others' mindsets, as well as whether there may be self-enhancement or self-improvement effects in how people view themselves vs. others (e.g., Heckhausen and Krueger, 1993). We also controlled for prior achievement (i.e., SAT scores), which suggests that these effects are not simply a function of students' prior academic performance. We extended prior studies that measured students' motivation, interest, or engagement in more general ways (e.g., Canning et al., 2019; LaCosse et al., 2020; Muenks

et al., 2020) by examining how students' perceptions of their professors' mindsets predicted specific motivational beliefs, values, and goals, using situated expectancy-value theory (Eccles and Wigfield, 2020) and goal orientation theory (Urdan and Kaplan, 2020) as theoretical frameworks. Interestingly, we found that students' perceptions of their engineering professors' mindsets were particularly strongly predictive of their *value* of engineering, as well as their belonging. That is, when students perceived their engineering professors to have unproductive mindsets about intelligence, effort, and failure, they reported that engineering was less useful, important, and interesting to them, and felt less like they belonged in engineering, even controlling for their own mindset beliefs. Perhaps professor messages that communicate to students that only the smartest students can succeed, that effort is a sign of low ability, and that failure is debilitating, lead students to place less emphasis on the value or importance of those classes in order to protect their self-concept (e.g., Harter, 1986). The results for belonging are consistent with prior literature and suggest that professors' communication of unproductive mindsets can undermine students' feelings of comfort and fit in those professors' classes (e.g., Rattan et al., 2018; LaCosse et al., 2020; Muenks et al., 2020). This is especially concerning given that students' value and feelings of belonging in STEM courses are very strong predictors of whether they remain in the STEM pipeline or drop out of it (Wang and Degol, 2013; Cromley et al., 2016).

Thus far, most of the work examining mindset contexts in academic settings has focused on the role of professors' or teachers' mindsets, as professors have the power to shape the classroom structure, policies, and culture (e.g., Schmidt et al., 2015; Canning et al., 2019; LaCosse et al., 2020; Muenks et al., 2020). However, the professor is not the only person who makes up the context of a classroom; peers also play a critical role (e.g., Song et al., 2015; Wentzel, 2017; Yeager et al., 2019; King, 2020). A major contribution of the present study is that we examined whether students' perceptions of their *peers'* mindsets predicted their motivation, belonging, and academic choices above and beyond their perceptions of their professors' mindsets (and their own mindsets). We hypothesized that even if students perceived their professors to have more productive mindsets about intelligence, effort and failure (i.e., having stronger growth mindsets, believing that effort and failure are important and useful), they may still experience decreased motivation or a sense of belonging if they perceive that their peers have unproductive mindsets. Indeed, we found that, on average, students did perceive their peers to have more unproductive mindsets than their professors—that is, to have stronger fixed mindsets about intelligence, to believe more strongly that effort is useless, and to believe more strongly that failure is debilitating. Further, when engineering students perceived their peers to have more unproductive beliefs about intelligence, effort, and failure, they reported lower intrinsic value, mastery goals, and belonging in engineering; they were also less likely to choose a difficult over an easy task, even after controlling for students' own mindsets and perceptions of professors' mindsets. These findings suggest that peers play a unique role in the mindset context of a classroom, particularly when it comes to how much students enjoy and feel like they "fit in" in their engineering classes, the extent to which they are oriented toward learning or mastery, and their willingness to choose challenging (yet useful) assignments. More research is needed to build a theoretical model of how perceptions of teachers' and peers' unproductive mindsets may be related to specific motivational beliefs, values, and goals.

Another contribution of the present study is a broader operationalization of students', professors', and peers' mindsets that extends beyond intelligence mindsets, which has been a major focus of previous research (e.g., Canning et al., 2019; LaCosse et al., 2020; Muenks et al., 2020). In this study, we not only examined mindsets about intelligence (i.e., whether intelligence is fixed or malleable; Dweck, 1999) but also mindsets about effort (e.g., Blackwell et al., 2007) and failure (e.g., Haimovitz and Dweck, 2016). Previous research by Haimovitz and Dweck, 2016; suggests that failure mindsets of parents and teachers may be more proximal to the learning context and thus more visible to students than intelligence mindsets; we expected that this may be the case for mindsets about effort as well. Though not a central focus of the present study, we did find some differences in which mindsets (or perceived mindsets) were most predictive of different outcomes. For example, when examining how students' perceptions of their professors' mindsets predict their value and belonging, intelligence mindsets seemed to play a key role. In contrast, when examining how students' perceptions of their peers' mindsets predict their intrinsic value, mastery goals, and academic choices, failure mindsets seemed to play a key role; and when examining how students' perceptions of their peers' mindsets predict their belonging, effort mindsets play a key role. These findings suggest that future researchers should consider the role of multiple mindsets, not just intelligence mindsets, on students' outcomes, particularly when examining students' perceptions of others' mindsets.

There were several aspects of motivation that were not predicted by students' perceptions of their professors' and peers' mindsets. Specifically, neither perceptions of professors nor peers predicted students' self-efficacy, performance goals (approach or avoidance), or choice of a difficult instructor. These results were somewhat surprising, as we expected that perceiving unproductive mindset contexts would undermine students' confidence and willingness to pursue difficult tasks. Further, previous research has found that goal structures of classrooms—which are conceptually similar to perceived mindset contexts—are predictive of students' own goal orientations (e.g., Meece et al., 2006). Perhaps there may be more complex associations between one's own mindsets, perceptions of professors' and peers' mindsets, and self-efficacy, such that perceived unproductive mindset contexts only negatively affect students' self-efficacy when students hold a fixed mindset themselves (e.g., Chen and Tutwiler, 2017). With respect to performance goal orientations, perhaps these are less affected by students' perceptions of mindset contexts in a major

that is already highly competitive, such as engineering (e.g., Goubeaud, 2010); however, future research should explore this further.

Several limitations of this study should be noted. First, this study is a cross-sectional, correlational study so we are unable to make any causal or directional claims about our effects. It is possible that students' feelings of motivation and belonging predict their perceptions of the mindset context around them, instead of the other way around. Though theory, prior experimental work (e.g., LaCosse et al., 2020), and prior longitudinal work (e.g., Muenks et al., 2020) have found that perceived mindset contexts (operationalized as students' perceptions of their professors' mindsets) influence or predict students' motivation and belonging, future research should further explore the directionality of these effects, specifically when it comes to students' perceptions of their peers' mindsets. Future researchers could also examine more complex process models, for example examining how students' perceptions of their professors' and peers' mindsets predict their self-efficacy and belonging, which then predict their goal orientations. Second, some of our motivation variables are measured with single items, due in part to the need for short surveys. Though research suggests that single-item measures can be appropriate for unidimensional constructs (e.g., Gogol et al., 2014), future researchers should use more robust measures of these constructs. Third, all of our measures asked about students' perceptions of their mindset context and their motivation and belonging in their Electrical and Computer Engineering classes in general, rather than about specific Electrical and Computer Engineering classes. These perceptions, though not specific to any one class, may nevertheless be important for predicting students' persistence and success within the field (e.g., Rainey et al., 2019). However, because we did not measure these perceptions in specific classrooms, we were unable to model contextual effects at the classroom level (e.g., Marsh et al., 2012). Future research should explore contextual effects using these methods to gain a more complete picture of how different mindset contexts could impact students' motivation and belonging. Finally, it is important to note that this study was conducted in a very particular context of Electrical and Computer Engineering, which is highly competitive (Goubeaud, 2010), male-dominated, and not particularly diverse with respect to gender and race/ethnicity. Our sample was largely male (78.6%), and Asian (51.8%) or White (28.1%), which, although representative of the specific department from which the sample was drawn, should not be generalized to all students. Future research should explore whether students also perceive their peers to have more unproductive mindsets than their professors in contexts that are less competitive, more cooperative, and/or more diverse. Further, although we examined whether gender moderated any of our effects and only found one interaction (see **Supplementary Table S11** in the Appendix), it is important to note that we had limited power to explore these interactions. Future research should examine, in more diverse samples, the extent to which these associations may look different for marginalized or minoritized students—that is, whether unproductive mindset contexts may be particularly harmful for students who are already negatively stereotyped in a domain such as engineering (e.g., Canning et al., 2020; LaCosse et al., 2020).

In sum, our findings emphasize the important role of the perceived mindset context in students' motivation, belonging, and willingness to choose difficult tasks. Our findings support and extend prior research that found that professors are an important part of the perceived mindset context, demonstrating that perceiving unproductive mindsets in engineering professors predict lower value and belonging in engineering. Importantly, we also find that peers are a critical part of the perceived mindset context, that students perceive their peers to have more unproductive mindsets than their professors, and that students' perceptions of their peers' unproductive mindsets uniquely predict their intrinsic value, mastery goals, belonging, and willingness to choose difficult assignments. Although future researchers should continue to explore this, these findings support a broader literature (e.g., Ames, 1992; Meece et al., 2006; Patrick and Ryan, 2008; Murayama and Elliot, 2009; Murphy and Dweck, 2010; Gasiewski et al., 2012; Schmidt et al., 2015; Canning et al., 2019; Fuesting et al., 2019; Yeager et al., 2019; King, 2020; LaCosse et al., 2020; Muenks et al., 2020) that emphasize the key role of perceived mindset contexts, and suggest that future interventions aimed to increase students' motivation, sense of belonging, and retention in STEM should focus on creating a more productive mindset context for students rather than simply focusing on changing students' own mindsets. Further, interventions at the teacher level should not only focus on changing teachers' own mindsets but also how to create productive mindsets among peers.

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 human participants were reviewed and approved by the Office of Research Support and Compliance at the University of Texas at Austin. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

KM, VY, and NT conceptualized the idea for the manuscript and assisted with data collection. KM conducted analyses and wrote the manuscript with assistance from VY.

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SUPPLEMENTARY MATERIAL

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What Predicts Quality of Learners' Study Efforts? Implicit Beliefs and Interest Are Related to Mastery Goals but Not to Use of Effective Study Strategies

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What goes into motivating students to take effective action? Ideally, students are not only motivated to invest time into their studying, but that they use their time in effective and productive ways. In the present study, we surveyed college undergraduates (*N* = 366) about how they engage in one of their college courses. Specifically, we explored how their motivation-related implicit beliefs (*ease and difficulty mindsets, intelligence mindset;* Dweck, 2000; Fisher and Oyserman, 2017) interact with perceived course interest and course importance to predict their achievement goal orientation for the course and the quality of their study strategies. We used a person-centered latent profiles analysis approach categorize meaningful profiles of implicit beliefs. Those who were likely to highly endorse motivation-increasing implicit beliefs and who found a course interesting were also more likely to hold mastery-approach goals; the relationship, however, was more complicated for performance-approach and performance-avoidance goals. Implicit beliefs profiles themselves did not directly relate to strategy use, but goal orientation did. In particular, mastery-approach goal orientation was uniquely related to all three of the effective study strategies subscales (e.g., elaborative, standard testing, generative testing). Mastery-avoidance was related to less use of elaborative strategies, and performance-goals were not related to any type strategy use. Perceived course importance was positively related to increased passive and elaborative strategies, but not the standard testing or generative testing strategies. We discuss implications for interventions.

Keywords: implicit beliefs, achievement goals, value, study strategies, interest

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INTRODUCTION

What goes into motivating students to take effective action? Research on motivation in the educational domain can be broadly categorized into the theories that relate to domain-general motivation-related implicit beliefs (e.g., interpretations of ease and difficulty, growth mindset) and those that relate to content-specific constructs (e.g., value of a particular task or subject). The existing literature largely focuses on how implicit beliefs and value matter for academics because they affect the ways in which students engage. Beyond just affecting the quantity of study

(students' studying harder and for longer), both domain-general implicit beliefs and task-specific value also affect the *quality* of study (students' studying smarter, in deeper, more effective ways). In the present study, we examine how these implicit beliefs and value affect students' quality of study in two ways: as achievement goals, and as study strategies. We build upon the existing literature in several ways. First, rather than pit one type of implicit belief against another, we consider different types of implicit beliefs collectively by identifying "latent profiles" of beliefs. Second, rather than examining how implicit beliefs and value separately relate to study engagement, we examine them together, finding interactions that may have important implications for intervention. Third, we examine how implicit beliefs, value, and achievement goals relate to students' use of study strategies, drawing on recent literature from cognitive psychology about different types of strategies.

In the following sections, we first clarify our definition of study quality as achievement goals and study strategies. For each, we describe the reasons for why they are important for academic achievement and how they may be influenced by implicit beliefs and value.

Studying Smarter, Not Just Harder: Achievement Goals and Study Strategies

Particularly in the college context and beyond, learners do not always have more time to study. Rather than focusing on how motivational constructs promote task persistence (studying harder), it is therefore also important to consider how they promote higher quality of study (studying smarter). In the present study, we examine two operationalizations of study quality. The first set of outcomes we are interested in is students' achievement goal orientations. Achievement goal orientations reflect the qualitative ways in which a student defines a successful learning outcome—are they aiming to just do well on course exams and assignments or are they also aiming to develop their competencies and truly learn the content. As such, achievement goals qualitatively change the target of study effort and are an important precursor for the ways students study. The second set of outcomes that we are interested in is students' use of specific study strategies (i.e., the qualitative differences in how they engage during study).

Achievement Goals Matter

Achievement goal theory (Ames and Archer, 1988; Elliot, 1999; Elliot and Murayama, 2008; Senko et al., 2011) highlights that there are different types of goals that a person may be oriented toward: performance goals (e.g., getting good grades, doing better than one's peer) and mastery goals (e.g., developing one's competence, mastering the to-be-learned content). These two types of goals are not the opposite of one another; individuals may hold both simultaneously. A student might both want to master the content and do well on their exams. But the two types of goals are also distinct: It is possible, for example, that a student will cram to get a good grade on the exam and not care if they forget the content soon afterward. Furthermore, these goals also have a valence: approach (focused on positive success, e.g., striving to get a high grade or learn deeply) or avoidance (focused on avoiding negative failure, e.g., striving to avoid failure, or not learning). This 2 × 2 conceptualization of achievement goals yields four types of goal orientations: mastery-approach, performance-approach, mastery-avoidance, and performance-avoidance.

Achievement goals are an important dependent variable to examine because they matter for academic behavior and outcomes. The avoidance-focused goals (mastery-avoidance and performance-avoidance) both tend to be related to negative outcomes (e.g., anxiety, disengagement; Hulleman et al., 2010). The two approach-focused goals (e.g., mastery-approach and performance-approach goals) share some overlapping outcomes, but also have some distinct outcomes. Both are positively related to academic achievement (although there is some suggestion that performance-approach goals might be more reliably related to academic achievement; Harackiewicz et al., 2002; Hulleman et al., 2010). Performance-approach goals, however, may also be uniquely related to maladaptive behaviors too such as increased anxiety and cheating (Anderman et al., 1998; Midgley et al., 2001; Karabenick, 2003; Murdock et al., 2004). Mastery-approach is thought to be uniquely related to more adaptive behaviors, such as intrinsic motivation, persistence and self-efficacy (Grant and Dweck, 2003; Liem et al., 2008).

Predictors of Achievement Goals

In the present study, we are interested in how implicit beliefs, interest, and value are related to achievement goals. Implicit beliefs shape how we interpret and respond to our experiences, and hence can affect achievement goals. Research on achievement goals has been closely linked to one particular type of implicit belief: belief about the nature of intelligence (Dweck and Leggett, 1988; Dweck, 2000). This research has focused on whether a person believes that intelligence is innate and cannot be changed (fixed mindset) or whether they believe that intelligence can be changed and increased through effort (growth mindset). If one believes that intelligence is fixed, they may become more preoccupied with demonstrating competence (i.e., performance), but if one believes that intelligence can grow, then they are more likely to take on a mastery-focus. Indeed, empirical research finds that growth mindset is related to higher mastery goals and lower performance-avoidance goals (Robins and Pals, 2002; Bråten and Strømsø, 2004; Chen and Pajares, 2010).

Belief about the nature of intelligence, however, is not the only implicit belief that can influence achievement goals. Separate from beliefs about intelligence, people may also directly hold beliefs about how the experience of ease or difficulty during learning is interpreted, and these can have an impact on whether learners are focused. For example, when a learner encounters difficulty in the process of learning, they might take that difficulty as a sign that the odds of success are low (*difficulty-as-impossibility),* and this may foster an avoidance focus: trying simply not to perform too poorly. In contrast, if the learner interprets that difficulty as a sign that the task is important for them (*difficulty-as-importance*) and hence that one should lean in and engage more deeply, then this may foster an approach-focus: to do well. Analogous interpretations of ease—*ease-as-possibility, ease-as-triviality*—are similarly distinct.

Indeed, Fisher and Oyserman (2017) found that the motivation-increasing ease and difficulty beliefs (difficulty-as-importance, ease-as-possibility) were related to approach-focused goals and while the motivation-undermining ease and difficulty beliefs (difficulty-as-impossibility, ease-as-triviality) were related to avoidance-focused goals.

Finally, whereas implicit beliefs tend to be relatively domain-general, content-specific factors also play key roles in motivation (e.g., Eccles et al., 1983; Schiefele, 1991). In the present study, we focus on two types of value: interest in course content and perceived importance of a course. Learners with a high individual interest in a topic are more likely to ask questions, process for meaning, be reflective, and engage in the mental work of re-organizing their conceptual understanding (Renninger et al., 2002, 2008). In a similar vein, increasing the perceived importance of a course or topic may also increase motivation and academic outcomes. Both correlational and experimental studies have found that increasing the interest and utility-value of course content (Schiefele, 1991; Hulleman and Harackiewicz, 2009; Harackiewicz and Hulleman, 2010) leads to better academic performance. But studies have also shown that may be important for the *quality* of study too. There is substantial literature connecting value to goals (Wigfield and Cambria, 2010). Interest, for example, is thought to both give rise to and is deepened by mastery goals (Harackiewicz et al., 2002; Hulleman et al., 2008; Renninger et al., 2008). A qualitative study by Lipstein and Renninger (2007), for example, found that students who with a more developed writing interest set themselves more sophisticated, mastery-oriented goals (as opposed to the more performance-oriented goal of "just get it done").

Effective Strategies Matter, but Are Not Always Intuitive

Operationalization of deeper learning strategies in the existing education literature has tended to be based on relatively outdated frameworks of learning strategies. In particular, much of the literature has focused on deep versus surface learning strategies (Biggs, 1985; Haggis, 2003). Deep learning strategies focus on understanding meanings and making connections, and include activities like self-explanation and elaboration. Surface strategies are those that focus primarily on memorization of facts. While there is still merit in the deep versus surface distinction, the past three decades of cognitive psychology research has seen a great deal of progress in understanding effective strategies for learning, including identifying other types of strategies as effective, perhaps even more so than the classic deep strategies.

The general understanding that effective strategies are ones that engage learners more deeply into the learning process has not changed. What has changed as a result of empirical research in the past decades, however, is an understanding that effective strategies (see desirable difficulties, Bjork, 1994; Yan et al., 2017) are not always obvious or intuitive (McCabe, 2011; Hartwig and Dunlosky, 2012; Bjork et al., 2013). In a large review of the empirical evidence behind the effectiveness of different study strategies, Dunlosky et al. (2013) rated various study strategies based on whether positive effects of the strategies generalized across learning conditions, student characteristics, materials, and different types of tests. The classic deep strategies, elaboration and self-explanation, were rated as moderate-utility strategies. Another classic deep strategy, summarization, was rated as having low-utility, together with other classic surface strategies, such as rereading and highlighting.

Self-testing, however, was rated as a high-utility strategy. Indeed, one of the most robust findings in cognitive psychology is the benefits of retrieving information from long-term memory—it deepens the learning and makes it more easily recalled in the future (Bjork, 1975; Roediger et al., 2011; Rowland, 2014, and it is often missing from operationalizations of deep learning strategies (e.g., as in the Motivated Strategies for Learning Questionnaire, MSLQ; Pintrich et al., 1991), or combined together with low-utility rereading strategies (e.g., as in the Learning and Study Strategies Inventory, LASSI; Weinstein et al., 1987). Moreover, there are benefits of self-testing even when you cannot retrieve anything. The very act of attempting to generate a response, and hence activating one's prior knowledge, helps to potentiate subsequent learning: that is, there are benefits to testing oneself even before initial learning (Yan et al., 2014b; Little and Bjork, 2016; Sana et al., 2020). These aspects of retrieval practice tend to be missing from the older formulations of deep learning, or are often combined together with the less effective strategies. Unlike the benefits of elaborative processing, the benefits of retrieval practice are consistently underappreciated, especially when compared to rereading (Roediger and Karpicke, 2006; Kirk-Johnson et al., 2019). In fact, Kirk-Johnson et al. (2019) found that the more effortful participants rated retrieval practice, the less effective they thought the strategy was. These results imply that learners, in general, believe that effortful learning is poor learning, and that these misperceptions of strategy effectiveness are related to their study choices.

In the present study, we broaden the examination of quality of how students engage in their studies (and the relationships to motivation) beyond surface and deep by measuring the use of each of these different types of strategies—the passive strategies (rereading, highlighting, summarizing), the elaboration-related strategies (self-explanation, elaboration), and the self-testing strategies (in its myriad forms). Although it was not reviewed by Dunlosky et al. (2013), we also add another strategy for which empirical research has shown pedagogical benefits: varying the way in which to-be-learned information is studied (McDaniel and Masson, 1985; Mannes and Kintsch, 1987).

Predictors of study strategies

There are good reasons to predict that implicit beliefs should matter for use of effective study strategies, especially for the "desirably difficult" strategies. To the extent that experiences of difficulty are interpreted as being a sign that "I must not be learning" and that experiences of ease are interpreted as well-learned (Koriat, 2008; Kirk-Johnson et al., 2019), learners may judge these effective strategies as being ineffective and vice versa. Given that the metacognitive experience of effective strategies is a key factor in whether people recognize their efficacy and choose to use them, the socio-motivational research on ease and difficulty beliefs, and on naive theories of intelligence, are likely relevant. Evidence currently remains fairly sparse. A number

of studies have shown that those with a growth mindset are less likely to be misled by experiences of fluency (Miele and Molden, 2010; Miele et al., 2011), although this work did not directly tie the implicit belief to study strategies. There is some indication that a growth mindset is related to appreciating the benefits of retrieval practice (Yan et al., 2014a) and difficulty-as-impossibility mindset as being related to endorsement of learning misconceptions (e.g., that learning should be easy, that rereading is more effective than testing; Yan and Oyserman, 2017). Hence, in the present study, we examine whether implicit beliefs are related to use of different types of strategies.

Content-specific value may also be related to use of better strategies. Lipstein and Renninger found that more interested students were also more likely to use effective strategies to meet their writing goals; Schiefele (1991) found that interest was related to use of deeper, more elaborative strategies (as measured by the elaboration subscale of the MSLQ). Those who value a course and see it as important for their future job, for example, are more likely to use deeper processing strategies and less likely to use surface processing strategies (Simons et al., 2004). Importantly, however, we do not know if the same patterns arise for the high-utility retrieval-based (self-testing) strategies. In Simons et al. (2004), for instance, their definition of deep strategies included summarization, rereading and underlining text—all strategies that Dunlosky et al. (2013) rated as low utility.

Finally, in the present study, we not only treat achievement goals as a dependent variable, but we also examine whether achievement goals are related to the use of different types of learning strategies. From the prior literature, there is some suggestion that mastery goals may be related to deeper learning and use of deeper learning strategies. Deeper learning strategies are those that lead to better long-term retention, but the benefits of these deeper learning strategies are not always apparent in the short-term. For example, retrieval practice is one of the most robust strategies for long-term memory but it does not always consistently lead to better immediate performance (Roediger and Karpicke, 2006; see Soderstrom and Bjork, 2015, for a review on the distinction between learning and performance). Hence, if the goal is to master learning and to be able to retain it long-term, then deeper strategies that involve more elaborative probes (e.g., actively searching memory for relevant knowledge, drawing connections between content) are important. On the other hand, if the goal is just to perform well, use of surface strategies may suffice—use of surface strategies such as rereading can result in good immediate performance. Moreover, if the goal is to perform well, then learners may be more focused on performing well along whatever criteria the teacher has set, and hence, focusing on studying whatever material the teacher has provided (Senko et al., 2013). This focus on pursuing the teacher-set learning agenda may lead students to use relatively passive strategies, such as going over course notes and readings (rereading, highlighting/underlining, summarizing). Indeed, performance goals do appear to predict use of surface strategies (Senko et al., 2011); however, the evidence for this mastery goal-deep strategy association is mixed (Nolen, 1988; Liem et al., 2008; Senko et al., 2011). However, as we elaborated above, the literature has tended to define deep as the relatively intuitive deep strategies (e.g., elaboration, self-explanation) or sometimes even low-utility strategies (e.g., summarization), and miss out of examining the empirically supported, but counterintuitive deep strategies (e.g., self-testing).

Profiles of Implicit Beliefs

While the fixed and growth intelligence beliefs tend to be conceptualized as opposite ends of a single belief spectrum, the difficulty and ease beliefs are generally considered to be distinct from each other. And although they may share similarities in motivational outcomes, psychometric analyses reveal that intelligence belief is distinct from the difficulty and ease beliefs; the correlations between these five implicit beliefs are small to moderate, indicating orthogonality (Fisher and Oyserman, 2017). However, the proliferation of implicit beliefs in the literature is reminiscent of the parable of the blind men and the elephant: each belief construct represents one part of truth and a better, more complete picture is understood when they are considered simultaneously. Whereas a typical analytic approach might involve entering each of the five implicit beliefs as predictors in a multiple regression, in the present study we take a person-centered approach and use latent profiles analysis (LPA) to examine whether meaningful *profiles* of the implicit beliefs emerge. The benefit of this approach is that it allows us to consider the implicit beliefs collectively rather than pitting them against each other and examining only the 'unique variance explained' by one belief after controlling for the others. Put another way, we were not interested in the explanatory power of any single implicit belief and instead were more interested in the collective "profiles" of implicit beliefs that are represented among students in our sample.

Research Questions

The existing literature has some notable gaps. First, most of the studies linking implicit beliefs to goal orientations have focused primarily on the growth mindset belief, rather than any other belief. The growth mindset belief may represent a very narrow slice of what beliefs influence human behavior. Moreover, there has been little research examining how implicit beliefs and values might interact to predict goal orientations. The present study represents an initial step toward exploring how domain-general and course-specific value might jointly relate to achievement goals. Hence, our first key research question in this study is: Do implicit beliefs and course-specific value relate to achievement goals, and do they interact? (RQ1) This research question is represented by the two solid arrows in **Figure 1**.

Second, the existing literature linking implicit beliefs and value to study strategies has not been updated to include the more recent findings about effective study strategies from cognitive psychology. Our present study draws from the wealth of cognitive psychology research from the past couple of decades to examine how implicit beliefs and values relate to the strategies students engage in their studies. Hence, our second key research question is: Do implicit beliefs and course-specific values relate to study strategies, and do they interact? (RQ2) This research question is represented by the two dashed arrows in **Figure 1**. Finally, although we treat achievement goals as the outcome variable

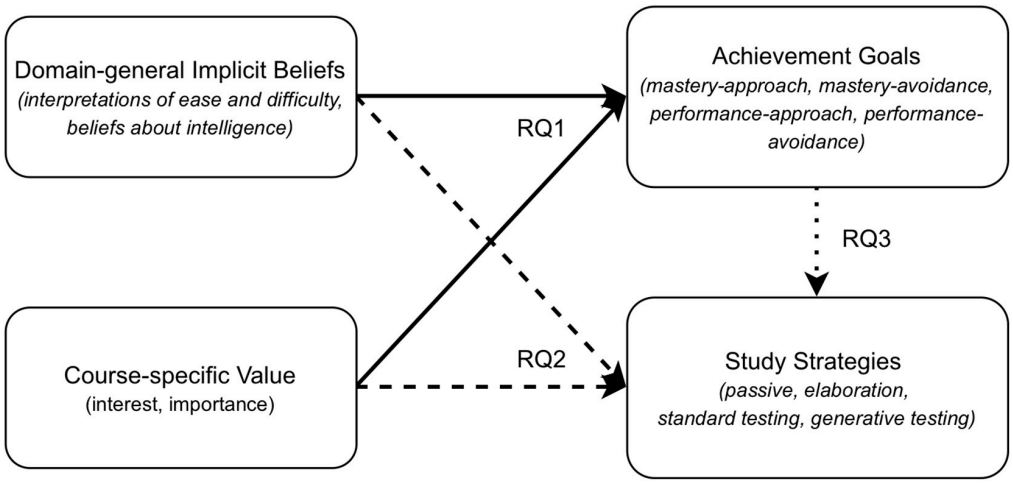

FIGURE 1 | Diagram representing three key research questions. Research Question (RQ) 1 is represented by the solid arrows, RQ2 is represented by the dashed arrows, and RQ3 is represented by the dotted arrow.

in RQ1, we recognize that there may also be a relationship between goals (especially mastery-approach) and study strategies, and hence our third key research question is: Do achievement goals relate to study strategies (controlling for implicit beliefs and value)? (RQ3) This research question is represented by the single dotted arrow in **Figure 1**.

MATERIALS AND METHODS

Participants

Undergraduate students (N = 458) were recruited from the educational psychology subject pool at a large public southwestern university and compensated with partial course credit. Data from 92 students were excluded because they failed the attention check (one item inserted in the final third of the survey: "For this statement, choose 'disagree' to indicate that you are paying attention"), resulting in data from 366 participants (242 females; age range 18–41, mean age = 20.49; 42% White, 22% Hispanic or Latino, 22% Asian, 6% Black, 6% multiracial, 2% other; 25% STEM majors, 25% Social Science majors, 14% Humanities and Arts majors, 36% other; 10% freshman, 24% sophomore, 26% juniors, 40% seniors +). This survey was administered in the second half of the Fall semester, so students had at least 6 weeks of experience in the course that they described.

Materials

Course Value

Course-specific motivation was operationalized as interest in the course and importance of the course. Each variable was measured by a single item: "How interested or uninterested are you in this course" and "How important is this course to you?," with the responses collected using a slide scale, where 0 = not at all interested/not at all important and 100 = very interested/extremely important.

Study Strategies

The study strategies were asked across two different pages. First, we provided a list of study strategies with brief descriptions. These strategies were largely drawn from the list of study activities reviewed by Dunlosky et al. (2013): rereading, highlighting or underlining, summarizing, elaborating, self-explaining, and varying your learning. Varying your learning was not part of the review by Dunlosky et al. (2013), but was added due to its appearance in reviews of desirably difficult learning strategies (Bjork, 1994; Yan et al., 2017). There were also a few strategies that Dunlosky et al. (2013) included in their review that we did not include: spacing (high-utility) and interleaving (moderate-utility) as these are strategies about how one distributes or sequences study, rather than what one does during a study session itself. We also did not include keyword mnemonics (low-utility) and imagery use for text learning (low-utility), as these two strategies are relatively domain-specific and not as applicable across the broad swath of college courses.

Next, we asked more specific questions about the different ways in which they could have used testing. We included this more detailed question about testing because of the multiple ways in which testing can be used to benefit learning (Roediger et al., 2011). Specifically, we asked about using testing as pre-tests, as a metacognitive check of what you already know, taking provided practice tests, self-testing, and generating test questions. For each strategy, we asked participants to indicate how often they used each study strategy for the course they had described using a 6-pt Likert scale (1 = "never/almost never" to 6 = "almost always/always").

Achievement Goal Orientation

We measured achievement goal orientation using the questionnaire developed by Elliot and Murayama (2008), which consists of four three-item subscales: mastery-approach (α = 0.87), mastery-avoidance (α = 0.75), performance-approach (α = 0.87), and performance-avoidance (α = 0.86). The

presentation order of the twelve items was randomized for each individual. The correlations between the achievement goal orientations are presented in **Table 1**.

Implicit Beliefs

We measured five subscales of implicit beliefs: difficulty-as-impossibility (α = 0.92), difficulty-as-importance (α = 0.91), ease-as-possibility (α = 0.93), ease-as-triviality (α = 0.90), and the growth mindset of intelligence (α = 0.85). The first four subscales each consisted of four items and were taken from Fisher and Oyserman (2017). The last subscale consisted of eight items (four fixed mindset, four growth mindset) and were taken from Dweck (2000). Items from each subscale were presented together, but the order of the items within a subscale was randomized, and the order of the subscales was randomized. Responses to the items within each scale were averaged to generate average subscale scores. The correlations between the implicit belief items are presented in **Table 1**.

Procedure

Participants were randomized to think of either a particularly interesting (n = 196) or uninteresting course (n = 170) that they were currently enrolled in. This manipulation ensured variance in the value of the courses described so that we didn't have participants choosing only to report on their favorite or most interesting course. To ensure that they had brought to mind details of the course, participants were asked details about the course (e.g., the course title, description). We then measured value directly by asking participants to rate the interest and importance of the course (using 0–100 slider scales). Rather than using the assigned condition as a predictor variable in our analyses, we directly use the interest and importance ratings instead.

The other critical variables were collected in the following order: participants rated how frequently they used different learning strategies in the course. Next, they were asked about their achievement goals for the course and finally, they completed the five domain-general implicit beliefs subscales. To conclude the survey, participants ended by completing a demographics survey.

RESULTS

Data Availability

The data and analysis script are available at https://osf.io/3SYKQ/.

Manipulation Check

First, we checked that our manipulation affected the interest ratings of the courses that participants described. Indeed, we found that those randomized to think of an interesting course (M = 78.27, SD = 22.72) rated their course as being significantly more interesting than those randomized to think of an uninteresting course (M = 39.04, SD = 30.77), Welch's $t(307.10) = 13.70$, $p < 0.001$. Those randomized to think of an interesting course were also more likely to rate their course as being more important (M = 67.55, SD = 25.69) than those randomized to think of an uninteresting course (M = 49.34, SD = 30.83), Welch's $t(312.60) = 5.92$, $p < 0.001$. Interest and importance were positively correlated, $r = 0.50$, $p < 0.001$, but not redundant.

Are There Meaningful Profiles of Implicit Beliefs?

The descriptive statistics and the zero-order correlations between the five implicit belief scales is presented in **Table 1**. As can be seen from the table, all of the correlations are small to moderate, ranging from $|r| = 0.09$ to 0.31, indicating orthogonality. That is, the implicit beliefs cannot be considered redundant and cannot be simply combined to form a single scale. Hence, in the present

TABLE 1 | Correlation matrix and descriptive statistics of implicit beliefs, achievement goals, and course-specific value (interest and importance).

	1	2	3	4	5	6	7	8	9	10	11
(1) Difficulty-as-importance	–	−0.18***	0.09	0.23***	0.20***	0.20***	0.08	0.11*	0.08	0.01	−0.02
(2) Difficulty-as-impossibility		–	0.21***	−0.16**	−0.31***	−0.20***	0.03	−0.08	0.07	−0.07	−0.05
(3) Ease-as-triviality			–	−0.14**	−0.17**	−0.04	−0.04	0.03	0.06	0.02	−0.10
(4) Ease-as-possibility				–	0.19***	0.12*	0.14**	0.23***	0.19***	0.07	0.02
(5) Growth mindset					–	0.22***	0.08	−0.01	−0.11*	−0.01	0.08
(6) Mastery approach						–	0.50***	0.33***	0.11*	0.38***	0.40***
(7) Mastery avoidance							–	0.29***	0.32***	0.18***	0.27***
(8) Performance approach								–	0.68***	0.06	0.12*
(9) Performance avoidance									–	0.02	0.07
(10) Course interest										–	0.50***
(11) Course importance											–
M	4.21	2.49	2.72	4.94	4.54	4.42	3.89	4.52	4.36	60.05	59.07
SD	0.92	1.02	0.89	0.86	0.81	1.09	1.12	1.07	1.22	33.13	29.59
Cronbach's α	0.91	0.92	0.90	0.93	0.85	0.87	0.75	0.87	0.86	–	–

n = 366, with the exception of course importance, where n = 346.
**p < 0.05; **p < 0.01; ***p < 0.001.*

paper, we take a person-centered approach rather than an item-centered one: to explore whether there were meaningful profiles of beliefs, latent profile analysis (LPA) was conducted using the tidyLPA package (Rosenberg et al., 2018) in R.

Latent Profile Analysis Model Selection

Latent profile analysis is a method that identifies clusters or profiles of individuals based on responses to a series of indicators (here, we are using implicit beliefs). In standard LPA, two sets of parameters are estimated: the number of profiles in the population, and the means (and variances and covariances) within each profile. The process is a data-driven one. We first explored one to nine latent profiles of implicit beliefs and specified the variance-covariance matrices across profiles to have: (1) equal variance, covariance fixed to zero (EV/FC); (2) varying variance, covariance fixed to zero (VV/FC); (3) equal variance, equal covariance (EV/EC); (4) varying variance, varying covariance (VV/VC), hence there were 36 potential solutions. Solutions with more than three profiles were unable to be estimated using the VV/FC and VV/VC parameter specifications (see **Supplementary Table 1** for the fit indices–AIC, AWE, BIC, CLC, KIC–for each solution).

To evaluate the various fit indices and to select the best fitting solution, we used three different approaches to converge upon a solution. First, we used an Analytic Hierarchy Process (Akogul and Erisoglu, 2017) that takes into account Akaike's Information Criterion (AIC; Akaike, 1973, 1987), Approximate Weight of Evidence (AWE; Banfield and Raftery, 1993), Bayesian Information Criterion (BIC; Schwarz, 1978), Classification Likelihood Criterion (CLC; Biernacki and Govaert, 1997), and Kullback Information Criterion (KIC; Cavanaugh, 1999). The Analytic Hierarchy Process compares a weighted composite of the information criteria for each alternative solution. This analysis is part of the tidyLPA package in R. Both the Analytic Hierarchy Process and BIC suggested that the three-profile solution with varying variance across profiles and covariance fixed to zero (VV/FC) was the best fitting solution.

The second approach we took was to compare a series of solutions with likelihood-based tests to examine the number of profiles and parameter specifications. Lo-Mendell-Rubin adjusted likelihood ratio tests (adjusted LMR; Lo et al., 2001) were used to compare solutions with different numbers of profiles: the 2-, 3-, and 4-profile solutions with VV/FC parameter specification. The three-profile solution significantly improved model fit from the two-profile solution: adjusted LMR(11) = 86.40, $p < 0.001$. The four-profile solution was unable to be estimated, so no adjusted LMR test was conducted. χ^2 difference tests were used to compare the three nested three-profile solutions with EV/FC, VV/FV, and VV/VC parameter specifications. The VV/FC model significantly improved model fit from the EV/FC model: $\chi^2(10) = 123.40$, $p < 0.001$. The VV/VC model also significantly improved model fit from the VV/FC solution: $\chi^2(30) = 76.50$, $p < 0.001$. However, as both the Analytic Hierarchy Process and BIC favored the VV/FC model over the VV/VC model, we choose the former, more parsimonious set of parameter specification.

The Analytic Hierarchy Process and likelihood-based tests all rely on fit indices, but it is also important to evaluate solutions on classification diagnostics and interpretability. Hence, the third approach we took was to visually inspect the Entropy, mean posterior probabilities, and profile sizes for each solution (see **Supplementary Table 1**). What we found was that the mean posterior probabilities across the models were all very similar. The three-profile VV/FC solution and 2- and 3-profile VV/VC solutions all showed a reasonable spread of participants across profiles; the VV/VC solutions, however, were less parsimonious (more parameters estimated) than the VV/FC solution. Although some of the other solutions may have had higher Entropy scores, they also had much more uneven profiles, or profiles with very few participants.

LPA Final Three-Profile Model

To sum, we selected the three-profile solution with VV/FC parameter specification. **Table 2** shows the classification table for this solution, with mean posterior probabilities of participants assigned to a given profile. Mean posterior probabilities of participants assigned to a profile other than their designated profile ranged from 0.04 to 0.12, indicating minimal overlap between profiles.

The mean endorsement of each implicit belief scale by profile is presented in **Figure 2**. One profile ($n = 94$) was those who were relatively low in their endorsement of the growth mindset, difficulty-as-importance and ease-as-possibility, and relatively high in difficulty-as-impossibility and ease-as-triviality. These

TABLE 2 | Classification table for the three-profile solution with VV/FC parameter specification.

Profile	Mean posterior probabilities associated with profile		
	1	2	3
(1) Motivation-undermining ($n = 94$)	0.86	0.12	0.06
(2) Neutral ($n = 146$)	0.10	0.77	0.12
(3) Motivation-increasing ($n = 126$)	0.11	0.04	0.82

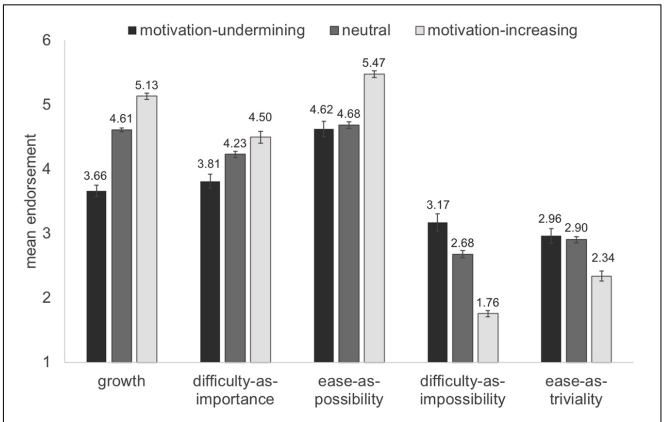

FIGURE 2 | Three latent profiles of implicit beliefs. Error bars represent standard error of the mean.

responses reflect a belief that one need not engage with either difficult or easy tasks. We refer to this group as *motivation-undermining beliefs*. Another profile (n = 126) consisted of participants who were relatively high in their endorsement of the growth mindset, difficulty-as-importance and ease-as-possibility, and relatively low in difficulty-as-impossibility and ease-as-triviality. These responses reflect a belief that both experience of ease and difficulty should be motivating. We refer to this profile as *motivation-increasing beliefs*. The third group (n = 146) fell in between the other two groups. We refer to this profile as *neutral beliefs*. In all subsequent analyses, we used implicit belief profiles as a categorical variable with the motivation-undermining profile as the reference profile.

RQ 1: Are Implicit Beliefs and Value Related to Achievement Goals?

What predicts achievement goal orientations? The descriptive statistics for the achievement goals and the zero-order correlations with other variables are presented in **Table 1**. As these zero-order correlations show, all four goal orientations were positively related to each other, but there are different patterns of relationship with the implicit beliefs and course-specific value constructs.

To answer our critical question, however, we ran hierarchical linear regressions for each achievement goal orientation: At step 1, we examine whether belief profile predicts endorsement of each goal orientation, and at step 2, we examine whether the relationships between implicit belief profile and achievement goals are moderated by course importance or interest[1]. The reference profile was the motivation-undermining profile (and this the case in all reported regression analyses).

The regression summaries are presented in **Table 3**. In general, those with motivation-increasing implicit beliefs were positively related to mastery-approach goals and this held even after controlling for interest and importance. Interest also mattered for mastery-approach goals—the more interested a participant was in their course, the higher their mastery-approach goals. Importance, however, was not related to mastery-approach, and no variable was significantly related to mastery-avoidance goals.

There were few direct relationships with the performance goals. In general, implicit belief profiles were not related to performance goals (with the exception of a negative relationship between neutral implicit beliefs and performance-avoidance, which was no longer significant once interest and importance were controlled for). There were however, significant interactions between profile and importance and between profile and interest. These interactions are depicted in **Figure 3**. Two patterns emerged: for those in the motivation-increasing beliefs group, course importance is positively related to performance-approach and performance-avoidance goals, and course interest is negatively related to performance-approach and performance-avoidance goals. For those in the other two groups, their performance goals were not sensitive to course importance and course interest, or in some cases, the pattern was even reversed.

RQ 2: Are Implicit Beliefs and Value Related to Study Strategies?

Four Strategy Subscales: Passive, Elaborative, Standard-Testing, and Generative-Testing

The description of each study strategy as it was presented to the participants and then average rated frequency of use are presented in **Table 4**. In general, there was a good amount of variation in the strategies that participants reported using. Given the large number of study strategies, we first used an exploratory factor analysis approach to examine whether the strategies could be grouped into factors. A parallel analysis and examination of a scree plot suggested a four-factor solution. We chose maximum likelihood with an oblique rotation as our exploratory factor analytic model. The oblique rotation allowed for correlations among factors. This solution showed excellent fit, TLI = 0.993, RMSEA = 0.018 (90% CI: 0, 0.047). The rotated factors and factor loadings are presented in **Table 5**. The factor correlations are presented in the **Supplementary Table 2**; the correlations were all small to moderate (r = 0.15 to r = 0.48). For each factor, we averaged the use frequency of the relevant strategies to create four strategy subscale scores. The average subscale scores are found at the bottom of **Table 5**.

The passive strategies subscale consisted of the strategies that were rated by Dunlosky et al. (2013) as low-utility: highlighting, summarizing, and rereading. The elaborative strategies subscale consisted of the two moderate-utility strategies—elaboration and self-explanation—as well as variation. The remaining two subscales reflect different uses of testing: one reflects the most common uses of testing, and included our generic item about testing (test), as well as the more specific forms about self-testing (self-test), taking practice-tests (practice), and using tests to check what one knows (check); the other reflects more generative uses of testing–using them as pre-tests (pre-test), and creating your own test questions (create). The standard testing subscale had the highest frequency of use ratings whereas the generative testing subscale had the lowest. The average frequency of use ratings for the passive and elaborative strategies subscales were just above the midpoint of the 6 point ratings scale, representing moderate usage.

What Predicts Strategy Use?

More importantly, we asked whether students in the different implicit belief profile groups used different types of strategies, and whether this relationship is moderated by course interest and importance. Again, we examine these patterns for each strategy using hierarchical regression models. At step 1, we predicted the use of each strategy subscale from belief profile. At step 2, we added in two interactions, examining how course interest and course importance each interacted with belief profile. At step 1, we did not find that the implicit belief profiles differed on any strategy subscale. At step 2, adding course interest and course importance to the model did not explain any additional variance for use of the standard testing strategies or for the generative

[1]Twenty participants did not complete the course importance rating; these twenty participants were hence removed from both steps of the hierarchical linear regression (to enable model comparison), as well as from all subsequent analyses. There were no other missing data.

TABLE 3 | Summary of regression coefficients, predicting achievement goals from implicit belief profiles, course interest, and course importance.

	Mastery-approach		Mastery-avoidance		Performance-approach		Performance-avoidance	
	Model 1	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**	**Model 1**	**Model 2**
Intercept	4.17 (0.11)***	4.16 (0.10)***	3.83 (0.12)***	3.83 (0.11)***	4.51 (0.11)***	4.50 (0.11)***	4.49 (0.13)***	4.46 (0.13)***
Neutral	0.22 (0.14)	0.27 (0.13)*	0.05 (0.15)	0.08 (0.15)	−0.08 (0.14)	−0.06 (0.14)	−0.28 (0.16)	−0.25 (0.16)
Motivation-increasing	0.54 (0.15)***	0.49 (0.13)***	0.12 (0.16)	0.08 (0.15)	0.19 (0.15)	0.17 (0.15)	−0.02 (0.17)	−0.03 (0.17)
Interest	–	0.30 (0.12)*	–	0.09 (0.14)	–	0.18 (0.13)	–	0.13 (0.15)
Importance	–	0.15 (0.12)	–	0.13 (0.14)	–	0.00 (0.13)	–	−0.19 (0.15)
Neutral*Interest	–	−0.02 (0.15)	–	0.03 (0.17)	–	−0.11 (0.17)	–	−0.01 (0.19)
Motivation-increasing* Interest	–	−0.02 (0.16)	–	−0.03 (0.18)	–	−0.37 (0.18)*	–	−0.47 (0.20)*
Neutral* Importance	–	0.06 (0.15)	–	0.16 (0.17)	–	−0.06 (0.17)	–	0.19 (0.19)
Motivation-increasing* Importance	–	0.28 (0.16)	–	0.20 (0.18)	–	0.37 (0.17)*	–	0.62 (0.19)**
Adjusted R^2	0.03**	0.23***	0.00	0.06***	0.01	0.03*	0.01	0.03*
R^2 change	$F(6) = 15.67$, $p < 0.001$		$F(6) = 5.19$, $p < 0.001$		$F(6) = 2.43$, $p = 0.026$		$F(6) = 2.59$, $p = 0.018$	

n = 346.
Interest and importance were both z-scored.
**p < 0.05; **p < 0.01; ***p < 0.001.*

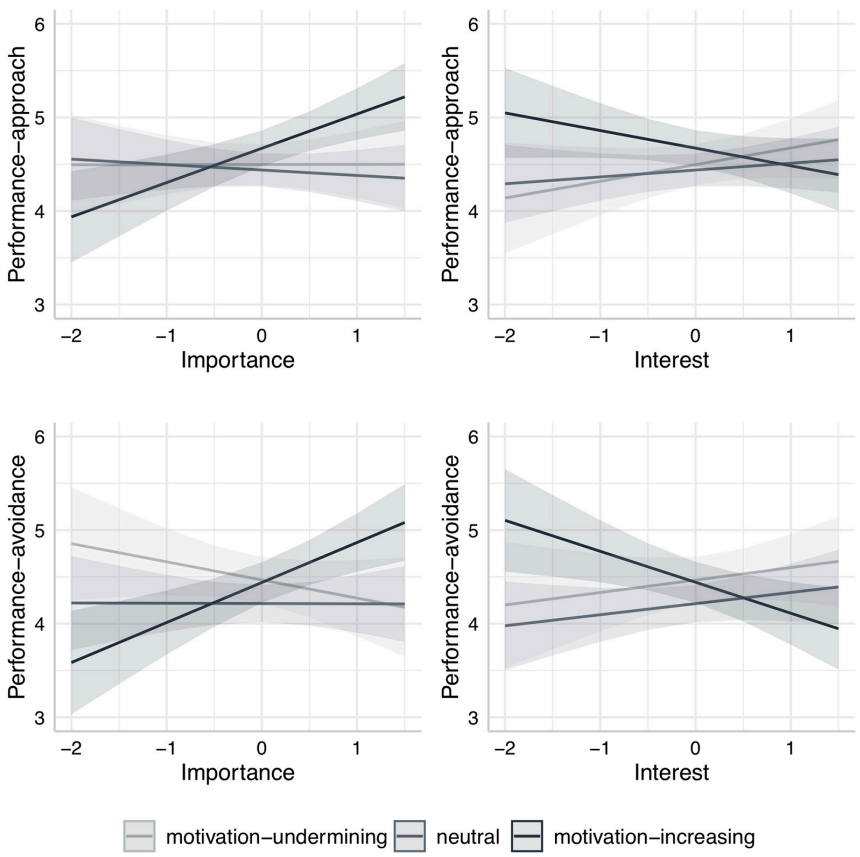

FIGURE 3 | Implicit belief profiles interact with importance and interest to predict performance-approach and performance-avoidance goals. Importance and interest values are standardized; performance-approach and performance-avoidance values have been left in their original units.

testing strategies. The regression summary statistics for these two strategy subscales are found in the **Supplementary Table 3**.

Including the interactions with course interest and importance did, however, explain significantly more variance for the elaborative strategies and for passive strategies. A summary of the regression statistics is presented in **Table 6**. The results show that importance mattered—the more important the student rated the course, the more likely they were to engage in elaborative

TABLE 4 | Mean and standard deviation for use of each study strategy by implicit belief profiles.

Study strategy	Profile			Overall
	Motivation-undermining	Neutral	Motivation-increasing	
Rereading Read learning materials again after initially reading them	4.30 (1.51)	3.90 (1.50)	4.13 (1.67)	4.08 (1.57)
Highlighting or underlining Mark potentially important portions of learning materials while reading	3.88 (1.73)	3.35 (1.73)	3.82 (1.83)	3.65 (1.78)
Summarizing Write summaries (of various lengths) of learning materials	3.41 (1.62)	3.38 (1.45)	3.59 (1.76)	3.46 (1.60)
Elaborating Generate an explanation for why a fact or concept is true	3.57 (1.51)	3.60 (1.32).	3.79 (1.66)	3.66 (1.49)
Self-explaining Explain how new information is related to known information, or explain steps taken during problem solving	3.95 (1.44)	3.98 (1.29)	4.29 (1.60)	4.08 (1.45)
Vary your learning Introduction variation in how a concept is studied, explained, or practiced	3.14 (1.31)	3.14 (1.21)	2.95 (1.46)	3.08 (1.33)
Test yourself Test yourself, in any way (e.g., take practice tests, try to recall things from memory, use flashcards)	3.91(1.56)	4.23 (1.44)	4.27 (1.66)	4.16 (1.55)
Check what I know Test yourself (e.g., take practice tests, try to recall things from memory, use flashcards) to find out what I do and do not know, after studying	4.26 (1.57)	4.26 (1.38)	4.55 (1.45)	4.36 (1.46)
Take practice tests Take practice tests provided by the textbook, instructor, or other sources (e.g., test banks)	3.82 (1.72)	3.80 (1.65)	3.65 (1.93)	3.75 (1.77)
Self-testing Try to recall information from memory, without looking at notes (e.g., by covering up notes and trying to write what you know)	4.17 (1.40)	4.34 (1.33)	4.54 (1.52)	4.36 (1.42)
Pre-testing Test yourself before you begin studying, to see what you already know	2.80 (1.62)	2.86 (1.44)	2.69 (1.69)	2.78 (1.58)
Create your own tests Try to generate test-like questions to test yourself on	2.13 (1.40)	2.16 (1.38)	1.98 (1.29)	2.09 (1.35)

n = 366.

and passive strategies. There was an interaction between profile and importance for the use of passive strategies: Whereas importance was positively related to use of passive strategies for both the motivation-increasing and motivation-undermining beliefs groups, it was unrelated to passive strategy use for the neutral beliefs group.

RQ 3: Are Achievement Goals Related to Study Strategies?

Finally, we asked whether the three types of achievement goals were related to study strategy use, controlling for implicit beliefs, course importance, and course value. We conducted four multiple regression analyses, one for each strategy subscale. The results are summarized in **Table 7**. Mastery-approach goals were positively related to the use of elaborative strategies and both types of testing strategies; they were not related to use of passive strategies. Mastery-avoidance goals were negatively related to the use of elaborative strategies, but did not relate to the other strategies. Neither of the performance goals were related to the use of any strategies.

DISCUSSION

In the present study we examined how motivation-related implicit beliefs and course value (interest and importance) relate not to quantity of study (e.g., study effort, persistence), but to the *quality* of study—the achievement goals that students hold and the study strategies that they engage. We selected

TABLE 5 | Factor loadings of the study strategies **(Top)** and descriptive statistics for the four study strategy factors **(Bottom).**

	Passive	Elaborative	Standard testing	Generative testing
Reread	0.58			
Highlight	0.49			
Summarize	0.37	0.32		
Elaborate		0.71		
Self-explain		0.66		
Vary		0.41		
Test			0.81	
Check			0.77	
Practice			0.58	
Self-test			0.66	
Pre-test				0.63
Create				0.64
M	3.73	3.61	4.16	2.44
SD	1.19	1.11	1.26	1.24
Cronbach's α	0.54	0.68	0.83	0.60

n = 366.
Factor loadings below 0.30 are not shown here.

TABLE 6 | Summary of regression coefficients, predicting study strategy use from implicit belief profiles, course interest, and course importance.

	Passive strategies		Elaborative strategies	
	Model 1	**Model 2**	**Model 1**	**Model 2**
Intercept	3.84 (0.12)***	3.87 (0.12)***	3.55 (0.12)***	3.58 (0.11)***
Neutral beliefs	−0.27 (0.16)	−0.29 (0.15)	0.02 (0.15)	0.01 (0.14)
Motivation-increasing beliefs	0.03 (0.16)	−0.02 (0.16)	0.17 (0.15)	0.10 (0.15)
Interest		−0.03 (0.15)		−0.10 (0.14)
Importance		0.39 (0.14)**		0.42 (0.13)**
Neutral*Interest		0.09 (0.18)		0.15 (0.17)
Motivation-increasing* Interest		0.09 (0.19)		0.23 (0.18)
Neutral*Importance		−0.38 (0.19)*		−0.14 (0.17)
Motivation-increasing* Importance		−0.17 (0.19)		−0.15 (0.17)
Adjusted R^2	0.01	0.04**	0.00	0.08***
R^2 change	$F(6) = 2.90$, $p = 0.009$		$F(6) = 5.78$, $p < 0.001$	

n = 346.
Interest and importance were both z-scored.
**p < 0.05; **p < 0.01; ***p < 0.001.*

TABLE 7 | Summary of regression coefficients, predicting study strategy use from achievement goals, controlling for implicit belief profiles, course interest, and course importance.

	Passive	**Elaborative**	**Standard Testing**	**Generative Testing**
Intercept	3.32 (0.38)***	2.30 (0.32)***	2.89 (0.40)***	2.43 (0.40)***
Neutral beliefs	−0.28 (0.16)	−0.09 (0.14)	0.09 (0.17)	−0.02 (0.17)
Motivation-increasing beliefs	−0.07 (0.17)	−0.09 (0.14)	0.04 (0.18)	−0.27 (0.18)
Interest	0.02 (0.07)	−0.07 (0.06)	−0.08 (0.08)	−0.07 (0.08)
Importance	0.17 (0.07)*	0.23 (0.06)***	0.00 (0.08)	0.06 (0.08)
Mastery approach	0.15 (0.08)	0.41 (0.07)***	0.29 (0.08)***	0.16 (0.08)*
Mastery avoidance	−0.12 (0.07)	−0.14 (0.06)*	−0.05 (0.07)	0.01 (0.07)
Performance approach	0.03 (0.09)	0.06 (0.07)	0.01 (0.09)	−0.12 (0.09)
Performance avoidance	0.05 (0.07)	−0.05 (0.06)	0.02 (0.08)	−0.02 (0.08)
Adjusted R^2	0.04**	0.19***	0.03*	0.01

n = 346.
Interest and importance were both z-scored.
**p < 0.05; **p < 0.01; ***p < 0.001.*

a set of implicit beliefs that are likely related to academic experiences, and which have been validated in the motivational literature: difficulty-as-importance, difficulty-as-impossibility, ease-as-possibility, ease-as-triviality (Fisher and Oyserman, 2017), and the growth intelligence mindset (Dweck and Yeager, 2019). Difficulty-as-importance, ease-as-possibility, and the growth intelligence mindset are motivation-increasing—they compel individuals to engage more with a task. Ease-as-triviality and difficulty-as-impossibility as motivation-undermining—they compel individuals to give up and desist. Rather than examining each individual implicit belief separately, we used LPA to reveal profiles of these beliefs, finding three distinct profiles–one that was motivation-increasing, one that was motivation-undermining, and one that fell somewhat in between the two, which we refer to as 'neutral.'

We examined the quality of student efforts in two ways. First, we looked at achievement goal orientations that students held for a particular course. Second, we looked at the specific study strategies that students reported using for that same course. Although both types of variables relate to the quality of student effort, we found that they were predicted by different variables.

What Factors Are Associated With Achievement Goals?

Previous literature finds that the motivation-undermining difficulty-as-impossibility, and ease-as-triviality are positively related to avoidance goals and that growth mindset is negatively related to performance-avoidance goals (Bråten and Strømsø, 2004; Chen and Pajares, 2010; Fisher and Oyserman, 2017). In our study, we did not find that the implicit belief profiles differed. In part, this might be due to the fact that the LPA approach reduces power by categorizing the beliefs. However, we did find interesting interactions: Interest and importance were related to performance goals, but only for those in the motivation-increasing beliefs group. Moreover, whereas the

existing literature tends to find similar patterns for interest and utility-value, we found that interest and importance were related to performance in opposite directions: The more important a course was (controlling for interest), the more those in the motivation-increasing beliefs group were performance-oriented. The more interesting a course was (controlling for importance), the less those in the motivation-increasing beliefs group were performance-oriented. One interpretation of this distinction is that importance in our study may reflect the importance of getting a good grade (an extrinsic motivation, aka performance-goal) whereas interest reflects an intrinsic motivation where performance is less relevant; the motivation-increasing beliefs hence may simply augment these goal orientations.

Prior literature also finds that difficulty-as-importance and ease-as-possibility are positively related to approach goals, difficulty-as-impossibility as negatively related to approach goals, and that growth mindset and value are positively related to mastery-approach (Bråten and Strømsø, 2004; Hulleman et al., 2008; Renninger et al., 2008; Chen and Pajares, 2010; Fisher and Oyserman, 2017). In line with these past findings, we found that both interest and motivation-increasing beliefs were related to having higher mastery-approach goals. Although the zero-order correlations showed that importance was related to mastery-approach goals, this relationship disappeared once interest was controlled for. One interpretation is that participants interpreted the meaning of "importance" as being about performance. Alternatively, it may point to the possibility that the positive effects of increasing perceived importance (e.g., utility-value) are mediated by increased interest.

What Factors Are Associated With the Use of Effective Study Strategies?

Previous studies that suggest implicit beliefs and interest are related to use of deeper, more effective study strategies (Schiefele, 1991; Lipstein and Renninger, 2007; Yan et al., 2014a), but our results did not support predictions based on these prior findings. Instead, we did not find that implicit belief profiles or interest to be related to the use of any of the study strategies subscales.

Only achievement goals and course importance were related to self-reported strategy use. Importance was related only to use of passive and elaborative strategies, but not to either of the self-testing strategy subscales. These results highlight the limitations of increasing value (though both importance and interest were positively correlated with mastery-approach). Above and beyond the other goal orientations and value, mastery-approach goals were uniquely related to increased use of all three of the effective strategies subscales (elaborative strategies, standard testing, and generative testing) and was not related to use of the less effective, passive study strategies. In other words, it uniquely promoted effective strategies, rather than simply promoting all strategies. In fact, mastery-approach was the only goal orientation that was related to the two self-testing strategies—study activities that are directed at retention and maintenance of knowledge. In contrast, mastery-avoidance was related only to reduced use of elaborative strategies. One speculation for this finding is that those trying to avoid revealing to themselves that they have not mastered the knowledge might be less likely attempt self-explanations. One could argue that self-testing should also reveal gaps in one's own knowledge, but that is only the case if the questions test deeper understanding rather than surface-level rote memorization (e.g., concept-definition multiple-choice questions). Future research could explore how achievement goals are related to the types of test questions that learners seek out and engage with.

In contrast to the prior literature that has linked performance goals to increased use of passive strategies (and in some cases, linked performance-approach with deep strategies, Liem et al., 2008; Vrugt and Oort, 2008), we did not find them to be related to the use of any strategies. One difference between our present study and prior studies may be the definition of passive strategies. Often, the rehearsal subscale of the MSLQ, which focuses on rote repetition (e.g., When I study for this class, I practice saying the material to myself over and over) is used to represent the least effective strategies for learning. Our passive strategies subscale includes popular strategies that might appear to be reasonable but have been empirically shown to be relatively ineffective (rereading, highlighting/underlining, summarization). It would be important for future studies to replicate these findings, but our results suggest that this more nuanced classification of strategies is meaningful for understanding the behavioral correlates of different achievement goals.

Implications for Interventions

These findings have nuanced implications for intervention. This study was exploratory and should not be taken as conclusive, but we describe some of the potential implications that future research might consider.

One implication of the findings is that interventions should target ways of increasing students' mastery goal orientations, given that mastery-approach goals were uniquely related to use of more effective study strategies. Other research has already shown that mastery-approach goals are associated with better learning outcomes, and the present study contributes that one way in which a mastery goal orientation might lead to better learning outcomes is by shifting students to using more effective study strategies. How should mastery-approach goals be promoted? Our findings suggest that mastery goals may be promoted by both increasing students' intrinsic interest as well as their motivation-increasing implicit beliefs—the results suggest that interventions that contain a combination of these two aspects may be more effective than either one alone.

Many existing interventions focus on the motivation-increasing implicit beliefs (Oyserman et al., 2006, 2018; Blackwell et al., 2007; Oyserman, 2015; Yeager et al., 2016, 2019). Often the interventions are focused on academic persistence or achievement rather than on quality of engagement. While we did find that motivation-increasing implicit beliefs were related to mastery-approach goal orientation, the lack of a direct effect between these beliefs and use of effective study strategies suggest that attending only to implicit beliefs may not be sufficient to truly increase the quality of study.

Finally, our results also suggest that increasing perceptions of course importance may not be particularly effective, especially if the manipulation of importance does not also increase interest. Controlling for interest, importance was related only to increased performance goals—but this was true only for those in

the motivation-increasing beliefs group—and it was not related to mastery goals. Importance was also not consistently related to the use of effective strategies—rather, it was related to increased use of passive strategies, and only one of the three effective strategy subscales. In other words, increasing importance might lead learners to study harder, but not necessarily smarter.

Limitations and Future Directions

A standard word of caution is that this study was a purely correlational, cross-sectional one, which means that the relationships reported in the present paper should not be interpreted as causal. Rather, the analyses conducted here are exploratory and the findings are meant to indicate potentially fruitful new avenues of research. Both longitudinal and experimental follow-up studies may illuminate new insights. For example, it is likely that students' achievement goals fluctuate across a semester with the ebb and flow of course demands (e.g., midterm examinations, final examinations; Corker et al., 2013; Lee et al., 2017). Rather than only looking at mastery and performance goals in a snapshot of time, it may be interesting to examine how the ebb and flow of goals itself is related to implicit beliefs, interest and importance. One could hypothesize, for example, those with motivation-increasing beliefs might be better able to maintain higher mastery goals all throughout a semester, while those with neutral or motivation-undermining belief might find their mastery goals dropping significantly around midterms or finals.

In the absence of intervention, our results show that the five different implicit beliefs that were measured were only weakly to moderately related to each other. One strength of our LPA approach helped to coalesce these into meaningful profiles, but a weakness of the approach is that it reduces statistical power by categorizing participants into one of three profiles. The LPA approach is also data-driven, which means that future datasets might yield different looking profiles. We view this as a potentially interesting and informative feature of the approach. For example, it may help illuminate what aspects interventions actually affect by examining how the emergent profiles are similar or different, either before and after an intervention, or between an intervention and control group.

Another limitation of the present study is that our course-specific motivation constructs of interest and importance were each only measured with a single item. Though the items themselves are face-valid, the educational literature on value has identified distinctions between different types of interest (e.g., situational and individual sustained interest; Schiefele, 1991; Renninger and Hidi, 2002; Hidi, 2006) and between different types of importance (e.g., utility value, attainment value; Eccles et al., 1983; Wigfield and Eccles, 2000). Our measurement of interest and importance leave it ambiguous as to what particular aspect participants are thinking about.

CONCLUSION

Nevertheless, the present study contributes to the educational psychology literature in three key ways. First, we provide an example of how various motivation-related implicit beliefs may be considered simultaneously. We take the view that there are many relevant different implicit beliefs that individuals may hold in mind and draw upon. Considering implicit belief profiles, rather than individual beliefs, may hence be a productive way forward in integrating multiple constructs in the existing literature and for identifying learners for different types of interventions. Second, we explore the integration of domain-general and course-specific motivational constructs as they are brought to bear on student engagement. Third, we integrate the social and educational psychology research on student motivation with the cognitive psychology research on effective study strategies, showing both that there are meaningful relationships between motivation and strategy use, but also that the relationship may not be straightforward and that there are still gaps to be filled.

DATA AVAILABILITY STATEMENT

The dataset and analysis script for this study can be found accessed at: https://osf.io/3SYKQ.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board (IRB) at the University of Texas at Austin. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

VY and LW designed and conducted the study together and they analyzed and interpreted the data together. VY primarily drafted the manuscript with assistance from LW. Both authors contributed to the article and approved the submitted version.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2021.643421/full#supplementary-material

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How Finnish and Portuguese Parents' Implicit Beliefs About Learning Actualize at Home

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The purpose of this qualitative study was to explore parental engagement in the home learning environment, and parents' implicit beliefs about learning underlying such engagement. Nineteen parents of school children between 7 and 12 years old were interviewed in two different cultural contexts, Finland (N = 10) and Portugal (N = 9). The interviews were subjected to inductive and deductive content analysis. Forms of parental engagement at home were similar in both countries, divided between two main categories: *engagement with their child's holistic development* and *engagement with the child's schooling process*. Parental narratives about engagement were, for the most part, embedded in a growth mindset (or an incremental meaning system). The most common actualizations of engagement included considering the child's learning contexts and emotions; encouraging effort, persistence and practice; approaching difficulties as a natural part of learning and suggesting strategies for overcoming them. Parental practices of engagement were combined with the actualization of their implicit beliefs to create parental engagement–mindset profiles. Twelve parents were classified as having a *growth mindset to support the child's holistic development* profile, and the other seven were distributed amongst the three remaining profiles. The study contributes to the growing interest on the association between parental engagement and their learning-related implicit beliefs, giving clear first-person illustrations of how both occur and interact in the home learning environment. Implications for practice are discussed.

Keywords: parental mindset, parental engagement, learning in the home, holistic development, Finland, Portugal

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INTRODUCTION

Research conducted over the past 40 years has highlighted the centrality of parental involvement in children's schooling and achievement (Grolnick and Slowiaczek, 1994; Epstein, 2011). However, the latest tendencies in global educational goals encourage a shift of the parental role in their children's learning and call for a different approach (OECD, 2012; Goodall, 2017). Parents have traditionally been seen as allies who support the schools' goals and who are sporadically involved in their children's schools or schooling (Epstein, 2011). As the realization dawns that versatile citizens are as essential to society as well-trained professionals, there is an increasing emphasis on truly engaging parents *with* their children's learning. Parents are, therefore, perceived as valuable partners (Goodall and Montgomery, 2014) in a learning process that includes the acquisition of transferrable home–school–work life competences such as managing daily life, active participation,

and interaction (FNBE – Finnish National Board of Education, 2016; DGE – Direção-Geral de Ensino, 2017; OECD, 2018, p. 4).

Carol Dweck's (2000) self-theories framework, or mindset theory, has been successful in enhancing understanding of people's approaches to learning-related situations in an array of contexts, such as work life, sports or the classroom. According to the author (Dweck, 2000, 2006); the mindset theory postulates that a person's mindset refers to implicit beliefs about their basic abilities. Thus, an individual with a growth mindset (or incremental implicit theory) believes his or her abilities can be developed through effort and will persist in the face of challenges in order to learn from them. On the other hand, an individual with a fixed mindset (or entity implicit theory) believes abilities cannot be changed and will be less motivated to learn from difficult situations. Mindset is considered a major element to be taken into account in the fight against inequitable education and the stereotyping of disadvantaged students (Dweck, 2010). Therefore, it has lately been gaining ground in studies of parenting styles and parental engagement with learning in the home (e.g., Moorman and Pomerantz, 2010; Muenks et al., 2015; Schiffrin et al., 2019; Justice et al., 2020).

Most of these quantitative studies focus on how the parental mindset about the fixedness of their children's abilities is associated with their engagement in their children's learning-related activities at home, and with parenting styles such as controlling versus autonomy-supportive. The findings are promising, indicating that the parental mindset may be associated with various patterns of parental style and engagement at home (Muenks et al., 2015), and that it could even serve as a predictor of specific forms of engagement (Justice et al., 2020). Such studies open new avenues for addressing old problems related to engaging all families and using the home environment of every pupil to support learning (Goodall, 2013). They also highlight the importance of studying different cultural settings to explore the variability of the parental mindset and engagement in their children's learning (Justice et al., 2020).

Existing research on the parental mindset is predominantly, if not entirely, questionnaire-based. Our aim is to broaden the methodological perspective by utilizing qualitative approaches, allowing phenomena to be studied in a way that presents their character on a deeper level (Larsson, 1998). This study, therefore, is intended to contribute to the debate on the *parental engagement–mindset* theme. Through parents' own narratives, we explore how they engage with their children's learning at home, and their mindsets regarding such engagement.

Finland and Portugal were selected for this study as both have recently been through major core curriculum reforms with a very similar aim. Finland and Portugal seek to adapt the goals of their curricula to a holistic perspective, aiming for students to develop not only competences in individual fields of knowledge, but also competences of the whole person (e.g., autonomy and teamwork) (FNBE – Finnish National Board of Education, 2016; DGE – Direção-Geral de Ensino, 2017). Nevertheless, Finland and Portugal implement their holistic educational goals from different starting points. Finland has undoubtedly been an example of well implemented educational reforms through decades (Tirri, 2014), serving as a model of good practices. Finland is, therefore, a promising environment for fruitful lessons about parental engagement to emerge. Therefore, our results will inform research and practice on how the home learning environment may be considered to support children's learning more effectively, in Finland, Portugal and other countries undergoing similar reforms.

Parental Engagement and the Home Learning Environment

A considerable body of research indicates that parental involvement in learning enhances school achievement among their children (for a meta-analysis, see Wilder, 2014). As a result, there has been extensive interest about the parental role in education over the decades, as researchers have questioned how this could better serve the *schooling process* (Grolnick et al., 1997). More recently, there has been a shift from a school-centered to a learning-centered approach, attention being directed to interactions in the home and parenting styles, instead of mere parental participation in school or schooling (e.g., Goodall, 2013; Sikiö et al., 2017).

According to Goodall and Montgomery (2014), the parental role could better facilitate the *learning process* of children if viewed as a three-point continuum of engagement with learning. The continuum covers what parents do both at school and at home. In practical terms, a continuum of parental engagement with learning means that parent and child constantly navigate through a variety of interactions that support the child's learning: for instance, from attending presentations or meetings in the school (engagement with the school), supervising or helping with homework at home (engagement with the schooling) to chatting with the child about their friendships or after-school football practice around the dinner table (engagement with learning). This third point has been described as the ultimate form of enhancing the home learning environment and relationships, in which both teachers and parents focus on the child as a whole person, and not solely on schooling goals. It constitutes genuine parental interest and support in all learning-related aspects of the child's life, accompanied by a stronger feeling of parental ownership of actions toward their children's learning. The framework acknowledges traditional forms of involvement as part of the continuum and argues that the more effective parental role in learning is engagement with their children's holistic development. Here, school, schooling and outside-of-school matters have equivalent importance and need for parental engagement in the life of a child (for a recent review on parental involvement and engagement, see Levinthal and Kuusisto, 2020).

This perspective builds on previous research attesting to the high relevance of the home learning environment. For example, longitudinal studies based on information from more than 3,000 3- to 7-year-old children and their educational contexts revealed that the home learning environment was the single strongest contextual factor affecting children's cognitive development. *What* parents did to support and encourage learning outside of the school context mattered more than their profession, income, or even educational level (Sylva et al., 2004). Children with higher scores on intellect and social behavior, for example, had parents

who engaged in reading with them, taught them songs and nursery rhymes, taught and played with letters and numbers, and engaged in painting, drawing, and visiting the library together. According to the findings, these parents would also create regular opportunities for their children to play with friends at home. Another study involving parents of kindergarten children from white, black and Hispanic ethnic background (Chen et al., 2012) reported a similar set of literacy activities amongst all ethnic groups as forms of engagement in the home. However, little is known about such ludic and broad forms of parental engagement among school-age children.

Studies on parental engagement at home from primary education onward assign a central role to homework supervision. Given the stronger association of home-based – over school-based – parental involvement with children's outcomes (for a meta-analysis, see Hill and Tyson, 2009), homework support has been studied from different perspectives. Having conducted a meta-analysis of 52 quantitative studies on parental involvement, Jeynes (2007) concluded that, although supervising homework might be a commonsense strategy for getting involved in children's learning, it does not affect school attainment. A more recent meta-analysis aimed to analyze common findings from studies regarding the relationship between parental involvement and student academic achievement. The author (Wilder, 2014) highlighted that, from the ten different definitions of parental involvement among the nine studies analyzed, the ones that defined involvement as homework assistance revealed no positive relationship or a negative correlation between homework assistance and academic achievement. On the other hand, it is reported in a recent study based on interviews with eight parents (Braunschweig et al., 2019) that the non-existence of homework could be perceived by parents as a loss of control over their children's learning, requiring the adaptation of school-home communication. According to Goodall (2013), more than helping with homework, what influences children's achievement is when parents link what is being learned at school with other aspects of their children's lives, and when they provide structure at home. Structure, in turn, constitutes a key dimension of parenting that contributes to optimal involvement, together with parental support of children's autonomy, positive affect, and support of process-focused learning (Pomerantz et al., 2012).

The debate on homework heralded a focus on parenting styles of involvement (e.g., Cooper et al., 2000). It is reported in a quantitative study among Portuguese elementary- and middle-school children (Mata et al., 2018) that those who perceived their parents as being more interested and learning-engaged tended to see interactions related to homework and conversations about school as more positive. Accordingly, quantitative longitudinal studies involving Finnish children at elementary school and their mothers (Silinskas et al., 2015; Sikiö et al., 2017) assessed maternal help in homework, maternal levels of warmth and behavioral control in parenting styles, as well as children's reading comprehension and pseudoword spelling abilities. According to the results, the most beneficial style of involvement with homework entailed positive parental affect and interaction.

Consistently, as stated in the OECD (2012) report on the parent factor in education, based on questionnaires distributed in thirteen countries, parents who read to their young children, and who engage in conversation with their adolescent children around the dinner table are more likely to have a significant impact on their children language-skills outcomes in secondary school. Positive parent–child interactions such as these, marked by genuine enjoyment, interest and engagement, have a long-lasting effect when they begin at a young age and continue throughout the child's development, beyond homework supervision. An authoritative parenting style, with high levels of warmth, autonomy-support and appropriate expectations, is regarded nowadays (Goodall, 2013) as the most promotive of effective parental engagement in all areas of children's development, and supportive of their growth and learning as whole persons.

Whole-person development or *educating the whole child* are well-known terms within holistic educational paradigms. Such paradigms are adopted by schools that value the children's learning context, that consider all areas of development just as important as academic achievement, and that pay attention to each child's feelings, aspirations and ideas (Miller, 2000). However, if such a paradigm is to be fruitful, schools and parents must collaborate closely, as a 'whole child' does not learn only in school or while doing homework. Although teachers around the world implement a whole-person approach in their classrooms (FNBE – Finnish National Board of Education, 2016; DGE – Direção-Geral de Ensino, 2017), most schools fail to encourage parents to engage with learning from a holistic perspective, and parental involvement practices at home might end up not serving children's and families' best interests (Goodall, 2017). The recent shift in research, from school-centered to learning-centered parental involvement practices, highlight the need to enhance knowledge about different ways parents may support their children's learning at home.

Parental Mindset in the Home Learning Environment

Parental engagement is a major asset promoting children's learning, but each family's reality is unique. Thus, engagement experiences at home may vary, influenced by parental motivation and role beliefs, teachers' requests or children's attributes (Deslandes and Rousseau, 2007; Eccles, 2007; Pomerantz et al., 2012). Parents have implicit beliefs about the abilities of their children (Dweck and Leggett, 1988; Dweck, 2000; Moorman and Pomerantz, 2010). In other words, they either engage in learning-related situations in the belief that their children's abilities are malleable and that their learning can be developed (a growth mindset or incremental implicit theory), or they believe that their children's abilities are static and that there are some things they may never learn (a fixed mindset or entity implicit theory) (Rautiainen et al., 2016).

Within the framework of implicit theories (Dweck and Leggett, 1988; Dweck, 2000) is a substantial number of studies on the impact of a growth or a fixed mindset on people themselves and on those around them (Blackwell et al., 2007; Zhang et al., 2017). An individual with a growth mindset concerning intelligence, for example, believes that people can become more

and more intelligent through experience, whereas someone with a fixed mindset believes that people are either permanently intelligent or not. Such implicit beliefs form a complex network of tendentially incremental or entity meaning systems, which tend to be activated in challenging situations (Plaks et al., 2009). In this study, we use *mindset* as a standard term that also encapsulates implicit beliefs and implicit meaning systems.

Mindsets are somewhat generalizable, in other words extendable to a variety of contexts (Dweck, 2000), but they may as well vary in different domains (Dweck et al., 1995). For example, someone might have a growth mindset about general intelligence, but a domain-specific fixed mindset in how they approach challenging math tasks (Gunderson et al., 2017).

Mindset theory has been studied in classroom and school contexts (e.g., Ronkainen et al., 2019; Seaton, 2018), underlining the role of the adult in building children's self-esteem. One of the most relevant discoveries from research on implicit theories is that praising children for their ability (person praise), instead of for their effort or strategies (process praise), undermines their motivation (Mueller and Dweck, 1998; Glerum et al., 2020), in that they devote energy not only to achieving a goal (mastery-oriented), but also to making sure they look smart in the eyes of others (performance-oriented). A framework for growth mindset pedagogy in basic education was recently developed and applied in Finland in a qualitative study (Rissanen et al., 2019). The authors concluded that certain features of the teaching style created a growth mindset atmosphere and were likely to boost student learning. These features included, among other things, avoiding judging students too quickly, promoting mastery-oriented rather than comparison-oriented learning, providing honest feedback in the form of "not yet," not shielding students from challenging situations, praising strategies and effort, emphasizing the positive aspects of challenges, failure, and mistakes in learning, and fostering situational attribution, i.e., behavior instead of traits.

Although home and school environments differ in nature and purpose, both constitute the two major childhood scenarios in which the young rely heavily on encouragement from adults to keep on joyfully embracing learning opportunities. It could thus be argued that a growth mindset atmosphere created in the classroom may find home learning equivalents in various features of parent–child learning-related dynamics (see Stern and Hertel, 2020, in this edition). However, most research on the parental mindset concerns its associations with the mindset of their children and their achievements (e.g., Rautiainen et al., 2016; Rowe and Leech, 2019), and sheds little light on the processes in which growth mindset parents engage to support their children's learning at home. Strengthening this trend, recent studies identify parental encouragement of effort as the most important feature of parent–child communication aimed at fostering a growth mindset in the child, more strongly predictive than the parents' own growth mindset (Haimovitz and Dweck, 2016, 2017). According to the authors, parental beliefs about the motivating or demotivating effects of failure, and their responses to their children's failure, are associated with various parental practices. Such incremental or entity implicit beliefs originate, respectively, in a *failure-is-enhancing mindset* meaning that the parent encourages process-focused thinking in their children to overcome challenges, or in a *failure-is-debilitating mindset* that may prevent their children from pushing further.

Schiffrin et al. (2019) recently carried out a quantitative study on this approach to failure. They adopted the term helicopter parenting to describe an overly involved and controlling parenting style that provides a level of developmentally inappropriate problem-solving assistance. Among the sample of 275 18- to- 25-year-olds, those reporting a failure-is-debilitating (as opposed to a failure-is-enhancing) parental mindset were also more likely to report helicopter parenting behaviors in their fathers.

In another study, Muenks et al. (2015) combined parental beliefs about their children's ability and practices of engagement at home. Their aim was to explore the beliefs of 300 parents about the fixedness of their children's abilities, based on questionnaire responses and self-reported mastery-oriented and autonomy-supportive behaviors. According to their findings, the more strongly the parents believed their children's abilities were fixed, the more readily they endorsed controlling (as opposed to autonomy-supportive) and performance-oriented (as opposed to mastery-oriented) behaviors at home, and the less frequently they reported engaging in academically related activities with their children in the home environment. Beyond the sphere of academically related engagement, Justice and collaborators (Justice et al., 2020) recently conducted a comparative quantitative study involving 497 United States and Danish parents of children aged from 3 to 5 years. They specifically set out to explore the association (if any) of a parental mindset related to ability and effort with home learning activities at home. Among the four practices of parental engagement they studied (family learning activities, learning extensions, parental time investment, and parental school involvement), the results showed that parents' effort mindset was a predictor of family learning activities at home and of parental time investment, and that the country moderated the relationship between an effort mindset and parental time investment. In the study, an effort mindset referred to the extent to which parents' beliefs reflected the importance of effort in their children's learning.

It is suggested that a complex network of implicit parental beliefs about their children's abilities is connected to a growth or fixed mindset (Plaks et al., 2009; Haimovitz and Dweck, 2016, 2017), that is constantly actualized in their relationships. Not only do mindsets affect praise and failure feedback, but they also tend to take over in any learning-related situation, especially challenging ones. In the case of a growth mindset, incremental implicit beliefs will actualize in the encouragement of persistence and process-focused thinking, implying that learning is a work in progress, and that it is a good thing (Rissanen et al., 2019). On the other hand, in the case of a fixed mindset, entity implicit beliefs will actualize in a crystalized way of interpreting people and situations, and the need to persist will be seen as a permanent weakness (Moorman and Pomerantz, 2010). It often happens that beliefs actualize in a combined and less antagonistic mixed form, thus mindsets should be perceived as one *spectrum* instead of two fixed opposite concepts. Given that implicit beliefs develop as a way of organizing one's world and giving meaning to

experiences (Dweck, 2000, 2017), they may fluctuate depending on the motivation and the emotion. In one specific domain and at one given time, an individual may tend toward either a fixed or a growth mindset (Seaton, 2018), but may as well show both growth and fixed tendencies in their behavior, indicating a mixed mindset (e.g., Laine et al., 2016).

Following a long period of positive attention and dissemination, the applicability of the mindset theory has been largely questioned in the last decade, especially due to failed mindset interventions replication and applicability (Dweck and Yeager, 2019; Yeager et al., 2019). After looking carefully into past research and conducting new studies, the mindset theory is building stronger assets to its foundation and confirming its applicability to learning contexts by two means: (a) recognizing and highlighting the central role of the environment revolving any mindset intervention, e.g., school culture, classroom climate and age of target-group (Dweck and Yeager, 2019), and (b) attempting to bring together complex psychological phenomena (Dweck, 2017) and an array of disciplines of study (Dweck and Yeager, 2019) to model effective mindset interventions. Such enlargement of scope, that considers people's beliefs, emotions, motivation, personality and intertwined environment, provides a rich framework to study parental engagement practices and mindsets in the home environment.

The Aim of the Study

The present study is part of the University of Helsinki's Copernicus project, which explores the implicit beliefs of parents, teachers and students, as well as home-school collaboration, in different cultural contexts. This study focuses on the parental role in children's learning, in Finland and Portugal. Our aim is, in an analysis of parental narratives, to characterize engagement with their children's learning at home, and the implicit beliefs about learning that underlie such engagement. The research questions are as follows.

(1) How do parents engage with their children's learning at home?
(2) How do parents' implicit beliefs about learning actualize in such engagement?
(3) What kind of engagement–mindset profiles are identifiable amongst the parents?

MATERIALS AND METHODS

Participants and Procedure

In seeking answers to our questions, we adopted a qualitative approach based on in-depth interviews. We sent invitation e-mails to a set of 50 Finnish English-speaking parents who had previously collaborated with the Copernicus project by answering a mindset survey in 2016 or 2017. The Portuguese parents received an invitation from the principal of the respective schools, and those wishing to collaborate enrolled through a hyperlink. All parents who volunteered were interviewed. The participants ($N = 19$) were parents of first- to sixth-grade children, ten Finnish parents from Helsinki and nine Portuguese parents from Lisbon.

In Finland, the parents came from two schools located in different socio-economic urban neighborhoods in Helsinki, to ensure diversity of parental experiences and narratives. One school with 900 students provides basic education from grades one to nine, and the other has 940 students in basic to upper-secondary education. The Portuguese parents came from one five-school *agrupamento* educating 2,550 pupils from kindergarten to the secondary level. Schools in Portugal work in groups (*agrupamentos*) of neighboring schools with complementary levels, under the same administration. Following the same principle as in Finland, we selected a Portuguese *agrupamento* that was in a heterogeneous and urban neighborhood.

The interviews in Finland were conducted in February 2020 and took place in different locations including the schools, the neighborhood library and the participants' homes. The Portuguese parents were interviewed between March and June 2020, via the videocall software Zoom on account of the coronavirus pandemic. The researcher took all the necessary precautions to ensure the participants' privacy and safety during face-to-face and online interviews. The Finnish and the Portuguese participants were interviewed in English and Portuguese, respectively.

Participation in the study was voluntary. The participants were informed that the interview concerned their engagement with their children's learning, and they signed an informed consent form regarding their participation (Finnish Advisory Board on Research Integrity, 2009). A more detailed explanation of the mindset-related purpose of the study was given after each interview, to ensure that it would not influence the parents' responses.

Table 1 gives background information about the parents, including mean age, gender, education, and child's grade. Parents' mean age were 43 years old ($M_{all} = 43.84$; $SD_{all} = 8.21$). In Finland, the mean age of parents was 47 ($M_{Finn} = 47$; $SD_{Finn} = 9.01$; $Min_{Finn} = 40$; $Max_{Finn} = 70$), whereas, in Portugal, it was 40 years old ($M_{Port} = 40.33$; $SD_{Port} = 5.83$; $Min_{Port} = 29$; $Max_{Port} = 50$). Most participants were female ($n_F = 14$; $n_M = 5$), and only one Portuguese mother, among all parents, did not have a university degree.

TABLE 1 | Participants' background information.

	Finland *N* = 10	Portugal *N* = 9
Age (in years) mean (SD)	47 (9)	40.33 (5.8)
Gender		
Female	6	7
Male	4	2
Education		
Secondary education	0	1
Higher education	10	8
Child's grade		
1st and 2nd	0	5
3rd and 4th	3	2
5th and 6th	7	2

Instruments

We used a semi-structured interview protocol to ensure consistency, while also allowing for spontaneous narratives to emerge (Legard et al., 2003). This study's data comes from a broader study about parental engagement practices and mindset. Interviewees were asked to speak rather freely about the topics of parental engagement with their children's learning at home and at school, dealing with their children's challenges and successes in learning, and parent-teacher learning-related collaboration. The opening question was *Please, tell me about what in your opinion makes for a successful teacher-parent partnership?* The narratives were followed by clarifying questions by the researcher, who would lead the conversation to the subsequent topic of discussion in a natural manner. Indicative questions used in the present study are *What does parental engagement with learning mean, from your point of view? How can parents engage with learning at home?* or *Can you recall a challenging learning episode that took place at home and how you approached it? Can you recall a successful learning episode that took place at home and how you approached it?* The sequence of questions varied from one interview to the other, to favor the spontaneous flow of the conversations.

The protocol was based on the literature (e.g., Goodall, 2013; Haimovitz and Dweck, 2017) and aimed at eliciting descriptions not only of the parents' experiences, but also their context, e.g., learning-related implicit beliefs, attitudes, and processes underlying engagement in the child's learning. The interviews varied in length from 30 to 120 min, the average length being 1 h. They were audio-recorded and later transcribed, generating 213 pages of text.

Before the interview, the parents filled in a short demographic questionnaire. They were also informed that the term 'at home' referred to all non-school-related occasions, such as in the park. Additionally, parents were asked what the word 'learning' meant in their own understanding. All definitions shared by the participants conveyed an idea of learning as an ongoing phenomenon in their children's lives and independent from the school context. It was thereby guaranteed a common interviewer–interviewee conceptualization of learning.

Analysis

A content-analysis method was employed to study the data. We chose content analysis because it is commonly used in research aimed at enhancing understanding of and retrieving meaning from rich verbal data in an objective and systematic manner (Krippendorf, 2004; Schreier, 2012). The unit of analysis varied from parts of sentences to whole paragraphs. As a criterion, each coded excerpt should constitute an independent element of meaning about the phenomena (Elo and Kyngäs, 2008). Atlas.ti 8 software was used to facilitate the analysis.

To find answers to our first research question we carried out an inductive content analysis, given that our purpose was to identify and contextualize forms of parental engagement in the home. Thus, all the codes derived from the data (Elo and Kyngäs, 2008). First, the first author coded each interview regarding parental engagement at home. Every time a new engagement-related topic emerged a new code was created. Second, through a process of reflection and discussion, the first and the second authors clustered the codes into thirteen subcategories, then five broader subcategories and, finally, in two main categories. The process necessitated iterative analyses of the data. Example 1 demonstrates a unit of analysis related to engagement in the schooling process, of which the code was *studying the clock*, subcategory *supporting studying*, broader subcategory *helping with schooling-related activities*, and main category *engagement with the children's schooling process*.

> Example 1: *She started to learn to tell the time at school, and it was a little bit difficult for me [to help her], because it is a little bit abstract. I tried to get something concrete. So, we drew a clock, you know, we had scissors and everything. We had a little bit of fun and did our own clock and then we started to practice with that.* (Parent 16)

With regard to the second research question, we used the features of a growth mindset, or incremental implicit beliefs, as the units of analysis that would convey intelligence as malleable, and challenges as boosters of learning. The features of a fixed mindset, or entity implicit beliefs, on the other hand, were the units that connoted intelligence as stable, and challenges as obstacles in the learning process. Within each main mindset category, we created six mirroring subcategories based on the theoretical model, e.g., giving process-focused (growth) and person-focused (fixed) praise. One fixed mindset subcategory was later merged with a similar one, giving a total of eleven subcategories. Example 2 exemplifies a unit of analysis related to a growth mindset of which the code was *embracing challenges*, subcategory *encouraging the seeking of challenging learning situations* and main category *growth mindset*.

> Example 2: *The learning journey has been spectacular. Because it has been hard, but, as I tell him, the hard things are the interesting ones [. . .] it has been very good, because we all learn every day, from the good and the less good moments.* (Parent 3)

We read through the transcripts of the interviews multiple times to make sure that we would interpret contexts and meanings as accurately as possible. To achieve consensus, the first and the second author reflected upon the coding decisions on four different occasions. Disagreements were discussed and recoded jointly.

In the final phase of the analysis, to answer our third research question and identify parental engagement–mindset profiles, we considered each interview as a whole. We calculated the frequencies of statements for the main categories separately for each parent so that we would be able to detect which aspects of parental engagement and mindset were emphasized in individual parental narratives (Tuomi and Sarajärvi, 2002). The statements were calculated per parent to determine whether he or she had described his/her engagement *mostly* related to the schooling process, or had engaged with his/her child *mostly* in an integrated way, i.e., engaging in holistic development. An overall engagement tendency was defined as holistic when the parent had more than 50% of engagement statements in

the main category **engagement with their children's holistic development**. Similarly, parents with over 50% of statements in the main category **engagement with their children's schooling process** were classified as having schooling-focused engagement in their children's learning. Even though engaging with the schooling process is considered an integral part of engaging with the holistic development (Goodall and Montgomery, 2014), the distinction here presented is possible, because the authors recognize engagement with the holistic development as the third and major point of the engagement continuum, that globalizes all forms of engaging with learning. Because all parents narrated engaging with their children's schooling process *and* holistic development, it is necessary to point out that parental engagement–mindset profiles reflect patterns found in our data, collected and analyzed in specific occasions. Therefore, they portray a *tendency* of engagement, instead of the whole continuum a parent and child might navigate through, in their learning-related interactions.

With regard to the parental mindset, those whose statements concentrated between 75% and 100% in the growth mindset category were assumed to have an overall Growth Mindset (GM). All the remaining parents' mindsets were classified as Mixed Mindset (MM) because their statements aligned with both the growth mindset and fixed mindset categories. Four parental profiles were created on the basis of the calculations.

RESULTS

Parental Engagement With Their Children's Learning at Home

The first research question concerned how Finnish and Portuguese parents engaged in their children's learning at home: a total of 313 statements ($f_{Finn} = 171$; $f_{Port} = 142$) citing parental engagement were identified and coded (see **Table 2**).

As **Table 2** shows, parental engagement practices were classified in two main categories based on whether narratives reflected engagement with children's schooling process or holistic development. No major differences between the Finnish and the Portuguese parents were identified in this respect, therefore we assess the results as a single group. The narrative exemplars transcribed below have been selected based on how well they represent the data in each category.

The first main category, engagement with the **children's holistic development** ($f = 191$), was prominent, the emphasis being on ***cultivating the relationship*** ($f = 86$) with their children and ***developing the character*** ($f = 68$). The following statements well demonstrate how parents in our sample see showing interest in their children as an intrinsic part of being engaged.

> *[Parental engagement] is my own interest and motivation to follow how my child is learning, what he is learning, how he is doing, what are the challenges for him. [. . .] And I feel it is very normal that I make some observations and I follow how he is doing. [. . .] The child should feel and experience that the parent is always ready to give support, to give his knowledge, to back this [learning] process.* (Parent 18, Finnish, Female, 44 years old)

> *To me, [engaging] is the interest we as parents have in the children's education . . . it is asking how their day went, to know about them, how did the school day go, what went well, what did not, if they remember what they learned, chats they have had during the day with classmates.* (Parent 3, Portuguese, Male, 40 years old)

Similarly, *encouraging autonomy* ($f = 37$) was the highlight of developing the character in learning-related experiences at home, as one parent said about his fifth grader.

> *What is needed is to [. . .] develop in the child the autonomy to be organized. Because, if not, then the child will be by herself until eleven in the evening [. . .] So, what we do is 'okay, you have until seven o'clock to do your homework.' When it's seven, then, it's over. 'Couldn't complete it? Well, next time you have to manage your time better.' That's what we try to stimulate in her, organizing skills.* (Parent 9, Portuguese, Male, 41 years old)

There were also references to ***supporting leisure-time activities*** ($f = 37$). Here, parents spoke of engagement as *providing* opportunities to try *new skills and experiences* ($f = 23$) beyond the world of school, as shown by the following mother.

> *We gave our daughter a book about programming for kids and bought, actually, this kind of small computer for kids, so she could start learning coding. Something that is in between, that are not books from school, but also not random.* (Parent 13, Finnish, Female, 40 years old)

The second main category, engagement with the **children's schooling process** ($f = 122$), was strongly present in the parental experiences of engagement at home. The emphasis was on directly ***helping with schooling-related activities*** ($f = 77$). Within this main category, *supervising homework* ($f = 44$) and *supporting studying* ($f = 25$) were recurrent topics of engagement. This Portuguese mother exemplifies her approach to homework supervision.

> *Being engaged is [. . .] to know what the children are learning, what they are doing, not necessarily knowing the content matter or being beside them doing the homework together, but at least, supervising, paying attention, being always, always present.* (Parent 6, Portuguese, Female, 44 years old)

Parents also reported indirectly engaging in their children's learning at home while ***updating their schooling-related information*** ($f = 45$): examples include *knowing their children's school routine* ($f = 20$), *communicating with the teacher* ($f = 20$) and *seeking information about the curriculum* ($f = 4$). The parents highlighted the importance of knowing what happens in the school and reaching out to the teacher if necessary, for instance.

Parents' Implicit Beliefs and Their Actualization in Parental Engagement at Home

The responses to the second research question concerning the actualization of the parents' implicit beliefs at home are presented as a table of frequencies (**Table 3**) showing which features of a growth and a fixed mindset prevailed in the

TABLE 2 | Frequencies of the subcategories and main categories of parental engagement at home.

Parents engaged with. . .	Number of statements		
	Finnish (*N* = 10) *f* (%)	Portuguese (*N* = 9) *f* (%)	Total (*N* = 19) *f* (%)
Their children's holistic development	**96 (56)**	**95 (67)**	**191 (61)**
Cultivating the relationship	**38 (22)**	**48 (34)**	**86 (27)**
Showing interest in their children	34 (20)	43 (30)	77 (24)
Taking the role of a parent	4 (2)	5 (4)	9 (3)
Developing the character	**39 (23)**	**29 (20)**	**68 (22)**
Encouraging autonomy	24 (14)	13 (9)	37 (12)
Teaching morality and rules	8 (5)	9 (6)	17 (6)
Giving socio-emotional support	7 (4)	7 (5)	14 (4)
Supporting leisure-time activities	**19 (11)**	**18 (13)**	**37 (12)**
Providing new skills and experiences	14 (8)	9 (6,5)	23 (7)
Spending leisure time together	5 (3)	9 (6,5)	14 (5)
Their children's schooling process	**75 (44)**	**47 (33)**	**122 (39)**
Helping with schooling-related activities	**48 (28)**	**29 (20)**	**77 (25)**
Supervising homework	28 (16)	16 (11)	44 (14)
Supporting studying	14 (8)	11 (8)	25 (8)
Preparing for exams	6 (4)	2 (1)	8 (3)
Updating schooling-related information	**27 (16)**	**18 (13)**	**45 (14)**
Knowing their children's school routine	15 (9)	5 (4)	20 (6)
Communicating with the teacher	9 (5)	12 (8)	21 (7)
Seeking information about the curriculum	3 (2)	1 (1)	4 (1)
Total of statements	**171**	**142**	**313**

TABLE 3 | Actualization of parents' implicit beliefs about learning in their parental engagement at home.

Parental implicit beliefs actualized in a. . .	Number of statements		
	Finnish (*N* = 10) *f* (%)	Portuguese (*N* = 9) *f* (%)	Total (*N* = 19) *f* (%)
Growth mindset	**126 (77)**	**108 (89)**	**234 (82)**
Considering the child's learning context and emotions	25 (15)	46 (38)	71 (25)
Encouraging effort, persistence and practice	36 (22)	19 (16)	55 (19)
Approaching difficulties as a natural part of learning and suggesting strategies	23 (13)	12 (10)	33 (12)
Encouraging the seeking of challenging learning situations	21 (14)	9 (7)	32 (11)
Giving process-focused praise	16 (10)	11 (9)	27 (10)
Advising to ask questions when in doubt	5 (3)	11 (9)	16 (5)
Fixed mindset	**38 (23)**	**14 (11)**	**52 (18)**
Interpreting personality	16 (10)	10 (8)	26 (9)
Comparing and rewarding performance	12 (7)	1 (0,5)	13 (4)
Approaching difficulties as obstacles to learning	3 (1,5)	2 (2)	5 (2)
Admiring effortless success	4 (3)	1 (0,5)	5 (2)
Giving person-focused praise	3 (1,5)	0 (0)	3 (1)
Total of statements	**164**	**122**	**286**

interviewees' narratives. We identified a total of 286 relevant statements (f_{Finn} = 164; f_{Port} = 122) indicative of parents' implicit beliefs about learning.

Next, we consider the most prominent subcategories in more detail. In general, we discuss the results as a whole, given that there were no major differences between the Finnish and the Portuguese parents. At some points in this section we discuss interpretations of the growth and fixed categories together given that they mirror each other, even though they are reported in separate segments in **Table 3**.

As **Table 3** shows, the parents' engagement narratives were consistently embedded in a **growth mindset** (f = 234), which was demonstrated in how they *considered the child's learning context and emotions* (f = 71) in the situation, rather than fixed traits such as *interpreting personality* (f = 26).

Other indications of a growth mindset were evident in their discourse, such as *encouraging effort, persistence and practice* (f = 55), as opposed to *admiring effortless success* (f = 5), which is indicative of a fixed mindset. Features indicating a growth mindset tended to relate to *process-focused praising* (f = 27),

whereas fixed mindset-related *person-focused praising* (f = 3) was seldom used. The following statement about giving feedback to her first grader about her success in a difficult writing task reflects both subcategories: *encouraging effort, persistence and practice* and *process-focused praising*.

> *I always congratulate her, because all victories are victories. You can only win the war with various smaller battles. I say 'You see? You just needed to have patience. Of course, if you work, you are calm and patient, things will get done.'* (Parent 7, Portuguese, Female, 35 years old)

Further evidence of growth mindset thinking in the parents' narratives relates to *approaching difficulties as a natural part of learning and suggesting strategies* (f = 33) for overcoming them, whereas responses reflecting the fixed mindset subcategory *approaching difficulties as obstacles to learning* (f = 5) were fewer. Avoiding the comfort zone and *encouraging children to seek challenging learning situations* (f = 32) was another prominent feature evidencing a growth mindset in the parents' discourse, especially among the Finnish respondents (f_{Finn} = 21; f_{Port} = 9). The following statement falls into this subcategory. The parent talks about allowing his children to explore the city without adult supervision.

> *The kids are expanding their area all the time, and we are trying to let them do that [. . .] We let them explore the world and hopefully not just sit and use their phones all day. And this is also an educational thing, that they take responsibility for themselves, [that] they know what to do if they get lost or if they hurt themselves or if they get hungry, [that] they know how to use money, to interact with people they don't know.* (Parent 14, Finnish, Male, 43 years old)

Finally, although the fixed mindset subcategories were not prevalent, *comparing and rewarding performance* (f = 13) featured in the Finnish parents' narratives (f_{Finn} = 12; f_{Port} = 1): 7% of the relevant statements mention some kind of material rewarding of children's achievements – such as a present, money or candy – based on an expected standard of performance. We should nevertheless point out that few statements were assigned to this subcategory.

Although the frequency tables were a major support in terms of identifying patterns in our data, we were intent on accessing individuals and understanding how their implicit meaning system connected to their overall engagement in their children's learning at home. In the next step of the analysis, we attempted to realize these associations and to situate parents, accordingly.

Parental Engagement–Mindset Profiles

To answer our third research question about what engagement–mindset profiles could be identified among the parents, we analyzed each participant's overall tendency to engage with learning and their mindsets about learning. We calculated the frequencies of statements for the main categories for each parent and built four parental profiles based on the calculations. **Table 4** and **Figure 1** illustrate the process and present the results.

Figure 1 depicts learning-related parental engagement and mindsets combined in four profiles, thereby giving a clearer picture of how parental mindsets actualize in their engagement with their children at home. The underlined text below refers to the names of the profiles; text in *italics* refers to the subcategories of engagement, reported in **Table 2**; and text in **bold** refers to the mindset subcategories, reported in **Table 3**.

Most of the parents we studied exhibited a growth mindset to support the child's holistic development (n = 12, nFinn = 5, nPort = 7). They treated their children as whole persons and engaged in their home learning in multiple ways, taking special advantage of spontaneous day-to-day routine as opportunities for engagement. The following statement exemplifies the actualization of a growth mindset in **approaching difficulties as a natural part of learning and suggesting strategies** for overcoming them when *teaching about morality and rules* and *encouraging autonomy*.

> *I told him how bad fake news is. [Because he appeared in a newspaper article], I told him 'tell me whenever you get the first message from anyone that you don't know, that seems to be somehow suspicious, a wrong message, show it to me. We can check it together if it's some kind of scam,' because his name is out there now. I told him 'it is possible that your face and some naked body will be put together, and that they ask you for money. It is possible if somebody wants to be mean' [. . .] He takes so many things into account, and I don't try to stop him by giving him unrelated, irrational orders. I rely on sensible talk and discussion.* (Parent 17, Finnish, Male, 70 years old)

The growth mindset of parents with this profile was also actualized in **encouraging effort, persistence and practice** and **considering the child's learning context and emotions** when *supporting studying*. A Finnish father and a Portuguese mother illustrate this in the examples below, when talking about their children's homework challenges.

> *I think that what we've tried to tell them is that if you work you will learn. That if you. . . It's not about being stupid, it's about doing more work. Because they might be frustrated and [say] that 'I'm stupid, I don't get it, I hate it,' and stop working and stop thinking. So we try to embrace their self-confidence [and say] 'it's not you, it's just that you need more time, and you need to focus on it.'* (Parent 14, Finnish, Male, 43 years old)

> *I help her with the homework . . . if I notice she is too tired and starting to act out and refusing it, I stop for a while and say 'look, we'll finish this later today,' because they do get tired, you know.* (Parent 2, Portuguese, Female, 41 years old)

Parents with the profile mixed mindset to support the child's holistic development [n = 2, nFinn = 1 (Parent 10), nPort = 1 (Parent 4)], also varied in their engagement at home. However, the variation was more evenly distributed between schooling-related and holistic engagement, meaning that these parents tended to engage more in the schooling process, compared to the previous group. The following example is a narrative of *socio-emotional support* from parent 4. She describes praising her daughter when she passed the level test for her swimming class, after receiving many negative behavior-related comments from the instructor in the previous months. She uses growth mindset **process-focused praise**, interspersed with a fixed mindset interpretation of her child's characteristics as fixed traits, i.e., **interpreting personality**.

TABLE 4 | Parental engagement–mindset profiles.

		Parental engagement *f* (%)						Mindset *f* (%)						
Parent	**Country**	**Statements (*f*)**	**Schooling (S)**		**Holistic (H)**		**Result**	**Statements (*f*)**	**Fixed (FM)**		**Growth (GM)**		**Result**	**Profiles**
2	Portugal	16	3	(19)	13	(81)	H	7	0	(0)	7	(100)	GM	Holistic development and growth mindset
3	Portugal	18	2	(12)	16	(88)	H	13	0	(0)	13	(100)	GM	
5	Portugal	5	1	(20)	4	(80)	H	15	1	(7)	14	(93)	GM	
6	Portugal	22	9	(41)	13	(59)	H	17	0	(0)	17	(100)	GM	
7	Portugal	24	11	(46)	13	(54)	H	24	3	(13)	21	(87)	GM	
8	Portugal	17	3	(18)	14	(82)	H	13	0	(0)	13	(100)	GM	
9	Portugal	7	0	(0)	7	(100)	H	7	0	(0)	7	(100)	GM	
12	Finland	11	4	(36)	7	(64)	H	8	0	(0)	8	(100)	GM	
13	Finland	21	10	(47)	11	(53)	H	15	0	(0)	15	(100)	GM	
14	Finland	22	5	(23)	17	(77)	H	15	0	(0)	15	(100)	GM	
17	Finland	11	2	(18)	9	(82)	H	18	4	(22)	14	(78)	GM	
18	Finland	30	11	(37)	19	(63)	H	25	2	(8)	23	(92)	GM	
11	Finland	7	4	(57)	3	(43)	S	11	4	(36)	7	(64)	MM	Schooling process and mixed mindset
15	Finland	7	4	(57)	3	(43)	S	13	4	(31)	9	(69)	MM	
19	Finland	16	11	(69)	5	(31)	S	18	14	(78)	4	(22)	MM	
1	Portugal	9	7	(78)	2	(22)	S	9	2	(22)	7	(78)	GM	Schooling process and growth mindset
16	Finland	22	12	(55)	10	(45)	S	27	2	(7)	25	(93)	GM	
4	Portugal	16	7	(44)	9	(56)	H	17	8	(47)	9	(53)	MM	Holistic development and mixed mindset
10	Finland	5	2	(40)	3	(60)	H	14	8	(57)	6	(43)	MM	

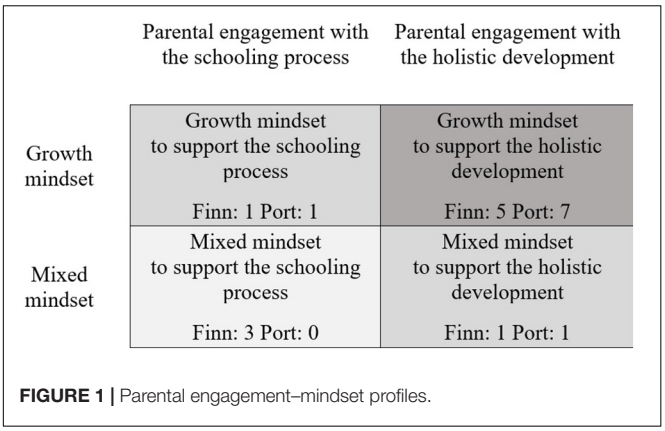

FIGURE 1 | Parental engagement–mindset profiles.

> *My attitude is always positive and in the sense of sharing her enthusiasm, 'wow, how awesome, you did it! You see [what happens] when you put in effort,' I try to show her the path she has walked along. If she had difficulties in the beginning, I try to make her see what she managed to overcome, 'do you remember how you did it before? You put in effort, now you achieved your goal, the path is not always easy, but if we put in effort, we can achieve our goals.' [. . .] And she gets happy, but she is normally a lazy person, really lazy, and only once in a while does she show this spectacular side.* (Parent 4, Portuguese, Female, 40 years old)

Two parents were placed in the growth mindset to support the child's schooling process (n = 2, nFinn = 1, nPort = 1) profile, and three parents in the mixed mindset to support the child's schooling process profile (n = 3, nFinn = 3, nPort = 0). Both profiles represent the parental approach of engaging in learning concentrated on schooling-related activities, but the mindset differs. Thus, although parents in the former group may be more supportive of their children's mistakes and their individual learning contexts as students, those in the latter group may convey standard-related expectations and a negative message with regard to learning difficulties.

The following statement, from a parent with a growth mindset to support the child's schooling process profile, shows how her growth mindset actualizes in her **process-focused praise** and **encouragement of effort, persistence and practice** when she gives feedback to her child related to achieving good marks in school exams, i.e., *preparing for exams*.

> *I encourage her 'this is the way to go,' but I never tell her that she has to be the best, because she doesn't. We have to be the best of ourselves, give it our best, not to be better than others [. . .] school is not a race.* (Parent 1, Portuguese, Female, 29 years old)

In the final example, on the other hand, which is from a parent in the mixed mindset to support the child's schooling process profile, the mixed learning-related mindset actualizes in *supporting studying* at home. Having considered this respondent's (Parent 19) position in **Table 4**, we understood the dominance of schooling-process-related engagement. In terms of mindset, the frequencies point to a prevalence of a fixed mindset (f = 14, 78%). In the example, when the mother talks about her child's mathematics skills she fits in the fixed mindset subcategory **comparing and rewarding performance** in using standardized comparisons, but she also reveals a growth mindset at the end of her discourse, specifically within the subcategories **considering the child's learning context and emotions** specific of the pre-puberty stage of development and **approaching difficulties as a natural part of learning** that will be eventually 'figured out.'

> *Her multiplication skills were a bit weaker, so during the summer I made cards and I told her that we needed to do the multiplication tables. I saw the way she was doing her math, that she was slow [. . .] I thought 'at this age, she should have known it really fast by now and not have to think so long' [. . .] And now she is getting lazy again about doing her multiplication tables, so it didn't stay with her. So, I thought 'yeah, I'm going to have to do it again.' This year it is probably going to be harder, because she is eleven and she thinks she is a teenager, so it's a big fight with the 'I don't want to do it.' She's in the pre-puberty stage, so it's a lot of 'no, no,' and sure that's an obstacle, but that is also quite normal and we're still trying to figure that out.* (Parent 19, Finnish, Female, 45 years old)

DISCUSSION

Our aim in this study was to make a qualitative contribution to the growing interest on parental engagement and growth mindset. Assessed by means of both inductive and deductive content analysis, our data comprised parental narratives about how they engaged in their children's learning at home, and how their mindset actualized in such engagement. We were also interested in finding out which parental profiles, if any, the combined framework of parental engagement as a continuum and the implicit theories (Dweck, 2000; Goodall and Montgomery, 2014) would generate. The study's participants were parents of 7- to 12-year-old children from two countries, Finland and Portugal. A further aim was to identify country-specific patterns of engagement and mindset actualization.

It is important to underline that conclusions derived from our study refer to a specific set of participants and their personal experiences, which does not allow generalizations, but apply only to the participants who have been interviewed. Moreover, the data gathered and analyzed captures a small sample of parents' experiences of engagement, narrated by themselves and interpreted and reported by the researchers of this study. This means that parental profiles are far from static and exact. Nevertheless, their interviews constitute a rich first-person set of narratives of interactions with their children, that allowed a detailed study of parental engagement and mindset in the home environment. This is one of the most relevant advantages of conducting qualitative research (Elo and Kyngäs, 2008).

Parental Engagement Practices at Home

Because our findings revealed no major differences between how Finnish and Portuguese parents engaged with their children at home, we opted to analyze the results of the whole group of nineteen parents. From the perspective of parental engagement as a continuum that encompasses parent–child learning-related interactions of different complexity of involvement, we found out that the interviewed parents engaged in learning at home

in a balanced manner, navigating through both their children's schooling process and their children's holistic development. While maintaining their role of reference in supporting their children's academic activities, such as supervising homework and supporting studying, the majority of the parents were aware of the extent to which simple everyday parenting activities such as showing an active interest in their children, encouraging autonomy, teaching them about morality and rules, and giving them opportunities to extend their skills and experiences beyond the school context, constituted key learning-related parental engagement initiatives that supported an integrated development of their child. Parents talked about their children's learning in a broad sense, from the beginning, tending to see learning as a natural part of experiencing life, in and outside the school.

Our results highlight the importance of approaching parental engagement in the home learning environment as a continuum ranging from schooling-related activities to the most spontaneous and genuine parent–child interactions in natural, school-independent settings (Goodall and Montgomery, 2014). In other words, focusing on the holistic development of the child. Although not generalizable, the fact that our strongest subcategory was *cultivating the relationship* adds a building block to the research regarding the importance of supportive and warm parenting styles in learning-related activities at home (OECD, 2012; Goodall, 2013; Silinskas et al., 2015; Sikiö et al., 2017). The results also point to the necessity of shifting the central role of homework involvement as the major context of parent learning-related engagement at home (Hill and Tyson, 2009) among parents of school age children. Scholars (e.g., Goodall, 2017) have called attention to the lack of attention of schools that already adopt holistic educational paradigms in the classroom in instructing families to engage in their children's holistic development at home. In that respect, our findings allow us to infer that our parents were well informed and awaken the importance of supporting their children's feelings, aspirations and ideas in different areas of development, not only in the academic realm (Miller, 2000). Although parents' level of formal education might be a plausible explanation, this still raises the question of whether the participants benefited from effective home-school partnership and teacher-parent communication that gave them the incentive to engage in such actions at home (Goodall, 2017).

Actualization of Mindset in Engagement

With regard to learning-related mindsets among parents, our results contribute to the growing interest on the association between mindset and parental engagement. We found evidence that a growth mindset featured in the vast majority of our participants' experiences of engagement with their children's learning. This implies that the interviewed parents, when engaging with their children's learning, conveyed the hidden message that their learning could be developed by means of effort and practice. Fixed mindset hidden messages, such as that children's learning outcomes depended on their fixed personality traits, were also present in our data, although much less frequently. These findings are in line with the results of previous research postulating that parents develop patterned implicit beliefs about their children's abilities (Dweck, 2000; Moorman and Pomerantz, 2010; Rautiainen et al., 2016). More specifically related to mindset and parental involvement practices, our findings are in line with previous research (Muenks et al., 2015; Schiffrin et al., 2019) that showed that parents who engaged in academic activities at home evidenced a growth mindset regarding their children's learning-related failure and ability.

Moreover, there is evidence that effort mindset is a predictor of parental engagement in family learning activities as well as time investment at home (Justice et al., 2020). Not only do our findings complement such evidence, but they also bring it to another level of analysis in allowing us to form a clear picture of such associations. Our main contribution comprises the parental engagement–mindset profiles we were able to draw up.

Parental Engagement–Mindset Profiles

Growth mindset features were distributed amongst all the parental profiles, differing only in terms of frequency. Both growth mindset and mixed mindset profiles were identified in the interviewed parents' narratives of engagement. Among the parents with a growth mindset, the overall tendency was to engage with the child's holistic development, instead of solely engaging with the child's schooling process. Parents in the mixed mindset group shared examples of engagement that implied a need to be, to some extent, constantly informed about their children's lives, and their narratives relied less on examples of engagement in autonomy-supportive interactions. These findings are in line with the results of previous research reporting associations between a helicopter parenting style and a failure-is-debilitating mindset (Schiffrin et al., 2019). When compared to the growth mindset group of parents, the mixed mindset parents interviewed by us more frequently focused their engagement narratives solely in schooling-related activities at home. This finding adds controversy to the debate on engagement–mindset research (Muenks et al., 2015) that concludes that less autonomy-supportive parents show a tendency to engage less in academically related activities at home. Given that Muenks et al. (2015) explored no other kinds of engagement beyond the academic sphere, and that they assessed mindset by means of questionnaires, we cannot agree or disagree with the findings. What we are able to conclude from our research is that parents in both the growth and the mixed mindset profile groups engaged in different ways with their children's learning, varying in emphasis between supporting their child's schooling process alone or supporting their child's holistic development, where the schooling process is as important as all other learning-related experiences of the child.

The majority of the parents in our study were situated in the growth mindset profiles, within which the most common was *growth mindset to support the child's holistic development*. These findings build on the recent work of Justice et al. (2020): they found that a parental mindset supporting their children's efforts to develop their abilities was a predictor of family learning activities such as telling stories, playing sports and doing science projects, and of parental investment in time at home. Our results reveal an association of a parental growth mindset, including acknowledgment of the role of effort in

learning, with broader forms of engagement that include shared leisure and other enjoyable activities. Parents in the *growth mindset to support the child's holistic development* profile gave examples of engagement involving calmer, more relaxed and spontaneous learning contexts. One possible interpretation is that these parents might not feel such a strong need to closely follow their children's learning process, which would allow them more time to engage in spontaneous and/or school-independent activities. This is in line with previous research on parenting styles and homework assistance implying that close schooling-related parental support could be a reaction to learning difficulties experienced by children, the researchers having found out that such engagement is associated with low schooling outcomes (Silinskas et al., 2015).

Finally, our results reveal how complex and dynamic the implicit meaning systems of parents can be in terms of their actualization in support of learning. We found that mindsets may actualize in different ways along the mindset spectrum (Dweck, 2000), depending on the context. All our parents used a variety of strategies to support their children's learning at home and to meet their learning needs, thereby evidencing a dynamic and ever-developing relationship with their children. We stress the importance of studying the parental mindset in relation to their engagement in learning at home *in context*, given that mindset is likely to manifest as mixed, even in one specific type of interaction such as parent–child communication. One good example of this is the way various parents with a growth mindset in our sample referred to offering and giving material rewards to their children and sometimes compared their outcomes to a standard. If not analyzed in context and in light of parental engagement as a broad concept, such as only with a questionnaire, such parental profiles may be open to misinterpretation, and end up being regarded as fixed mindset.

It is necessary to take into account while interpreting our results the fact that, with the exception of one parent whose highest level of education was secondary school, all parents had university degrees. This brings important implications to this discussion of findings, as it is likely to influence parents' practices of parental engagement at many levels. Well-educated parents may benefit from more resources, such as money or time flexibility, and an easier access to information and guidance, such as academic research on parenting or reliable professionals.

Implications

The present research contributes to the debate on parental engagement and a growth mindset from a unique perspective, by combining implicit theories and parental engagement theoretical conceptualizations, studying children and families beyond the preschool context, and content analyzing parents' own narratives. We did not set out with an initial hypothesis, nor were we intent on confirming or refuting evidence presented in previous studies. On the contrary, we aimed to open the door on the engagement–mindset debate even wider. Our study gives insights into the association between growth mindset and engagement practices, and suggests optimal contexts for supporting children's learning. It also highlights the need for qualitative research on the parental mindset in the home learning environment.

In terms of practice, this research should attract the attention of school principals and teachers. Each child's home environment must be taken into account in any attempt to foster whole-child learning. These clear examples of growth and fixed mindset actualization in parental engagement illustrate how schools should approach parents, specifically in terms of what to encourage and how to advise them on home-related engagement. For instance, when a child shows signs of learning difficulties in school-related matters, it is not uncommon that parents receive instructions to reinforce the children's schooling at home. Many times, this prolonging of school hours in the home may have a negative impact in parent–child relationships (Silinskas et al., 2015; Sikiö et al., 2017). Our findings support the argument that teachers should instruct parents to engage with their children's learning at home from a holistic point of view, investing their time together in both school- and non-school related activities. Additionally, teachers could enhance parents' awareness about the fact that their communication with their children is constantly embedded in incremental or entity implicit theories, and about how to build a growth mindset environment at home when supporting children's learning. Such apparently simple and light support from schools may have the power to disseminate a growth mindset atmosphere at home (Dweck, 2010), and thereby to break down barriers to the engagement of all families (Goodall, 2017).

Limitations

We interviewed nineteen parents for this research, therefore the results cannot be generalized. Moreover, the small numbers of participants from each country do not allow for reliable cross-cultural comparisons. We therefore recommend that future research on the topic should encompass a larger number of participants, as well as different cultural backgrounds.

Another limitation concerns the background profile of the participants. Even though the selected schools were heterogeneous to ensure variability in parental experiences and realities, all the participants who reached out to us and wanted to collaborate had a university degree, with the exception of one mother who had completed secondary education. Even though we did not measure the socio-economic status of the parents, it was evident that none of them faced fundamental challenges, such as financial, to be engaged with their children's learning, and all were aware of the need to do so. Parental engagement is an important tool that schools could use to fight against inequality and to close the achievement gap between low- and high-income families (Goodall, 2017). We therefore recommend that in future qualitative research every effort should be made to listen to and give space to a more diverse group of participants.

We should also address the methodological limitations of our study. The results we present here are not crystalized portraits of participants' engagement practices and implicit beliefs. No methodology could provide such portraits, but we suggest that future research should use combined qualitative data-collection methods such as interviews and non-participant observations

to support the researcher's interpretations of parental narratives and actions. The outbreak of the coronavirus pandemic in the beginning of our data collection phase posed major challenges and adaptations to our initial plan. Therefore, we recommend future researchers to draw contingency plans from start when planning qualitative research based on face-to-face interviews.

Despite the limitations and constraints, this paper has considerable strengths. Besides the methodological design already mentioned, the fact that the first author also conducted and transcribed all the interviews is one of them, as it allowed a thorough and detailed study of the meanings in the participants' narratives.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, upon request.

ETHICS STATEMENT

This study followed the ethical guidelines of the Finnish Advisory Board on Research Integrity. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

CL, EK, and KT developed the research project. CL administered the data collection and analyses, with the contribution of EK and KT. All authors contributed to the article and approved the submitted version.

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The Effect of a Computerized Growth-Mindset Intervention on Teaching Students' Mindset and Cognitive Stress Appraisal

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The present study assessed the impact of a one-time computerized mindset intervention on teaching students' cognitive stress appraisal before an upcoming exam. Previous research highlights the long-term effectiveness of growth-mindset interventions. Based on theoretical assumptions derived from the transactional stress theory as well as recent empirical evidence on intelligence mindset and stress, we proposed that changing students' mindset would also impact their cognitive stress appraisal. In order to test this hypothesis, a sample of teaching students received a one-time computerized growth-mindset intervention aiming to foster viewing abilities as incremental. We found a significant as well as relatively lasting impact on participants' mindset but no significant effect on participants' stress appraisal. Nevertheless, an exploratory mediation analysis revealed that the intervention's effect on participants' appraisal of their coping ability (as part of the cognitive stress appraisal) was fully mediated by participants' mindset. The results highlight the effectiveness of the utilized intervention and provide first practical insights into how a person's mindset and their stress appraisal relate.

Keywords: mindset intervention, growth mindset, short intervention, transactional stress theory, implicit theory of intelligence, academic self-concept, growth mindset, cognitive stress appraisal

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INTRODUCTION

How individuals subjectively perceive and interpret the world has a fundamental impact on their well-being, their thoughts, and, in turn, their actual behavior (Greifeneder et al., 2018). This subjective construction and interpretation of a person's social reality and, consequently, their reactions to it depends on the social context. In addition, a person's subjective perception is substantially influenced by naïve or implicit theories (Dweck et al., 1995; Molden and Dweck, 2006). In academic contexts, for example, the subjective construal and perception of intelligence—a person's *intelligence mindset*—affects their perception of performance and learning. A person's reaction to academic shortcomings, their reactions when facing academic challenges, and their achievement trajectories are all affected by their intelligence mindset (Dweck and Leggett, 1988; Aronson et al., 2002; Molden and Dweck, 2006; Blackwell et al., 2007; Yeager and Dweck, 2012; Paunesku et al., 2015; Yeager et al., 2019). People's view of intelligence can be categorized into two opposing assumptions: a *fixed mindset* or a *growth mindset*. Someone adhering to a fixed mindset perceives intelligence as a fixed entity that cannot be changed or modified, whereas someone with a growth mindset views intelligence as something that can be molded and cultivated through sufficient effort and time (Dweck and Leggett, 1988; Dweck and Yeager, 2019).

Previous research has repeatedly demonstrated the benefits of a growth mindset (as compared to a fixed mindset) regarding a variety of academic outcomes (Aronson et al., 2002; Blackwell et al., 2007; Paunesku et al., 2015; Yeager et al., 2019). Moreover, the beneficial value of a growth mindset seems to be especially apparent in challenging performance situations (Aronson et al., 2002; Blackwell et al., 2007). Furthermore, how challenging a performance situation is perceived to be should not only be impacted by a person's perception of intelligence as fixed or moldable but should additionally be impacted by an individual's subjective evaluation of their academic abilities, for example, a student's *academic self-concept*. The academic self-concept represents the cognitive representation of a person's own abilities in academic settings (like mathematics). This concept is partly based on previous performance experiences and partly on comparisons made to an important comparison group (Dickhäuser et al., 2002; Moschner and Dickhäuser, 2018). Previous studies have already highlighted the link between students' academic self-concept and how they effectively react to performance situations (Frenzel et al., 2007; Ahmed et al., 2012). A higher academic self-concept is generally associated with less negative affect regarding performance situations (Frenzel et al., 2007) as well as with less negative consecutive performance-related emotions like math anxiety (Ahmed et al., 2012).

Due to the benefits associated with a stronger growth mindset, much of the current research focusing on intelligence-mindsets has been dedicated to designing interventions that promote and nurture a stronger growth mindset (Aronson et al., 2002; Blackwell et al., 2007; Paunesku et al., 2015; Yeager et al., 2016). These interventions have repeatedly proven to be effective in shaping students' mindsets (Aronson et al., 2002; Blackwell et al., 2007).

As a consequence of the positive impact those initial growth-mindset interventions had, there has been a growing demand for more practical mindset interventions that can easily be scaled up and, therefore, be relevant to policymakers and practice (Paunesku et al., 2015; Yeager et al., 2016; Dweck and Yeager, 2019). However, most of these initial mindset interventions were designed to be applied in either a classroom or a laboratory setting and therefore generally require repeated intervention sessions as well as guidance by an instructor. As a consequence, the application of such interventions on a grander scale involves a significant investment of time and resources.

The current study expands upon these approaches by using existing intervention materials (Aronson et al., 2002; Paunesku et al., 2015) in designing and testing a relatively short (25 min), one-time, easily applicable online mindset intervention for teaching students. The intervention materials were especially designed for teaching students due to the influence teachers' beliefs have on their teaching, the feedback they give in the classroom, and, consequently, their students' beliefs (Esparza et al., 2014; Schmidt et al., 2015; Dickhäuser et al., 2017).

Mindset researchers have started to investigate further benefits associated with a stronger growth mindset beyond academic achievement outcomes. For example, King et al. (2012) found that middle school students' intelligence mindset significantly predicted their negative achievement-related emotions such as anxiety and shame. In a longitudinal intervention study, Miu and Yeager (2015) found that teaching adolescents a growth mindset about personal traits, that is, that people can change, reduced the incidence of clinically significant levels of self-reported depressive symptoms 9 months after the intervention.

In the present study, we investigate a subjective experience that is most likely affected by a person's mindset, that is, a person's cognitive *stress appraisal when facing challenging performance situations*. The idea that a person's mindset could potentially impact a person's cognitive stress appraisal is based on the theoretical rationale formulated in the *transactional stress theory* (Lazarus, 1966; Lazarus and Folkman, 1984). According to this theory, stress results from cognitive appraisal processes in which 1) potentially threatening external events and 2) one's own capacity in successfully mastering these events are assessed (Lazarus and Folkman, 1984). Since a person's mindset influences how they interpret and perceive performance and learning situations (Dweck and Leggett, 1988; Dweck and Yeager, 2019), lastingly impacting students' mindset could prove to be effective in reducing the stress students experience before such a challenging performance situation. Furthermore, the impact the mindset has on the evaluation of performance situations should be even more pronounced the more challenging a performance situation is perceived to be (Dweck and Yeager, 2019). A recent finding by Lee et al. (2019) seems to support this theoretical reasoning. Lee et al. (2019) tested the assumption that academic stressors (e.g., a decline in grades upon the entry of high school) lead to a stronger physiological stress response (measured as salivary cortisol level) for students with more of a fixed mindset than for students with more of a growth mindset. Their results supported this assumption: students who viewed their intelligence as a fixed entity were more likely to have elevated cortisol levels when their grades declined upon entering high school, and they showed a higher overall negative stress response compared to students with more of a growth mindset (Lee et al., 2019).

Building upon these previous findings and the presented theoretical arguments, the present study investigates the impact of a relatively short one-time computerized growth-mindset intervention designed for teaching students on their mindset. Moreover, we investigate the potential benefit of this novel growth-mindset intervention for participants' stress appraisal when faced with a challenging upcoming exam. Furthermore, the influence of a person's academic self-concept is taken into account for the potential stress-reducing effect of the administered mindset intervention.

THEORETICAL BACKGROUND

A Practical Mindset Intervention for Teaching Students

A person's mindset creates a meaning system, which in turn affects how ability-related situations are evaluated and approached (Dweck and Yeager, 2019). Even though there is a growing body of research aimed at examining potential benefits associated with a growth mindset (e.g., Yeager et al., 2019), there

have also recently been studies questioning and testing the actual magnitude of the effects reported by mindset-research on learning and performance outcomes (Burgoyne et al., 2020). Additionally, other researchers questioned whether mindset has a causal role in influencing students' achievement or if there is not even a bidirectional relationship between mindset and students' achievement (e.g., see Zhang et al., 2017 for a review). These results additionally highlight the importance of further and rigorously designed mindset-research that replicates and tests the effects of a person's mindset on the perception of performance and learning occurrences as well as their effects on actual performance and learning.

At the same time, previous research has indicated that depending on a person's mindset, an academic failure, struggle, or success will yield different cognitive interpretations (e.g., lower helplessness attributions when faced with academic setbacks for a stronger growth mindset; Blackwell et al., 2007) and affective responses (e.g., a stronger fixed mindset predicts negative achievement-related emotions; King et al., 2012). Further, a person's mindset also affects behavioral outcomes in such situations (e.g., improvement in GPA-scores; Aronson et al., 2002; Blackwell et al., 2007).

Moreover, research highlights that a person's mindset itself is not something that is unchangeable and can be impacted through mindset interventions (Aronson et al., 2002; Blackwell et al., 2007; Paunesku et al., 2015; Yeager et al., 2019). A prominent example of such a mindset intervention was designed by Aronson et al. (2002). Aronson and colleagues sought to lastingly affect students' mindsets. First, they introduced participants to the idea that they could develop their intelligence and abilities. Second, they asked participants repeatedly to support this claim 1) by making participants endorse the assumption that abilities are malleable in front of another person and 2) by having participants generate supportive examples based on their own experiences. These initial face-to-face mindset interventions successfully impacted students' mindsets and, beyond that, their academic performance (e.g., Aronson et al., 2002; Blackwell et al., 2007). Nonetheless, as Dweck and Yeager (2019) pointed out, many of these interventions had not been designed for or tested on a grander scale. They had mostly been applied in classrooms or in laboratory settings and require participants to partake in repeated intervention sessions as well as continuous guidance and instruction by a teacher or a researcher (Aronson et al., 2002; Blackwell et al., 2007; Dweck and Yeager, 2019). Therefore, in recent years, there has been a growing interest in designing more practical growth-mindset interventions that can easily be scaled up and applied in larger contexts (Paunesku et al., 2015; Yeager et al., 2016; Dweck and Yeager, 2019). Building upon already existing and successful classroom and laboratory interventions (Aronson et al., 2002; Blackwell et al., 2007), Paunesku et al. (2015) and Yeager et al. (2016) responded with two successful and relatively short online interventions. Whereas Paunesku et al. (2015) tested existing *generic* growth-mindset intervention material for its successful applicability on a sample of high school students, Yeager et al. (2016) adapted existing materials for a more tailored user-centered intervention targeting middle school students transitioning to high school.

The current study expands upon these approaches by using existing intervention materials (Aronson et al., 2002; Paunesku et al., 2015) in designing and testing a relatively short (25 min), one-time, easily applicable online mindset intervention for teaching students. The designed intervention followed recommendations by Aronson et al. (2002) who applied an approach based on persuasion research (i.e., Higgins and Rholes, 1978; Higgins, 2012). In our intervention, students were first asked to read a short text about the plasticity of intelligence and were then asked to respond to a fictitious school scenario in which they were approached by a student after a lesson in which they had discussed the text in class that questioned the text's applicability to their personal experience (i.e., the student claimed to be too dumb for mathematics). Participants were asked to describe in 150 words how they would react to the student (i.e., they were asked to formulate supportive arguments about why abilities are malleable through effort). Furthermore, participants were asked to describe in 120 words a personal experience in which they were able to successfully master an academic obstacle through investing effort and working hard. The text was supposed to be published anonymously on a website for a project for motivating underperforming students.

The intervention materials were especially designed for teaching students due to the influence teachers' beliefs have on their teaching, the feedback they give in the classroom, and, consequently, their students' beliefs (Esparza et al., 2014; Schmidt et al., 2015; Dickhäuser et al., 2017). For example, Dickhäuser et al. (2017) were able to show that classes with a higher teacher tendency to report growth to their students (the so-called temporal reference norm orientation) were associated with more positive development of students' motivation as compared to classes with a lower temporal reference norm orientation of teachers. Furthermore, the effectiveness of mindset interventions targeting students depends on the class teacher's mindset (Esparza et al., 2014; Schmidt et al., 2015). These findings emphasize the relevance of designing and testing interventions that target teaching staff as well as future teachers due to the potential benefit that such interventions could provide beyond solely influencing teachers' and teaching students' mindsets and their approach to performance situations. Therefore, this study explores the effect of a one-time computerized growth-mindset intervention specifically designed for teaching students.

Based on the previously expressed theoretical arguments and empirical results, we derived and tested the following hypotheses: Our computerized one-time growth-mindset intervention will have a significant impact on the mindset of a sample of university students studying to become teachers (H1). For the intervention group, we further hypothesize that this one-time administered mindset intervention will lead to a significant gain in growth mindset (H1a). Furthermore, we hypothesize that there will be a significant difference in growth mindset when comparing the intervention group with the active control group after the intervention (H1b).

Beyond Mindset's Effect on Academic Outcomes: The Effect on Cognitive Stress Appraisal

Lazarus and Folkman (1984) conceptualize stress as resulting from two consecutive cognitive appraisals about 1) the potential of an external event to harm well-being (i.e., *threat appraisal*) and 2) one's own capabilities in dealing with this event (i.e., *coping-ability appraisal*). Inherent in this approach is the idea that those consecutive evaluative stress appraisal processes are prone to be influenced by a person's naïve theories and generalized beliefs (Lazarus and Folkman, 1984). One especially important naïve theory in an academic context is a person's intelligence mindset (Dweck and Yeager, 2019). This crucial belief about the malleability of abilities could in turn influence a person's perception of how well they are equipped to deal with a demanding performance situation and in turn affect the resulting overall cognitive stress appraisal.

To this point, research has not examined the potential processes that could link a person's intelligence mindset and their cognitive stress appraisal. Nevertheless, it seems probable that a person's generalized idea about the plasticity of intelligence (i.e., their intelligence mindset; Molden and Dweck, 2006) could substantially influence their perceptions of a demanding academic performance situation. An individual's perception of an academic performance situation in turn should affect their resulting cognitive stress appraisal.

A recent field study conducted by Lee et al., 2019, supports this reasoning. The researchers hypothesized that, depending on a person's mindset, their appraisal of an intellectually demanding situation should differ. More specifically, they tested the hypothesis that high school students would show differing physiological stress responses (measured as salivary cortisol levels) during an academically challenging transition to high school depending on their mindset. In support of their assumption, they found that students whose grades were declining and who held more of a fixed mindset were more likely to exhibit elevated salivary cortisol levels, compared to students who held more of a growth mindset. In addition, students whose grades were declining and held more of a fixed mindset were also more likely to perceive that they did not possess the resources to adequately cope with their daily stressors.

The assumption that one's mindset could potentially influence similar control-related beliefs had previously already been introduced through a study conducted by King et al. (2012). They proposed that a person's mindset could potentially influence control-related assessments and, therefore, have an impact on achievement-related emotions. Their results partially support this idea: A person's fixed mindset positively predicted negative achievement-related emotions, such as anger, anxiety, and shame, whereas such a relation was not found for predicting positive achievement-related emotions (King et al., 2012).

Based on these theoretical arguments and previous empirical findings, we investigate the impact of a growth-mindset intervention on participants' overall cognitive stress appraisal regarding a challenging upcoming exam. We tested the following hypotheses: The applied growth-mindset intervention will influence participants' cognitive stress appraisal regarding an upcoming challenging performance event (H2). Within the intervention group, we further hypothesize that the growth-mindset intervention will lead to a significant reduction in reported cognitive stress appraisal (H2a). Finally, we assume that the intervention group will show a significantly lower reported cognitive stress appraisal than the active control group after having received the growth-mindset intervention (H2b).

Academic Self-Concept's Influence

A person's perception of their ability to successfully deal with a demanding performance situation is impacted by how they view their own abilities, that is, their academic self-concept (Kadir and Yeung, 2016). A person's academic self-concept is based on previous performance experiences as well as on a person's abilities compared to a relevant comparison standard (Kadir and Yeung, 2016). Therefore, the academic self-concept is an important determinant for cognitive and affective responses to performance situations (Frenzel et al., 2007; Ahmed et al., 2012). A higher academic self-concept is generally associated with less negative affect regarding performance situations (Frenzel et al., 2007) as well as with less negative subsequent performance-related emotions like math anxiety (Ahmed et al., 2012).

We therefore propose that, when considering the effects of a person's mindset on their cognitive stress appraisal regarding a demanding performance situation, the person's academic self-concept needs to be taken into account. A pronounced cognitive stress response should accordingly only emerge if a person perceives their abilities to be low and therefore is not sure whether they can display the required performance. If a person is convinced of their abilities, then even an upcoming challenging performance situation should not be perceived as a threat. In consequence, independent of a person's mindset, no pronounced stress response should emerge. Only when a person believes that his/her academic abilities are rather low–which implies that the situation would be seen as more challenging and potentially threatening–, the person's mindset should influence his/her stress appraisal. This assumption is based on the notion that a person's mindset influences motivation and behavior especially in challenging performance situations (Dweck and Leggett, 1988; Dweck and Yeager, 2019).

Accordingly, we hypothesize that an individual's academic self-concept moderates the influence of the intervention on the ensuing cognitive stress appraisal. We expect that the positive (i.e., reduction in cognitive stress appraisal) effect of the intervention on a participant's cognitive stress appraisal will be more pronounced for individuals with a lower academic self-concept (H3).

MATERIALS AND METHODS

Participants

The final sample consisted of $N = 77$ participants (56 female), all from the same German university. The mean age of the

participants was $M = 21.6$ years ($SD = 2.35$) and participants were on average in the fourth semester ($M = 4.32$; $SD = 2.41$). Requirements for participating in the study were that participants were teaching students and that they were currently facing an imminent personally challenging performance situation (e.g., an upcoming graded exam) which was assessed through self-reported assessment of the upcoming performance situation as demanding.

General Procedure

Participants were recruited online, through e-mail or advertising on university bulletins and distributed in classes. They were told that the primary aim of the study was to assess middle school materials and that they would have to evaluate these materials. First, participants had to preregister. During this preregistration, they indicated if they were enrolled in the BA Education Study program and if they found themselves facing an imminent challenging academic performance situation (e.g., an exam). Additionally, their initial intelligence mindset and cognitive stress appraisal regarding said upcoming exam were assessed as well as their general academic self-concept. Participants were assured that their responses would remain confidential and would be used for scientific purposes only. Second, participants meeting the inclusion criteria were invited to participate in the computerized intervention that was conducted in one of the research laboratories of the university. We randomly assigned participants to either the active control condition or the growth-mindset intervention condition. The growth-mindset intervention as well as the control exercise lasted approximately 25 min and the administered surveys in total lasted approximately 20 min. Right after the laboratory session, participants answered a postintervention survey that assessed their mindset and cognitive stress appraisal regarding their indicated upcoming exam. Third, two days after the laboratory session, participants received an e-mail with a link for the follow-up survey that assessed participants' mindset and cognitive stress appraisal as well as demographics. On average, participants answered the follow-up survey $M = 4.6$ ($SD = 2.22$; $Min = 2$; $Max = 13$) days after the intervention. Participants were rewarded with the corresponding amount of participant credits assigned to study participants by the university.

Measures

Challenging Upcoming Exam

Participants were asked to indicate if they had any upcoming relevant and personally challenging performance situations (e.g., an exam). This could range from written to oral exams and graded papers to ungraded presentations. After participants affirmed that they had a challenging exam coming up, they were asked to indicate the name of the class that required the indicated performance.

Academic Self-Concept

Additionally, we assessed participants' academic self-concept through the scale of academic self-concept ("Skala zum akademischen Selbstkonzept"; $\alpha = 0.95$; Dickhäuser et al., 2002). The scale consists of 22 items and four subscales. Participants' agreement with the presented items (e.g., "My academic competencies are. . .") was assessed through a 7-point semantic differential scale (e.g., 1 = low; 7 = high). The academic self-concept was calculated as mean agreement with the items. Higher values indicate a higher academic self-concept. See **Supplementary Appendix A** for a frequency distribution of academic self-concept.

Mindset

The mindset of the participants was assessed at three points in time (premeasurement, postmeasurement, and follow-up measurement) through the German version of the implicit theories scale by Dweck et al. (1995). The German scale has already been repeatedly successfully evaluated for German student samples (Spinath and Stiensmeier-Pelster, 2001). The scale consists of three items that indicate a fixed mindset (e.g., "I possess a certain amount of intelligence, and there is not much I can do about it"). Participants indicated how much they agreed with the presented statements through a 6-point Likert scale (1 = *I completely agree*; 6 = *I don't agree at all*; $\alpha_{t0} = 0.80$, $\alpha_{t1} = 0.85$, and $\alpha_{t2} = 0.86$). Due to the sample size being too small to calculate for measurement invariance (see, e.g., Kline, 2015), we calculated Cronbach's alpha for the intervention and control condition as an approximation. The results indicate acceptable reliability in both groups ($\alpha = 0.74$ for the intervention group; $\alpha = 0.82$ for the control group). The mindset of participants was computed by averaging the agreement with the statements. Higher values represent a growth mindset and lower values represent a fixed mindset.

Cognitive Stress Appraisal

At three points in time, the reported cognitive stress appraisal of participants when thinking of their upcoming exam was assessed through the *Primary Appraisal Secondary Appraisal* questionnaire (PASA; Gaab, 2009). After having indicated the title of the upcoming challenging exam, participants were explicitly asked to think of this exam when answering the PASA's questions (at the post- and follow-up measurement, participants were asked to reindicate the title of the exam stated at premeasurement and they were reminded to consider this upcoming exam when answering the PASA's questions). The PASA is based on the transactional stress theory (Lazarus and Folkman, 1984) and allows a separate assessment of participants' primary (threat appraisal) and secondary appraisal (coping-ability appraisal) regarding a specific challenging potentially stress-inducing situation (Gaab, 2009). The questionnaire consists of two primary scales (threat appraisal: $\alpha_{t0} = 0.83$, $\alpha_{t1} = 0.85$, and $\alpha_{t2} = 0.87$; coping-ability appraisal: $\alpha_{t0} = 0.81$, $\alpha_{t1} = 0.82$, and $\alpha_{t2} = 0.81$) that each consists of eight items. Participants indicated their agreement to statements through a 6-point Likert scale (1 = *completely false*; 6 = *completely true*). The threat appraisal scale assessed the evaluation of the threat potential of the situation (e.g., "This situation challenges me."). Higher threat appraisal values indicate that a situation is perceived as highly threat inducing, whereas higher values in the coping-ability appraisal indicate a stronger perception of one's own ability to cope with the situation successfully (e.g., "I don't

know at all what I am supposed to do"). The PASA score is calculated as the difference between the threat appraisal and coping-ability appraisal scale and results in an overall cognitive stress appraisal measure. There are no normed reference values that differentiate between high and low cognitive stress appraisal values. The values have to be interpreted in the specific context and can be used as a means to compare participants' cognitive stress appraisal (Gaab, 2009).

Demographics

Participants were asked if they were enrolled in the BA Education program of the University. After finishing the follow-up survey, participants were asked to indicate their age, gender, and their semester.

Quality Check

Participants were randomly given three instructed response items (Merkle et al., 2016) that asked them to check a certain answer (e.g., "please check the option at the far left"). This was done in order to assess how attentively participants were answering the questionnaires. This approach is in line with recommendations given by Oppenheimer et al. (2009).

Experimental Manipulation and Manipulation Checks

Growth-Mindset Condition

The applied novel growth-mindset intervention is based on materials that have already been successfully applied in previous research (Aronson et al., 2002; Mindset Works Inc., 2002; Paunesku et al., 2015) and that were adapted for a German sample of teaching students. At first, participants were instructed to read a text titled "*You can develop your intelligence*" and to assess if this text could potentially be used as classroom material for teaching biology to middle school students. Before participants proceeded with the intervention tasks, they answered two multiple choice questions referring to the text's content in order to assess if participants had read the text carefully, which was a prerequisite for the following intervention instructions. To ensure that the sample size would not have to be diminished due to inattentive participants that would not be able to answer the multiple choice questions correctly, participants who did not correctly answer the multiple choice items at first were asked to reread the intervention text. In the two subsequent tasks, participants were then asked to endorse and support the text's main arguments. The first task asked participants to describe how they would answer and motivate a student that believes that she can never change her ability in mathematics based on the previously read text. Then in a second task, participants were instructed to connect the arguments they used to persuade the student with a personal experience in which they had successfully mastered a similar challenge and subsequently grown their abilities through investing effort and hard work. Participants received the information that their personal example could supposedly be selected for a university funded project to strengthen the motivation of middle school students with academic difficulties. Through a link (https://ein-blick-hinter-die-kulissen.jimdosite.com/), participants were able to access said website in order to maintain the believability of the scenario. In order to affect participants' mindsets lastingly, the study was built upon intervention materials and tasks that had already proven successful in previous research (Aronson et al., 2002) and that are based on different approaches and findings in persuasion research (e.g., Gopinath and Nyer, 2009). For example, the study applied the *saying-is-believing effect* (Higgins, 2012) by asking participants to write a text that reflects the opinion that intelligence is malleable. The underlying assumption is that explicitly and publicly endorsing an opinion influences the speaker's (in this case "the writer's") own opinion in the direction of the publicly endorsed one. This shifting of one's own opinion to the publicly advocated opinion often happens unintentionally (Higgins, 2012; Higgins and Rholes, 1978). Additionally, we tried to create an atmosphere of public commitment by telling participants that their texts could be published (see **Supplementary Appendix B** for the intervention group's tasks) which should induce an even stronger acceptance of one's publicly endorsed opinion (Cialdini, 2009).

Active Control Condition

Participants in this condition read a text illustrating the functions of the brain's different regions which addresses middle school students (Hilmer, 2017). A text for the ninth grade was chosen for the control group in order to maintain as much similarity as possible between the intervention and control group materials. The intervention group material was evaluated through a small pilot test with teaching students (n = 3) who had to evaluate which grade level the intervention group's material could realistically be used in. Mean evaluation was M = 9.67.

Participants had to evaluate the text's appropriateness for middle school students as classroom material. Afterward, participants had to reproduce the text's main message as they would convey it to a student who did not completely understand the text's content. In a second task, participants were asked how they would teach the summarized content to a class of middle school students (see **Supplementary Appendix C** for the control group's tasks).

Debriefing and Final Questions

Debriefing

Since participants were repeatedly confronted with their challenging upcoming exam, participants were consequently given a few examples of how to deal with stressful events positively. Participants were asked to indicate how they dealt with stress. Additionally, participants received the website and phone contact of the university's psychological counseling center and were encouraged to seek support if needed. Participants were given the opportunity to leave their e-mail to be notified about the study and its results.

Final Questions

Participants had the opportunity to indicate any reason as to why their data should not be used at the end of the post- and follow-up

questionnaire. Additionally, participants had the option to comment on the study.

Attrition, Exclusion of Participants, and Missing Data

Attrition

In total, we collected a sample of $N = 90$ who completed the premeasurement and, subsequently, $N = 83$ participants who participated in the intervention. Of these participants, $n = 41$ were in the intervention group (70.7% female) and $n = 42$ in the control group (71.4% female). At the follow-up measurement, data of $N = 82$ participants, $n = 40$ in the intervention group (72.5% female) and $n = 42$ in the control group (71.4% female), were assessed. Overall, there was attrition of 9.1% ($n = 8$) from premeasurement to follow-up measurement. To test if dropout was systematic, we first created a dummy variable (1 = dropout; 0 = no dropout).

A multivariate analysis of variance (MANOVA) with initial mindset and stress as dependent variables revealed a statistically nonsignificant overall multivariate effect of the dropout on mindset, $F_{(1,\ 86)} = 1.36$, $p = 0.247$, and $\eta_p^2 = 0.02$, and on stress, $F_{(1,\ 86)} = 1.30$, $p = 0.258$, and $\eta_p^2 = 0.02$.

Exclusion of Participants and Missing Data

Of the $N = 83$ participants that took part in the intervention, we excluded $n = 6$ participants from the analysis due to repeatedly incorrectly answering the quality check items (participants were only excluded if they answered the quality check items for at least two measurement points incorrectly). Of those excluded participants, $n = 4$ belonged to the intervention group and $n = 2$ participants to the control group with a mean age of $M = 23.20$ ($SD = 3.63$; 50% female). To test for systematic differences between the excluded and not excluded participants, we created a dummy variable (1 = included in the analysis; 0 = excluded from the analysis).

A MANOVA with mindset and stress at pre-, post-, and follow-up measurement revealed a statistically nonsignificant effect of the dummy variable on mindset at pre-, post-, and follow-up measurement, ps > 0.507, as well as for stress at pre- and follow-up measurement, ps > 0.081. However, a significant effect of the dummy variable on stress at postmeasurement, $F_{(1,\ 78)} = 4.06$, $p = 0.047$, and $\eta_p^2 = 0.049$, was found.

Overall, 6.3% of the data values were missing. Missing data ranged from low of 2.2% to high of 8.9% (e.g., for items assessing mindset at the follow-up measurement). As suggested by Schlomer et al. (2010), we calculated Little (1988) MCAR test: the results indicate that the data values were missing at random, $\chi^2\ (10) = 11.10$; $p = 0.350$.

Analytical Procedures

To test effects on mindset and cognitive stress appraisal, we conducted two separate repeated measures analysis of variance (ANOVA) with mindset and cognitive stress appraisal as dependent variables. Time (time: premeasurement (t_0) vs. postmeasurement (t_1) vs. follow-up measurement (t_2)) was a within-subjects factor and condition (condition: intervention condition vs. control condition) was the between-subjects factor.

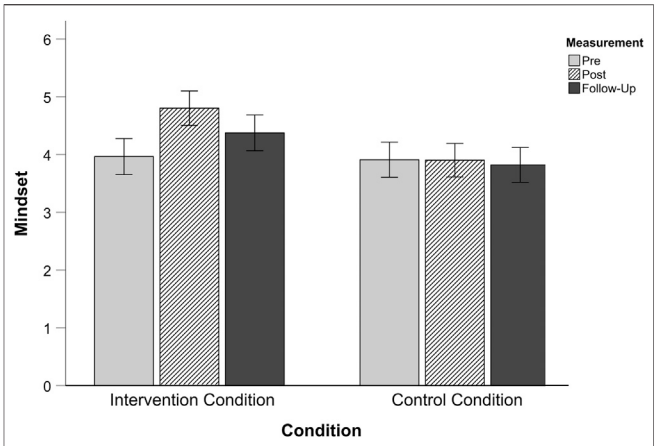

FIGURE 1 | Mean mindset values of the intervention and control condition at premeasurement, postmeasurement, and follow-up measurement. Error bars represent standard errors (95% CI). A mindset value ≥ 4 corresponds to a growth mindset.

RESULTS

Preliminary Analyses

Before testing our main hypotheses, we ran preliminary analyses to check whether randomization of participants to the two experimental conditions was successful and whether preliminary differences between the two groups regarding the interesting variables existed. Several independent sample t-tests with condition as a predictor and mindset and threat and coping-ability appraisal as dependent variables revealed no statistically significant preliminary differences between the two groups (all ts < 0.19).

Effects on Mindset

In line with the first hypotheses, we found a significant main effect of condition, $F_{(1,\ 73)} = 5.53$, $p = 0.021$, and $\eta_p^2 = 0.07$. Mean values of mindset for the conditions for each measurement point are depicted in **Figure 1**. To test hypotheses 1a and 1b, multiple Bonferroni-corrected pairwise contrasts were tested for significance. In correspondence with hypothesis 1a, a significant difference in the intervention condition was found for mindset-value pre- and postintervention, $M_{Diff} = 0.92$, $p < 0.001$, $d = 1.22$, and 95% CI (0.63, 1.20). Participants in the intervention condition had a lower mindset preintervention, $M = 3.90$ ($SD = 0.85$), than postintervention, $M = 4.81$ ($SD = 0.72$). Furthermore, a significant difference between mindset preintervention and the follow-up measurement was found, $M_{Diff} = 0.48$, $p < 0.01$, $d = 0.65$, and 95% CI (0.15, 0.81). Participants in the intervention condition had a lower mindset score at premeasurement, $M = 3.90$ ($SD = 0.85$), than at the follow-up measurement, $M = 4.38$ ($SD = 0.83$). Additionally, we tested whether the decrease in mindset for the intervention condition from the postintervention measurement ($M = 4.81$; $SD = 0.72$) to the follow-up measurement ($M = 4.38$; $SD = 0.83$) was significant. We found a significant decrease in mindset from the postintervention measurement to the follow-up measurement, $M_{Diff} = -0.44$, $p < 0.01$, and 95% CI (−0.70, −1.67)

TABLE 1 | Means, SD, and range for threat appraisal, coping-ability appraisal, and cognitive stress appraisal scores for all three measurement points and academic self-concept at premeasurement separated by condition.

Scale	Statistical values							
	Intervention group				Control group			
	M	SD	Min	Max	M	SD	Min	Max
Threat appraisal								
t_0	35.19	6.60	19.00	48.00	34.00	8.62	0.00	48.00
t_1	36.60	6.95	22.00	48.00	35.28	6.63	19.00	48.00
t_2	36.46	7.50	21.00	48.00	35.70	6.34	21.00	48.00
Coping-ability appraisal								
t_0	34.86	6.70	19.00	48.00	33.56	7.76	0.00	46.00
t_1	36.16	6.04	22.00	44.00	35.28	4.55	24.00	46.00
t_2	36.81	5.54	26.00	48.00	34.70	5.33	22.00	47.00
Cognitive stress score								
t_0	0.33	12.03	−25.00	24.00	0.44	10.10	−21.00	33.00
t_1	0.78	11.24	−18.00	22.00	0.00	9.46	−25.00	24.00
t_2	−0.35	11.63	−22.00	19.00	1.00	9.84	−26.00	26.00
Academic self-concept	4.96	0.72	3.09	6.41	4.83	0.70	2.64	5.91

Note. *The cognitive stress score is calculated as the difference between coping-ability appraisal and threat appraisal values. Higher stress score values correspond to a higher level of cognitive stress appraisal.* t_0 *= premeasurement (before the intervention),* t_1 *= postmeasurement (directly after the intervention),* t_2 *= follow-up measurement (three days after the intervention ends). The academic self-concept was only measured at premeasurement. Higher values indicate a higher academic self-concept (theoretical range: 1–7).* N = *77 (intervention group:* n = *37; control group:* n = *40 participants).*

Additionally, hypothesis 1b was supported, as a significant difference in mindset score between the intervention and control condition at the postmeasurement was found, $M_{\text{Diff}} = 0.90$, $p < 0.001$, $d = 1.06$, and 95% CI (0.48, 1.32). Participants in the intervention condition had more of a growth mindset, $M = 4.81$ ($SD = 0.72$), than participants in the control condition, $M = 3.91$ ($SD = 1.06$).

Effects on Cognitive Stress Appraisal

No significant effect of condition on the composite cognitive stress appraisal score was found, $F < 1$. To test hypothesis 2a that there would be a difference in cognitive stress appraisal in the intervention condition between pre- and post- as well as pre- and follow-up cognitive stress appraisal, Bonferroni-corrected pairwise contrasts were tested for significance. No significant differences were found (all $ps \geq 1$). Hypothesis 2b, which predicted that there would be a significant difference between the control and intervention condition at the postmeasurement in cognitive stress appraisal, was also tested through a Bonferroni-corrected pairwise contrast. Hypothesis 2b could not be supported ($p > 0.71$; mean values and standard deviations and range for the threat appraisal scale, the coping-ability appraisal scale, and the overall cognitive stress appraisal separated by condition are presented for all measurement points in **Table 1**. Additionally, mean values and standard deviations for the whole sample are presented for all measurement points in **Supplementary Appendix D**).

Interaction of the Academic Self-Concept and the Intervention Condition

In hypothesis 3, we formulated the assumption that the academic self-concept moderates the relation between the intervention condition and the ensuing cognitive stress appraisal (mean values, standard deviations, and range separated by condition are presented in **Table 1**). To test this hypothesis, two separate regressions were conducted with cognitive stress appraisal (postintervention and at the follow-up measure). The intervention condition was dummy coded (0 = control condition; 1 = intervention condition). We found a significant main effect of the academic self-concept on cognitive stress appraisal at postmeasurement, $b = -8.14$, $SE = 1.44$, $t(74) = -5.66$, and $p < 0.001$, and on cognitive stress appraisal at the follow-up measurement, $b = -8.06$, $SE = 1.52$, $t_{(74)} = -5.30$, and $p < 0.001$. But no significant main effect of the intervention condition on cognitive stress appraisal was found for the postintervention nor for the follow-up-intervention measurement, $|ts| < 0.94$. Additionally, no significant interaction of the condition x academic self-concept on cognitive stress appraisal at the postintervention-measurement point, $|t| < 1$, nor on the cognitive stress appraisal at the follow-up measurement point was found, $|t| < 1$. Therefore, hypothesis 3 was not supported.

Exploratory Analyses

We expected an effect of the intervention condition due to our assumed impact of students' actual mindset on their subsequent cognitive stress appraisal. The reason is that people with a stronger fixed mindset would view their abilities as less malleable. Therefore, a person with a stronger fixed mindset would believe that they possess less control over dealing with a challenging performance situation (Dweck and Leggett, 1988; Dweck and Yeager, 2019). This assumption seems to be in agreement with recent results reported by Lee et al. (2019) who found that students whose grades were declining and held more of a fixed mindset were more likely to report being less confident in handling their daily academic stress (i.e., their

ability to cope with the academic stressors). Therefore, we conducted additional exploratory analyses to test whether we would find a direct effect of students' mindset on their cognitive stress appraisal (especially their coping-ability appraisal) and whether in line with this argumentation the intervention would show an indirect effect on students' cognitive stress appraisal mediated by the participant's mindset. We therefore conducted a series of additional exploratory regression analyses.

Direct Effect of Mindset on Cognitive Stress Appraisal, Threat Appraisal, and Coping-Ability Appraisal

To test whether students' mindset significantly predicted students' overall cognitive stress appraisal (postmeasurement), their coping-ability appraisal, and threat appraisal at the postmeasurement, we conducted three separate regression analyses. We did not find a significant direct effect of students' mindset at postmeasurement on their cognitive stress appraisal at postmeasurement, $b = -0.12$, $SD = 1.13$, and $p = 0.290$, nor on their threat appraisal at postmeasurement, $b = 0.01$, $SD = 0.09$, and $p = 0.960$. However, we did find a significant and positive effect of students' mindset on their coping-ability appraisal at postmeasurement, $b = 0.25$, $SD = 0.07$, and $p = 0.031$. Thus, there seems to be a direct effect of participants' mindset on their coping-ability appraisal.

Furthermore, to test whether students' mindset significantly predicted students' overall cognitive stress appraisal (follow-up measurement), their coping-ability appraisal, and threat appraisal at the follow-up measurement, we conducted three additional separate regression analyses. We did not find a significant direct effect of students' mindset at postmeasurement on their cognitive stress appraisal at follow-up measurement, $b = -1.67$, $SD = 1.17$, and $p = 0.156$, nor on their threat appraisal at follow-up measurement, $b = 0.00$, $SD = 0.09$, and $p = 0.998$. However, we did find a significant and positive effect of students' mindset on their coping-ability appraisal at postmeasurement, $b = 0.20$, $SD = 0.07$, and $p = 0.006$. Thus, there seems to be a direct effect of participants' mindset on their coping-ability appraisal.

Mediating Influence of Mindset Postintervention on the Relation Between Condition and Coping-Ability Appraisal

Since we exploratively found a direct effect of students' mindset on their coping-ability appraisal, we tested whether mindset mediates the effect of the intervention on coping-ability appraisal and threat appraisal at the postmeasurement by conducting two separate mediation analyses using PROCESS version 3.0 for SPSS (Hayes, 2018). In both analyses, we incorporated mindset (postintervention measure) as a mediator. The results reveal a statistically significant indirect effect of the intervention on coping-ability appraisal (postmeasurement) through mindset (see **Figure 2**). Mindset fully mediated the intervention effect on coping-ability appraisal, $b = 0.16$; 95% BCA CI (0.035, 0.351). Students in the intervention group reported a stronger growth mindset than students in the active control group, $b = 0.97$; $p < 0.001$, and the more students reported having a growth mindset, the more they reported being able to cope with the threatening event, $b = 0.17$; $p = 0.042$.

The results of the mediation analysis on threat appraisal reveals no significant indirect effect of the intervention through mindset, $b = -0.05$; 95% BCA CI [−0.387, 0.283].

Mediating Influence of Mindset on the Relation Between Condition and Coping-Ability Appraisal at the Follow-Up Measurement

Additionally, we tested whether the mediating influence of mindset on the relation between intervention condition and coping-ability appraisal would still show at the follow-up measurement. We conducted an additional mediation analysis using PROCESS version 3.0 for SPSS (Hayes, 2018). We incorporated mindset (follow-up-intervention measurement) as a mediator. The results reveal a statistically significant indirect effect of the intervention on coping-ability appraisal (follow-up measurement) through mindset (follow-up measurement). Mindset fully mediated the intervention effect on coping-ability appraisal, $b = 0.11$; 95% BCA CI (0.009, 0.246) (see **Figure 3**). Students in the intervention group reported a stronger growth mindset than students in the active control group, $b = 0.57$; $p = 0.012$, and the more students reported having a growth mindset, the more they reported being able to cope with the threatening event, $b = 0.19$; $p = 0.020$.

DISCUSSION

Our aims with this study were threefold. First, we assessed the effectiveness of a novel one-time computerized mindset intervention specifically designed for teaching students. Second, we examined the intervention's influence on students' cognitive stress appraisal. Third, we investigated whether the assumed effect of our mindset intervention on students' subsequent cognitive stress appraisal would be more pronounced for those with a lower academic self-concept.

The first hypothesis expressed the assumption that the intervention would have a significant and stable effect on participants' mindset. This assumption was supported. After the intervention, participants in the intervention group displayed, on average, more of a growth mindset, whereas participants in the control group had, on average, more of a fixed mindset. Furthermore, the intervention still showed a significant effect on the intervention group's mindset, on average, five days after the intervention session with a medium-sized effect of $d = 0.65$ (on average, participants answered the follow-up survey $M = 4.6$ days after the intervention; $SD = 2.22$; $Min = 2$; $Max = 13$)[1].

The tested intervention materials and tasks that extended and modified existing intervention materials (Aronson et al., 2002) specifically for a sample of teaching students effectively impacted teaching students' mindset. The applied variations were in fact

[1]We tested whether the length of delay between postmeasurement and follow-up measurement had a significant effect on the intervention condition's change in mindset. No significant effect of delay on magnitude of mindset change was found, $b = -0.06$; $p = 0.122$.

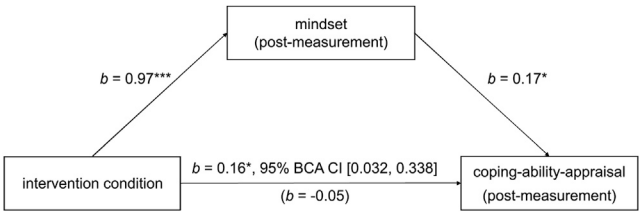

FIGURE 2 | Mediation model for the relationship between the intervention and coping-ability appraisal at postmeasurement mediated by mindset at postmeasurement indicated by standard regression coefficients. The standardized regression coefficient between the intervention and coping-ability appraisal, controlling for mindset, is in parentheses (direct effect). BCA CI, bootstrapped CI. *$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$. $N = 77$.

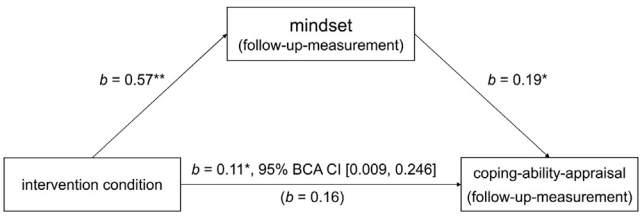

FIGURE 3 | Mediation model for the relationship between the intervention and coping-ability appraisal at follow-up measurement mediated by mindset at follow-up measurement indicated by standard regression coefficients. The standardized regression coefficient between the intervention and coping-ability appraisal, controlling for mindset, is in parentheses (direct effect). BCA CI, bootstrapped CI. *$p < 0.05$, **$p < 0.01$, and ***$p < 0.001$. $N = 77$.

quite simple; we presented a scenario in which teaching students found themselves confronted with a student doubting their ability to change their mathematics achievement. They were further asked to convey a personal example that stresses the value of effort in developing one's ability that would supposedly be used for a project that encourages underperforming students. Furthermore, the described results relate to results reported by Paunesku et al. (2015) who showed for a sample of high school students that even a variation in the tasks provided in the initial intervention given by Aronson et al. (2002) could create relatively lasting mindset changes (they shortened the intervention tasks used by Aronson et al., 2000 to a one-time 45 min-long intervention session). It seems that even relatively short mindset interventions can effectively impact participants' mindsets. The present research moreover extends these findings by displaying their applicability to a sample of teaching students. The results therefore illustrate that even interventions that require little time and resources can have an impact on participants' mindsets. The tested intervention thus responds to the demand for more economic and practical mindset interventions that can efficiently be applied on a grander scale (Dweck and Yeager, 2019).

The second hypothesis furthermore expressed the assumption that the intervention would directly impact participants' cognitive stress appraisal regarding an upcoming performance situation. This claim was based on the assumption that a person's mindset as a generalized belief would influence a person's appraisal of how well they would be able to cope with a self-identified stress-inducing performance situation and therefore influence the overall cognitive stress appraisal. Contrary to our hypothesis, no significant main effect of the intervention on participants' cognitive stress appraisal was found.

Even when taking participants' academic self-concept into account, we found neither a direct effect of the intervention on participants' cognitive stress appraisal nor a significant interaction between students' academic self-concept and the intervention condition on students' cognitive stress appraisal. What we found was that participants' academic self-concept significantly related to participants' cognitive stress appraisal. Participants with a higher academic self-concept already showed at premeasurement a significantly lower stress response regarding their reported upcoming exam and kept this low level of cognitive stress appraisal until the follow-up measurement. This finding concurs with previous research that has already displayed academic self-concept's link to achievement-related cognition and emotions (Frenzel et al., 2007; Ahmed et al., 2012). For example, Frenzel et al. (2007) were able to show that students who viewed their own mathematics abilities as low showed more negative achievement-related emotions than students who viewed their mathematics abilities as higher. Additionally, Ahmed et al. (2012) reported that students' mathematic self-concept significantly influenced their subsequent achievement-related emotions (here: math anxiety).

Even though we did not find any evidence for a direct effect of our intervention on participants' overall cognitive stress appraisal, we found an indirect effect of the intervention on

participants' coping-ability appraisal as a secondary step in the formation of cognitive stress appraisal (a person's appraisal of their capabilities in dealing with an event; Lazarus, 1966) that was fully mediated by participants' mindset. These findings correspond to recent results reported by Lee et al. (2019). Lee et al. (2019) found that students whose grades were declining and who held more of a fixed mindset were more likely to exhibit elevated salivary cortisol levels, compared to students who held more of a growth mindset. In addition, students whose grades were declining and held more of a fixed mindset were also more likely to perceive that they did not possess the resources to adequately cope with their daily stressors (measured through the following item: "overall how confident are you that you can handle the stresses you experienced today?"; Lee et al., 2019).

Furthermore, our results reveal a potential benefit that could be derived from utilizing mindset interventions in not only changing how students approach challenging learning and performance situations but also could potentially—through influencing their mindset—change how students cognitively appraise academically challenging situations and in turn influence their cognitive stress appraisal as well as their physiological stress response. Obviously, further research is required to examine these propositions and to shed further light on the processes that link a person's mindset to their cognitive stress appraisal and their physiological stress response.

At the same time, new questions arise regarding the theoretical rationale in which to position our and previous results that point to a connection between a person's mindset and their cognitive or physiological stress response. In order to investigate these questions and build upon our and previous research, other frameworks that try to explain the genesis of stress when encountering academic challenges or other achievement-related emotions could be taken into account.

The control-value theory of achievement emotions (Pekrun et al., 2007) potentially provides a preliminary framework that links a person's mindset to either their physiological stress response, their belief of being able to cope with current academic stressors (Lee et al., 2019), or achievement-related emotions like anxiety (King et al., 2012). The control-value theory of achievement emotions integrates a vast variety of emotion-related theories. Among these, the theory takes the predictions and theoretical assumptions of the transactional stress theory into account (Lazarus and Folkman, 1984; Pekrun et al., 2007). Test anxiety, for example, is assumed to be dependent on two main factors: a person's control appraisals and the value a person ascribes to the outcome of the performance situation. Accordingly, test anxiety ensues if a person views an upcoming exam as highly relevant and their ability to effectively be able to control the outcome as highly unlikely (Pekrun et al., 2007). Extending this argumentation, we argue that a person's mindset—if it has no direct impact on the overall cognitive stress response itself—could potentially influence a person's control appraisals, which in turn would then influence the ensuing cognitive stress response. The control-appraisal on the other hand is, according to Pekrun et al. (2007), dependent on a person's achievement-related convictions. A person's mindset represents such an implicit achievement-related belief that should in turn influence a person's appraisal of their capacity to deal with a demanding performance situation (Molden and Dweck, 2006).

Limitations and Future Directions

Even though the intervention was effective in influencing participants' mindset and we discovered an interesting insight into how participants' mindset relates to their appraisal of their coping ability, the following limitations need to be addressed.

First, even though we assessed the development of participants' cognitive stress appraisal through repeated measurements, no conclusion can be drawn about the actual stress potential of the reported exam and performance situations. Additionally, we did not explicitly assess when the reported exam had to be taken. Therefore, we cannot conclude if the time proximity of the upcoming exam might have played a relevant role in the actual stress potential of the situation. In addition, we did not test whether the repeated prompt for participants to write down the title of their upcoming exam before asking for their appraisal of the stress potential was able to activate a vivid representation of the upcoming performance situation.

In order to test the replicability and applicability of the designed intervention for teaching students and teaching staff, the material needs to be further tested in order to assess their long-term robustness and effectiveness. Even though the intervention's effect was still significant a few days after the intervention was conducted (M = 4.6; SD = 2.22), the effect was less pronounced than right after the intervention. From a practical point of view, this observation suggests that a second intervention at this time point could potentially aid the long-term effectiveness of the intervention.

Additionally, in order to test their actual generalizability and practical use, the materials could be applied to a sample of high school or middle school teachers. For example, the effect of applying the utilized intervention materials to a sample of teachers and how this could affect their students' mindset and performance could be assessed to evaluate the utility of the intervention for a potentially larger scale utility.

Future research should also revisit the question of a connection between mindset and stress appraisal and the crucial role the mindset plays in participants' coping-ability appraisals when faced with demanding performance situations. This could be done in a more standardized manner by manipulating how demanding a performance situation is or by examining the effects of mindset interventions on stress appraisal of students taking the same upcoming exam.

Lastly, even though we did not find a main effect of the intervention on the overall cognitive stress appraisal, our exploratory results point to an indirect effect of the intervention through mindset on participants' coping-ability appraisal. This provides a noteworthy insight into the potential link between a person's mindset and their cognitive stress appraisals facing academic challenges. Taking previously reported research results into account (King et al., 2012; Lee et al., 2019) as well as our own, a potential route to take for subsequent research could be to extend the provided theoretical rationale and further investigate potential processes that link a person's mindset to their overall emotional and cognitive experiences when faced with academic challenges.

CONCLUSION

This study highlights the beneficial and robust effects of a novel growth-mindset intervention designed for teaching students. Furthermore, this study provides insights into how a person's mindset relates to their cognitive stress appraisal. The question about the influence of a person's mindset on their overall stress response and the underlying mechanisms can at this point not be unequivocally answered but our results point to a possible interesting avenue for subsequent research and provide insights into a potential overarching theoretical framework.

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 human participants were reviewed and approved by the Ethics Committee of the University of Mannheim. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2021.634684/full#supplementary-material.

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Children's Gender Stereotypes in STEM Following a One-Shot Growth Mindset Intervention in a Science Museum

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Women are drastically underrepresented in science, technology, engineering, and mathematics (STEM) and this underrepresentation has been linked to gender stereotypes and ability related beliefs. One way to remedy this may be to challenge male bias gender stereotypes around STEM by cultivating equitable beliefs that both female and male can excel in STEM. The present study implemented a growth mindset intervention to promote children's incremental ability beliefs and investigate the relation between the intervention and children's gender stereotypes in an informal science learning site. Participants (n = 143, female n = 77, male n = 66, 5–12-years-old, M^{age} = 8.6, SD = 1.7) were visitors to a science museum who took part in an interactive space science show. Participants who were exposed to a growth mindset intervention, compared to the participants in the control condition, reported significantly less gender stereotyping around STEM by reporting equitably in the stereotype awareness measure. Relatedly, participants in the control condition reported male bias gender stereotype in the stereotype awareness measure. Further, children between 5 and 8-years-old reported greater male bias stereotypes awareness and stereotype flexibility in space science compared to children between 9 and 12-years-old. Lastly, children demonstrated in-group bias in STEM ability. Male participants reported gender bias favoring males' ability in stereotype flexibility and awareness measures, while female participants reported bias toward females' ability in stereotype flexibility and awareness measures. These findings document the importance of a growth mindset intervention in buffering against STEM gender stereotyping amongst children, as well as the significant role a growth mindset intervention can play within an informal science learning site.

Keywords: growth mindset intervention, implicit theories, gender stereotypes, STEM, informal science learning

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INTRODUCTION

Women are underrepresented in science, technology, engineering, and mathematics (STEM) careers (European Commission, 2019; WISE, 2019). In the United Kingdom, only 16% of computer science professionals and 10% of engineering professionals are women (WISE, 2019, 2020). Along with this gender disparity, the STEM workforce is facing a severe shortage in the number of skilled

Abbreviations: ISLS, informal science learning sites; STEM, science, technology, engineering, and mathematics

graduates required to meet the demand for STEM job vacancies (Bosworth et al., 2013; UKCES, 2014). One contributing factor that can help explain this gender disparity is gender stereotypes about STEM that associate "brilliance" in these fields with men more than women, which may undermine women's willingness to pursue a career in STEM (Shapiro and Williams, 2012; Leslie et al., 2015; Meyer et al., 2015).

The present study examines the relation between a one-shot growth mindset intervention and children's gender stereotypes about STEM ability in the context of space science – a highly male-dominated domain (Flaherty, 2018). Growth mindset taps into the beliefs that people's intelligence and ability are malleable and are subject to change (Dweck, 2015), thus opposing gender stereotypical views that boys are innately smarter than girls and that girls might not have the same innate ability to do well in STEM domains.

Gender stereotypes about females' ability in STEM can limit women's future engagement in STEM careers. Specifically, studies show that women are underrepresented in areas where success is believed to require high intellectual abilities, as these abilities are associated with men more than women (Leslie et al., 2015; Meyer et al., 2015). These gender stereotypes contribute to the widening gender gap in STEM disciplines (National Science Foundation, 2013; Wang and Degol, 2017). From the age of six, children begin to show gender-stereotypical beliefs that boys are better than girls in some STEM subjects, such as programming (Master et al., 2017a). Within the same age group, children also believe that boys are in general smarter than girls (Bian et al., 2017). Considering the possibility that female disengagement in STEM may develop early, efforts to challenge gender stereotypical beliefs about STEM should focus on children from a young age. This is why the present study examines the effectiveness of a growth mindset intervention on gender stereotypes among children from the age of five to twelve in the context of an informal science learning site (ISLS; e.g., science centers, museums, zoos, and aquaria).

Implicit Theories of Intelligence

The implicit theories of intelligence proposed by Dweck and Leggett (1988) posit that an individual's beliefs or views about intelligence can influence how one approaches challenges, orientates goals, and responds to criticisms (Dweck, 2015). For people with a fixed view of intelligence (i.e., a fixed mindset), intelligence in a specific area is viewed as a fixed entity and innate ability with limited opportunity for growth. In contrast, people with a malleable view of intelligence (i.e., growth mindset) believe that one can get smarter through learning and work toward that as a goal for self-improvement (Dweck and Leggett, 1988). Relatedly, a person with a growth mindset focuses on the process of learning and developing their ability, while a person with a fixed mindset focuses on the end goal of validating personal ability (Dweck and Leggett, 1988; Gunderson et al., 2013). As such, individuals with growth mindsets react to difficulties with adaptive and helpful learning strategies such as persistently trying to answer difficult questions and set achievable goals, while people with fixed mindsets react with helplessness such as giving up on difficult learning tasks (Blackwell et al., 2007; Rattan et al., 2015).

A large body of literature shows that children's implicit theories about intelligence can set them on very different trajectories of motivation and learning (Yeager and Dweck, 2012; Dweck, 2015; Rattan et al., 2015). Endorsing a growth mindset is positively related to academic performance in schools (Yeager et al., 2019), particularly for students facing learning difficulties (Blackwell et al., 2007; Claro et al., 2016). Further, in a longitudinal study that followed college students through a calculus course, researchers found that the more women perceived their college peers as having a malleable view on math ability, the more they felt a sense of belonging to math (Good et al., 2012). This sense of belonging, in turn, led to an increased desire to pursue math, even when the environments were perceived to be highly gender stereotypical. This study suggests that the perception of math ability as a malleable entity led to a heightened sense of belonging in a stereotypical male domain for women and buffered against the negative effects of gender stereotyping which include a decreased intention to pursue math. In this study, even in the face of negative stereotypes about females' ability in math, female students maintained high intention to pursue math in the future, felt greater belonging and earned high grades in math when they endorse a growth mindset. However, the relationship between a growth mindset and gender stereotyping is unclear amongst children.

Arguably, beliefs that the brains of both boys and girls are capable of growth, and that intelligence can be developed by learning, should be related to more equitable beliefs about STEM gender abilities. One of the ways to test this prediction is to investigate the relation between a growth mindset intervention and children's gender stereotypes in a specific STEM domain. The present study does this and aims to improve our understanding of how growth mindset is related to children's STEM gender stereotypes.

Gender Stereotypes

Developmental findings suggest that gender stereotyping in STEM emerges early. A recent study found children from 3 to 5 years of age endorsed strong gender stereotypes about STEM and found less support for counter-stereotypical STEM career options (Mulvey and Irvin, 2018). From the age of six, children believe that boys are better in robotics than girls (Master et al., 2017a). Within the same age group, children believe that boys are smarter than girls (Bian et al., 2017). It is important to note that gender differences cannot be seen in academic ability (Kovas et al., 2007), yet young children still exhibit gender stereotypical attitudes toward STEM career options and interests. This phenomenon is especially apparent in domains where gender inequality is seen in the working world. Data shows that men constitute more than 80% of the workforce in engineering and technology (WISE, 2019), which requires mathematics skills. Elementary school children reported boys liking mathematics more than girls (Cvencek et al., 2011), although this may not be reflected in grade attainment (Kovas et al., 2007). On that note, it is important to pay attention to children's responses about whom they think *usually* does well in STEM. In other words, this is their awareness of gender stereotypes in STEM (Liben and Bigler, 2002), which is reflective

of what children think the world is *currently* like. Further, it is also important to focus on children's stereotype flexibility, as it reflects who they believe *can* do well and succeed in STEM (Liben and Bigler, 2002), which is reflective of what they believe the world *can* be like. In this study, we are interested to explore both stereotype flexibility and stereotype responses. Based on past studies, stereotype awareness and flexibility can be considered separately with children from age 4- to 11-year-old (Liben and Bigler, 2002; Trautner et al., 2005). In this study, we utilized stereotype awareness and flexibility measures by Liben and Bigler (2002) to investigate children's knowledge of and beliefs about gender stereotypes. Furthermore, past studies demonstrate interesting gender differences in children's gender stereotyping around STEM. In a recent study conducted at five ISLS, researchers found children from 5 to 8-years-old were more likely to report that members of their own gender group usually and can do well in STEM (McGuire et al., 2020). However, for older children (aged 8–11), boys were more likely to show in-group gender bias in gender stereotyping. Boys were significantly more likely to state that boys can do well when asked about STEM ability, whereas girls in this age range do not share the same in-group bias. Another study conducted in three countries with undergraduate students found a similar trend whereby men endorsed more male-favoring stereotypes than women, while women endorsed female-favoring stereotypes more than men (Moè et al., 2020). This effect was more pronounced in countries with a larger gender gap index in STEM. Put together, these findings demonstrate interesting gender differences observable across children throughout young adulthood, as well as pointing toward the critical window to intervene with promoting girls' beliefs in their gender group's ability to do well in STEM early in age.

Moreover, children in different developmental stages display varying levels of gender stereotypes around STEM. For example, research found younger children engage in more gender stereotyping than older ones (McGuire et al., 2020). Further, Moè (2018) found that children endorse gender stereotype beliefs from the age of eight, but these stereotypes did not relate to children's performances in mathematics. Besides, children before 8 years of age show strong gender stereotypes around intellectual ability (Bian et al., 2017). This is because from 8 years of age, children transition from preoperational to concrete operational thought (Piaget, 1971). This means that at 8 years old or younger, children are less likely to perceive differences in ability between gender groups and pre-judge an individual based solely on their gender group membership and not any other characteristics they may display. However, research suggests that with age (from approximately 8 years), children show an age-related increase in the ability to process multiple classifications and, therefore, show more stereotype flexibility (Bigler and Liben, 2007; Martin and Ruble, 2010). The current research is interested therefore to explore the developmental differences between children before the age of eight and after. In theory, interventions targeting STEM ability may be more effective in challenging stereotypes beliefs among children below 8 years old.

Gender stereotypes are damaging to girls' career aspiration and motivation (Reuben et al., 2014). Gender stereotypes also have the potential to impact other factors such as self-efficacy, identity, belonging, engagement, and persistence in STEM (Eddy and Brownell, 2016). Thus, to equalize the gender representation in STEM fields, research suggests that it might be necessary to go back to early school science education (Kerkhoven et al., 2016), as children's gender stereotypes develop rapidly between the ages of 6 and 10 (McKown and Weinstein, 2003) and gender biases in STEM fields emerge early in age (Mulvey and Irvin, 2018; McGuire et al., 2020). However, so far, interventions have been limited to formal educational settings, such as schools. Young people also spend time engaging in informal learning outside of the formal education environment, such as science centers and museums.

In the United Kingdom, 5.3 million people visited five of the largest science museums in 2017 (Science Museum Group, 2018). International data from 181 museums and science centers worldwide documented that over 67 million people visited ISLS in 2016 (ATSC, 2016). Less work has been done, however, within these contexts to understand how, coupled with theory-based educational interventions, ISLS can be effective in challenging STEM gender stereotypes among young people. Research on growth mindset interventions have largely been conducted at formal educational settings (i.e., schools and universities); thus, the present study extends research on growth mindset interventions to ISLS.

Growth Mindset Interventions

Interventions that communicate growth mindsets have effectively promoted students' incremental beliefs about intelligence (DeBacker et al., 2018). Further, research on growth mindset interventions has also led to positive outcomes in students' academic achievements and motivation in schools (Blackwell et al., 2007; Good et al., 2012; Paunesku et al., 2015; Yeager et al., 2019). Research shows that growth mindset interventions can be effectively executed through one-shot (single session) programs. These interventions can take place in schools or through online platforms (Blackwell et al., 2007; Yeager and Dweck, 2012; Rattan et al., 2015; Yeager et al., 2016; DeBacker et al., 2018; Burgasser, 2019).

Despite a mounting interest in growth mindset interventions, this approach has yet to be applied to informal learning contexts, as most research has been conducted at formal learning settings (Aronson et al., 2002; Blackwell et al., 2007; DeBacker et al., 2018). However, one line of research shows that growth mindset messages can be communicated through interactive educational video games (O'Rourke et al., 2016). In this study, a 3-min growth mindset message was related to higher persistence as children played more levels of the game after receiving growth mindset related feedback, as compared to children in the control condition. There is a need for research to examine the effectiveness of delivering a growth mindset intervention in ISLS.

The Present Study

Therefore, in the current study, we uniquely partnered with ISLS practitioners in designing and examining the relation between a growth mindset intervention and children's gender stereotypes around STEM. Here, a growth mindset intervention

was delivered as part of an interactive space science show within a science museum. Growth mindset is a domain-specific construct (Dweck, 2015), so in this study, the focus is specifically on the domain of space science. Space science was selected as the STEM subject of study because women are drastically under-represented in this discipline and there is a higher dropout rate of women in space science as compared to men (Hill et al., 2010; Flaherty, 2018; Porter and Ivie, 2019).

This study focuses on children's (age 5–12 years old) responses to who they think *can* do well (stereotype flexibility) and *usually* do well in space science (stereotype awareness). Children begin to categorize the world based on gender early in life (Quinn et al., 2002) and from 5-years of age they can segregate occupations by gender roles and place different values on traditionally masculine and feminine careers (Weisgram et al., 2010). The present study tested the relation between growth mindset intervention and gender stereotypical views around space science as well as to compare the developmental differences between children in middle childhood (age 5–8 years old) and children in late childhood (age 9–12 years old). We draw the same predictions for both stereotype awareness and stereotype flexibility.

Hypotheses

H1: Children in middle childhood (8 years old or below) will report greater gender stereotyping by showing more male bias (i.e. favoring male ability over female ability) in space science ability compared to those in late childhood (9 years old or above).
H2: Children in the growth mindset condition will exhibit significantly less gender stereotyping in space science with more equitable responses, while children in the control condition will exhibit significant gender stereotyping by showing more male bias in space science.
H3: The growth mindset intervention will be particularly effective for children within middle childhood (8 years old or below). Specifically, children in middle childhood within the growth mindset condition will respond more equitably to gender stereotype measures compared to children in the control condition.
H4: Male participants will show in-group bias by reporting greater gender stereotyping in favor of male's ability than reported by female participants.

MATERIALS AND METHODS

Participants

One hundred and sixty-seven participants completed the study in a science center in the Midlands of the United Kingdom. Five participants who reported their gender as "other" were excluded from the analysis due to insufficient power to include the gender-other category in the analysis. In addition, two participants with no age information were excluded, and 17 participants older than 13-years were also excluded as the present study focused on middle and late childhood rather than adolescence. An *a priori* power analysis was conducted using G*Power3 (Faul et al., 2007) to identify the total sample required to achieve a power of 0.80 using a two-tailed test with a medium effect size of 0.25. The results showed that a total sample of 128 participants was required. Altogether 143 participants were included in the analyses (female n = 77, male n = 66). Seventy-three participants (female n = 45, male n = 28) were in the growth mindset condition and 70 participants (female n = 32, male n = 38) were in the control condition. Participants were divided into two age groups: middle childhood (n = 75, M^{age} = 7.21, SD = 0.81, minimum = 5-years, maximum = 8-years) and late childhood (n = 68, M^{age} = 10.04, SD = 1.06, minimum = 9-years, maximum = 12-years). Overall, 77% of participants were White, 12% Asian, 3% mixed-race/dual heritage, and 8% chose not to disclose ethnicity. Parental consent and child assent were obtained for all participants.

Procedure and Experimental Manipulation

All measures were approved by the Goldsmiths, University of London's Ethics Committee as part of the project "Growth mindset intervention among children". The protocol was completed in a science center following an hour-long interactive space science show. The space science show includes images of both male and female astronauts. When visitors were invited to take part in the show, both male and female visitors were invited at the same time. Participants in the experimental condition received a growth mindset intervention during the show. The intervention was adapted from "You Can Grow Your Intelligence" (designed by Mindsets Inc.; Blackwell et al., 2007) and tailored to fit the space science show at the science museum. The intervention conveyed a message about brain malleability and highlights how ability can be developed through persistent learning. It also frames setbacks and challenges as opportunities for learning and growth. The growth mindset message was delivered by either a female or a male voice accompanying a photograph of astronauts. Voice gender was varied in order to control for any influence of this factor on our dependent variables. Participants in the control condition experienced the same interactive space science show without hearing the growth mindset message below.

> *"It was nearly an impossible task to send astronauts to the moon, but this year we are celebrating the 50th anniversary of this great achievement. This was all possible because all of us, including you, have an amazing brain that can develop and become smarter as you learn! You cannot see it, but each time you learn a new thing, the tiny connections in your brain multiply and get stronger. The more you challenge yourself to learn, the more your brain will develop and grow. Just like children, who first don't know how to read, but after learning and practising and making many mistakes (just like the video of the astronauts we watched, learning how to walk on the moon and keep falling) they can eventually learn how to read! The baby's brain has now changed, it has gotten smarter. Like a muscle that grows when we exercise, our brain grows smarter when we keep learning and trying! Especially when you are learning a difficult subject or trying a challenging task, these are the perfect opportunity for your brain to grow and be stronger! Would you like to strengthen your brain and be smarter? You can! At whatever age*

you are, your brain develops and become stronger when you learn new things."

The intervention as a whole consisted of three elements: a growth mindset message, a writing task, and a manipulation check at the end of the survey. The writing task asked participants to write a short message of encouragement to a friend who is struggling to learn about space science (adapted from DeBacker et al., 2018). This writing task is rooted in getting participants to advocate for a particular position (here, growth mindset beliefs in learning space science), a phenomenon called the "saying-is-believing effect" (Higgins and Rholes, 1978). At the end of the survey, participants answered two manipulation check items (e.g., "According to the show, what happens to our brain when we learn new things?"). All participants answered at least one manipulation check question correctly and were therefore included in the analyses presented below. Children who participated in this study received a gift bag worth £5 in exchange for completing the survey. All participants were part of family groups visiting the science center, consisting of at least one adult and one child.

Gender Stereotypes Measures

The gender stereotype measure was adapted from Liben and Bigler (2002) to assess children's stereotype awareness and stereotype flexibility. Participants read a series of sentences and marked on a line to indicate their agreement with the sentence from 0 = not true at all to 100 = very much true with a slider marked in increments of 10. For *Stereotype Awareness* the items are "I think that girls usually do well in space science" and "I think that boys usually do well in space science", whereas, for *Stereotype Flexibility,* the items are "I think that girls can do well in space science" and "I think that boys can do well in space science". Using these measures, male bias score for stereotype awareness and stereotype flexibility were created by subtracting the response to the question about girls from the response to the question about boys. The male bias score scaled from −100 (maximum female bias = participant responded 100 to girls' question and 0 to boys' question) to 100 (maximum male bias = participant responded 100 to boys' question and 0 to girls' question) and as the mid-point of the scale, zero score indicates an equitable gender stereotype response.

Data Analytical Strategy

To observe the differences in children's gender stereotyping based on their age, gender, and experimental conditions, we conducted a 2 (Age; Middle Childhood, Late Childhood) × 2 (Gender; Female, Male) × 2 (Mindset condition; Growth mindset, Control) independent ANOVA with male bias stereotype awareness and male bias stereotype flexibility as the dependent variable respectively using SPSS Version 25 (IBM Corp, 2018). Where appropriate, simple main effects comparisons were conducted using Bonferroni corrections for multiple comparisons. To test the direction of gender bias in a given condition, we carried out one-sample *t*-tests to determine whether the mean of a given group (i.e. middle childhood) differed significantly from the criterion value of zero (i.e. no bias toward male or female ability).

RESULTS

Stereotype Awareness

Consistent with H1, a significant main effect of age was observed, $F(1,133) = 8.03$, $p = 0.005$, $\eta_p^2 = 0.06$ Participants in middle childhood reported significantly greater male bias ($M = 11.12$, SD = 28.74) compared to participants in late childhood ($M = -2.69$, SD = 29.07). Responses in middle childhood [$t(72) = 2.39$, $p < 0.05$, $d = 0.28$] differed significantly from the mid-point of the scale, in the direction of male bias. In contrast, responses in late childhood did not differ from the mid-point of the scale [$t(67) = 1.09$, $p > 0.05$, $d = 0.13$].

Further, in line with the second hypothesis, the analysis yielded a marginally significant effect of growth mindset, $F(1,133) = 3.54$, $p = 0.062$, $\eta_p^2 = 0.03$ (**Figure 1**). In partial support of H2, participants in the control condition reported greater male bias ($M = 8.80$, SD = 29.25) than participants in the growth mindset condition ($M = -0.37$, SD = 28.59). Further analysis revealed that responses in the control condition differed significantly from the midpoint of the scale in favor of male bias [$t(67) = 2.57$, $p < 0.05$, $d = 0.31$]. In contrast, participants in the growth mindset condition did not differ from the mid-point of the scale [$t(72) = -0.64$, $p > 0.05$, $d = 0.07$]. Hypothesis 3 was not supported as no significant interaction effects were observed between mindset condition and age, $F(1,136) = 0.002$, $p = 0.97$, $\eta_p^2 = 0.001$, indicating that the effect of the mindset intervention was the same for both age groups. Results did not support the prediction that the intervention would be particularly effective for children within middle childhood (8 years old or below).

In support of H4, a main effect of gender was observed, $F(1,133) = 17.89$, $p = 0.001$, $\eta_p^2 = 0.12$. Male participants reported male in-group gender bias ($M = 14.52$, SD = 28.69) while female participants reported female in-group bias ($M = -6.09$, SD = 31.47). Male participants' responses differed significantly from the midpoint of the scale in favor of male ability [$t(63) = 3.80$, $p = 0.001$, $d = 0.47$] and female participants' responses differed significantly from the midpoint of the scale in favor of female ability [$t(76) = -2.17$, $p = 0.03$, $d = 0.47$). There were no significant interactions between participants' gender and

TABLE 1 | Stereotype awareness response difference score by mindset condition, age, and gender.

		Middle childhood		Late childhood		Total
		Male	Female	Male	Female	
Growth mindset condition	*M*	18.67	−4.70	0.31	−15.78	−2.34
	SD	37.94	23.89	13.18	35.19	31.54
Control condition	*M*	30.82	−0.33	8.26	−3.57	9.19
	SD	38.94	24.12	22.28	16.10	29.51
Total	*M*	9.45		−3.47		
	SD	33.80		26.35		

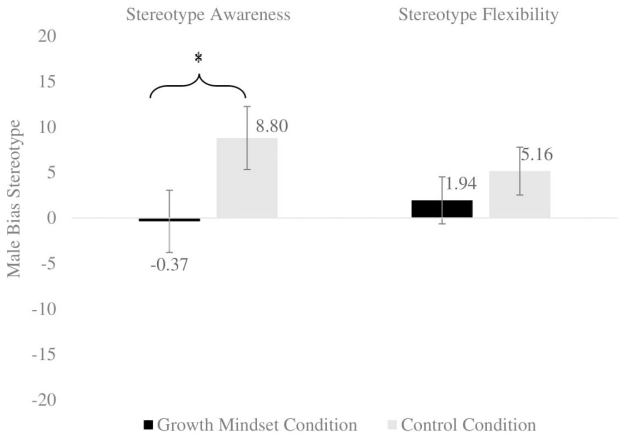

FIGURE 1 | Male bias stereotype as a function of stereotype measure and experimental condition (scores above zero indicate response in favor of male's ability, zero scores indicate equitable response and below zero indicate in favor of female's ability; error bars represent standard error of the mean). Stereotype awareness measures who children believe *usually* do well in space science while stereotype flexibility measures who children believe *can* do well in space science. *Denotes $p = 0.06$.

the mindset conditions, $F(1,137) = 0.02$, $p = 0.97$, $\eta_p^2 = 0.01$. The means and standard deviations for stereotype awareness response by mindset condition age, and gender are included in **Table 1**.

Stereotype Flexibility

Consistent with H1, a significant main effect of age group was observed, $F(1,132) = 8.57$, $p = 0.004$, $\eta_p^2 = 0.06$. Participants in middle childhood reported greater male bias ($M = 8.93$, SD = 21.82) than participants in late childhood ($M = -1.84$, SD = 21.91). Responses in middle childhood differed significantly from the mid-point of the scale, in favor of male ability [$t(71) = 2.3$, $p < 0.05$, $d = 0.27$], while responses in late childhood did not differ from the mid-point of the scale [$t(67) = -0.81$, $p > 0.05$, $d = 0.10$].

We did not observe a significant main effect of mindset condition on stereotype flexibility, $F(1,132) = 0.56$, $p = 0.38$, $\eta_p^2 = 0.006$. No significant difference was observed between participants in the control condition ($M = 1.94$, SD = 22.05) and participants in the growth mindset condition ($M = 5.16$, SD = 21.54). Participants' responses in the control condition [$t(66) = 1.74$, $p = 0.09$, $d = 0.21$] and participants' responses in the growth mindset condition [$t(72) = 0.167$, $p = 0.87$, $d = 0.02$] both did not differ from the mid-point of the scale. Thus, H2 was not supported by the analyses on stereotype flexibility. Further, H3 was not supported as there were no interaction effects between mindset condition and age group, $F(1,132) = 2.52$, $p = 0.12$, $\eta_p^2 = 0.019$. Particularly, results did not show, as had been predicted, that the intervention will be particularly effective for children within middle childhood (8 years old or below).

Lastly, a main effect of gender was observed as predicted in H4, $F(1,132) = 22.40$, $p = 0.001$, $\eta_p^2 = 0.15$. Male participants reported greater male in-group gender bias ($M = 12.27$, SD = 21.62) while female participants reported greater female in-group bias ($M = -5.18$, SD = 22.0). Male participants' responses differed significantly from the midpoint of the scale in favor of male ability [$t(63) = 4.05$, $p = 0.001$, $d = 0.51$] and female participants' responses differed significantly from the midpoint of the scale in favor of female ability [$t(75) = -2.23$, $p = 0.03$, $d = 0.26$]. There were no significant interactions between participants' gender and mindset conditions, $F(1,136) = 2.97$, $p = 0.60$, $\eta_p^2 = 0.01$. The means and standard deviations for stereotype flexibility response by mindset condition age, and gender are included in **Table 2**.

TABLE 2 | Stereotype flexibility response difference score by mindset condition, age, and gender.

		Middle childhood		Late childhood		Total
		Male	Female	Male	Female	
Growth mindset condition	*M*	14.53	−5.47	4.0	−5.05	0.37
	SD	27.24	15.55	8.72	14.71	18.95
Control condition	*M*	25.64	1.29	4.89	−11.21	5.88
	SD	34.48	24.14	12.91	24.77	27.64
Total	*M*	7.56		−1.81		
	SD	27.85		16.93		

DISCUSSION

The present study found, as predicted, that participants who were exposed to a growth mindset intervention compared to the participants in the control condition reported significantly less gender stereotyping around STEM, by demonstrating less male bias in the stereotype awareness measure. However, no difference was observed between participants who experienced a growth mindset intervention and participants in the control condition for stereotype flexibility measure. Participants in both conditions responded equitably. The findings also showed how those children between 5 and 8-years-old reported greater male bias stereotypes awareness and stereotype flexibility in space science compared to children between 9 and 12-years-old. Further, children demonstrated in-group bias for their own gender group. Male participants reported greater bias favoring males in stereotype flexibility and awareness measures, while female participants reported greater bias toward females in stereotype flexibility and awareness measures.

The present research makes two novel contributions to the literature. First, the findings of the study demonstrate a relation between a one-off growth mindset intervention and children's gender stereotypes awareness in the domain of space science. Secondly, the present study extends previous growth mindset interventions research by demonstrating how a growth mindset intervention can be executed in an interactive science show at an informal learning setting, such as a science museum.

Examining gender stereotypes about space science across children in middle childhood and late childhood, we observed that younger children reported greater male bias in stereotype awareness and stereotype flexibility compared to older children. The lack of male bias in gender stereotype in STEM ability is consistent with prior studies investigating stereotypes around

math and science ability among children in late childhood (Muzzatti and Agnoli, 2007; Kurtz-Costes et al., 2014). The present finding is also consistent with recent research conducted at ISLS in the United Kingdom and the United States, which documented greater male bias stereotypes around STEM with younger children compared to their older counterparts (McGuire et al., 2020). Efforts to challenge these stereotypes should begin early with children in middle childhood as evidenced in the present study.

An important contribution of the current study was that we investigated how growth mindset intervention in an ISLS relates to children's male bias stereotypes in the male dominated domain of space science. Specifically, the present study found mindset intervention a buffer against STEM gender stereotyping in some ways. In this study, we explicitly measured children's stereotype awareness to elicit *knowledge* of gender stereotypes, and children's stereotype flexibility to elicit *attitudes* toward stereotypes (Signorella et al., 1993; Liben and Bigler, 2002). Notably, we found that in the growth mindset intervention condition, children reported equitable responses to the stereotype awareness measure, as compared to children in the control condition who responded with greater male bias. Although the effect size was small, these findings indicate that the understanding of brain malleability is associated with more equitable responses for both boys' and girls' understanding of who usually does well. This is an interesting finding as national statistics show that space science-related careers including astronomy are highly male-dominated, suggesting perceived male superiority in these careers (Cesarsky and Walker, 2010; Porter and Ivie, 2019), yet we observed that a growth mindset message is associated with more equitable stereotype awareness responses. This finding has promising implications because when children believe that both boys and girls *usually* do well in space science, both gender groups should be likely to engage in space science-related studies or activities in the future. This is especially important for girls as they tend not to engage in STEM activities that they view as not suitable for them or that they cannot do well in (Bian et al., 2017; Master et al., 2017a).

We did not find the same relation between mindset intervention and stereotype flexibility. Notably, children in both conditions responded equitably on this measure, indicating that they believe both boys and girls *can* do equally well in space science. Since this measure elicits children's attitudes toward stereotypes (Signorella et al., 1993), this finding suggests that children were less willing to show gender biased attitudes toward space science ability explicitly. One possible explanation is that this research was conducted in an interactive space science show that was facilitated by both male and female ISLS educators and throughout the show, both boys and girls had equal chances to take part in space science activities during the show. ISLS often encourage boys' and girls' involvement in STEM to promote interest and engagement of all (National Research Council, 2010) which may in turn be related to more equitable beliefs about who succeed in these areas.

Another possible explanation for the equitable responses in both control and growth mindset condition could be that children are less inclined to explicitly report stereotypical *attitudes* toward boys' and girls' ability. In contrast, when the measure was less directive as it taps on their *knowledge* of the gender representation in STEM (i.e., who *usually* do well) children are more likely to demonstrate gender biases. This could be due to social desirability artifacts and that children may respond in ways which they believe are more socially desirable or acceptable, especially when they are answering the questions in the presence of their family members at the space science show. On that note, it would be interesting to look at how children respond to gender stereotype endorsement using implicit stereotype measures at ISLS. With regards to a socially sensitive domain such as gender stereotypes, utilizing implicit stereotype measures might be recommended (Hofmann et al., 2005; Greenwald et al., 2009; Cvencek et al., 2011).

Furthermore, the present findings show participants' gender played a role in their gender stereotype responses independent of the experimental condition and age. Both male and female participants reported significant in-group bias in awareness and flexibility measures. This is consistent with recent research (McGuire et al., 2020) and the developmental literature pertaining to children's strong support for their ingroup which may sometimes result in manifestations of biases against other groups (Bigler and Liben, 2007). These findings present important implications for practice. Practitioners could consider ways to leverage on female in-group biases to foster a strong interest in STEM and cultivate a sense that females, along with males, can all do well in STEM activities.

One way to enhance these beliefs is by organizing group activities for female visitors. Past studies demonstrate that a sense of social group membership (boys and girls mixed group) can enhance children's persistence on a STEM task, and increase interest and perceived self-efficacy in the STEM task (Master et al., 2017b). Encouraging girls to participate in a STEM activity together, for instance, having a female science activity group to take part in a stereotypically male activity (e.g. build a car engine), may foster female's interest in these activities. Besides that, more work should consider the impact of male in-group bias in STEM and how this can cultivate boys' interest without hindering girls' engagement. More research in these areas is important because children's perception of who is able to do well in STEM has a significant impact that lasts for a lifetime as it directly influences their educational and career engagement in the future (Francis, 2000; Davies et al., 2005; Cheryan et al., 2011).

The present research breaks new ground by demonstrating how growth mindset intervention can be effectively executed at ISLS. The findings of the present study show that mindset interventions can be successfully carried out in a science museum with the collaboration between researchers and practitioners. This research-practice partnership offers many opportunities to explore research questions, test novel educational interventions, and design and implement impactful theory-based and outcome-focused practice (Anderson and Shattuck, 2012; Mulvey et al., 2020).

Limitations and Future Directions

Future research should aim to examine how growth mindset messages relate to adolescents' gender stereotypes in STEM ability. Adolescence is a crucial stage where there is a developmental decline in engagement and attitudes toward

science (Osborne et al., 2003), especially among female teenagers in male-dominated areas such as engineering (Sadler et al., 2012). These developmental ages are pivotal moments to challenge stereotypes, and promote STEM interest and engagement. Given the relation between the growth mindset intervention and stereotypes in the present study, future work could explore how mindset interventions in informal learning sites may buffer against the negative effects of stereotype threats when gender identity is made salient among adolescents. Past studies show that in formal educational settings such as universities and schools, growth mindset messages are associated with less stereotype threat for minority status groups in academic attainment (Aronson et al., 2002). Yet, less is known about the relation between growth mindset and stereotype threat in STEM among children and adolescents in the context of informal learning.

Further, it is not clear whether the gender of the voice delivering the intervention may have been related to different effects in children's stereotypical beliefs about STEM ability. In the present study, the voice of the growth mindset was treated as a control, whereby half of the participants heard the intervention delivered by a female voice and half by a male voice. Future research can build on this to investigate the effect of gendered growth mindset messages on children's gender stereotype beliefs. Moreover, less is known about how the growth mindset message and gender stereotypes in STEM ability may reciprocally influence each other over time. A longitudinal research design would shed light onto how experiencing growth mindset intervention at ISLS relate to children's gender stereotypes, attitudes and engagement around STEM. Prior growth mindset intervention research has shown promising long-term impact of mindset intervention with young people's academic attainment and motivation (Yeager et al., 2019), but the relationship between mindsets and gender stereotypes in the long run is unclear. We found small effect sizes for the effectiveness of the one-shot mindset intervention. Future research can explore the possible effects of more than one shot intervention with a follow up intervention design over time.

Finally, the growth mindset intervention was conducted in a space science show at a science museum. It will be important for future research to examine the pattern of transfer of this mindset intervention into other areas such as children's performance in school. Moreover, the current research explored the domain of space science specifically, while other interventions have investigated growth mindset messages in other STEM domains such as chemistry (Fink et al., 2018) and mathematics (Boaler et al., 2018). Less is known about the whether the effectiveness of growth mindset interventions transfers from one STEM domain to another. An important direction for future research is to investigate the transfer of the effects of growth mindset intervention from one STEM domain to another.

CONCLUSION

For the first time, the current study examined the relation between delivering a one-off growth mindset intervention in an interactive space science show and children's gender stereotypes. The findings demonstrate that knowledge about the malleability of ability is associated with more equitable gender stereotype awareness around STEM. The application of implicit theories in ISLS can play a role in children's gender stereotype beliefs about STEM ability, which are known to be instrumental in the rising gender disparity between men and women in STEM (Sadler et al., 2012; Legewie and DiPrete, 2014). In our mission toward a more equitable STEM future, more research needs to be done to understand how to challenge children's gender stereotyped beliefs about STEM ability from a young age. ISLS offer vibrant and dynamic activities aimed to increase engagement, interest, and motivation in STEM (National Research Council, 2010); thus, providing valuable opportunity to advance developmental science research around STEM and exciting platforms to develop research-based interventions for the public.

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 human participants were reviewed and approved by the Goldsmiths, University of London. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

FL designed the study, developed the hypotheses, performed the data collection, analyzed the data, and drafted the manuscript. LM participated in the study design and performed data collection, and helped to draft the manuscript. MW participated in the study design and helped to draft the manuscript. AR supervised the study design, oversaw the development of the hypotheses and statistical analyses, and helped to draft the manuscript. All authors read and approved the final manuscript.

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How Classmates' Gender Stereotypes Affect Students' Math Self-Concepts: A Multilevel Analysis

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The present research is the first to examine how students' individual and their classmates' math-related gender stereotypes, endorsing that math would be a typically male domain, relate to students' math self-concepts. To this end, data of N = 1,424 secondary school students from Germany were analyzed using multilevel analyses. As expected, strong individual beliefs in the math-related gender stereotype were related to lower math self-concepts for girls, but to higher math self-concepts for boys. Moreover, classmates' shared beliefs in this stereotype showed a negative relation to girls' self-concepts, whereas no significant relation between classmates' shared beliefs and boys' self-concepts was found. These relations also persisted after controlling for students' math grades and age. In sum, the results demonstrated that gender stereotypes shared by students' classmates can have a substantial impact on students' math self-concepts, beyond their individual gender stereotypes. This finding emphasizes the significance of classmates as important socializing peers in the process of students' self-concept formation.

Keywords: academic self-concept, beliefs, classmates, contextual effects, gender stereotypes, math self-concept, peers

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INTRODUCTION

Although gender differences in math performance have largely vanished today, female students still tend to consider themselves as being less competent in math than their male counterparts (e.g., Hyde et al., 2008; Niepel et al., 2020). These gender differences in students' math self-concepts remain a cause for concern—not only because subject-specific self-concepts strongly relate to students' attitudes and affects toward school subjects (e.g., Goetz et al., 2008; Schurtz et al., 2014), but also because students include their self-concepts in their career choices (e.g., Parker et al., 2012, 2014). For that reason, the lower math self-concepts of females might hamper current political efforts to reduce the underrepresentation of women in fields related to math, science, technology, and engineering [Niepel et al., 2020; Organisation for Economic Co-operation and Development (OECD), 2020].

In the last decades, gender differences in students' math self-concepts have been examined in plenty of studies (e.g., Eccles-Parsons et al., 1983; Skaalvik and Skaalvik, 2004; Preckel et al., 2008). Among these, some studies have addressed the question of how gender differences in students' math self-concepts depend on gender stereotypes. Interestingly enough, these studies found that the gender differences in students' math self-concepts are larger, the more students believe that

math would be a subject for boys rather than for girls (e.g., Nosek et al., 2002; Steffens and Jelenec, 2011; Passolunghi et al., 2014). However, all of these studies only considered the relations between students' math self-concepts and their math-related gender stereotypes at the individual level, while neglecting the potential effects of math-related gender stereotypes shared by students' classmates. Given prior findings on the impact of significant adults' (teachers' and parents') math-related gender stereotypes on students' attitudes toward math (e.g., Gunderson et al., 2012), as well as the role of classmates as important socializing peers (e.g., Berndt and Murphy, 2002), it would seem reasonable to assume that classmates' math-related gender stereotypes affect students' math self-concepts beyond their individual stereotypes. Moreover, Muntoni et al. (2021) provided empirical evidence that students' self-concepts are affected by gender stereotypes shared in the classroom. In this study, the authors found that boys' reading self-concepts were lower, the more their classmates believed in the stereotype that reading would be a typically female domain. However, although most research on the relations between subject-specific gender stereotypes and students' self-concepts has focused on the math domain, no empirical study has so far examined whether Muntoni et al.'s (2021) findings would also apply to the math domain (i.e., whether girls show lower math self-concepts, the more their classmates believe in the stereotype favoring boys in math).

The present research addresses this research gap. To this end, I will analyze data collected in a large sample of secondary school students from Germany who reported both their math self-concepts and their math-related gender stereotypes. For the first time, I will examine whether and how girls' and boys' math self-concepts are affected by math-related gender stereotypes held by themselves and shared by their classmates. Thus, this study will make an important contribution to the literature by significantly enhancing our knowledge of the emergence of gender differences in students' math self-concepts. Beyond that, it is the first study to test whether Muntoni et al.'s (2021) findings—which have received considerable attention not only in the scientific community [e.g., Gesellschaft für Empirische Bildungsforschung (GEBF), 2019] but also in the media (e.g., Deutsches Schulportal, 2020; Society for Research in Child Development, 2020)—will generalize to another domain. This research will therefore provide us with valuable information to assess whether Muntoni et al. (2021) have discovered a psychological mechanism that operates across domains, or whether the relations shown in their study may be more specific to the domain of reading.

Impact of Students' Own Gender Stereotypes on Their Math Self-Concepts

Stereotypes can be defined as shared beliefs about traits that are characteristic of members of a certain social category (e.g., Greenwald and Banaji, 1995). Although they may facilitate human behavior and decision-making in complex environments, they often come along with negative effects for the stereotyped group (e.g., Steele and Aronson, 1995; Schmader et al., 2004; Ihme and Möller, 2015). Concerning math, prior studies on gender stereotypes have repeatedly found support for the prevalence of the stereotype endorsing that math would be a typically male domain (e.g., Nosek et al., 2002; Steffens et al., 2010; Cvencek et al., 2011; Steffens and Jelenec, 2011; but see Plante et al., 2009). This finding is somewhat paradoxical in that girls do not (any longer) perform significantly worse than boys in math [e.g., Hyde et al., 2008; Else-Quest et al., 2010; Lindberg et al., 2010; Niepel et al., 2020; Organisation for Economic Co-operation and Development (OECD), 2020] and even receive slightly better math grades (Voyer and Voyer, 2014). Yet, the prevailing view that males would be more competent in math may be a key reason as to why girls on average report lower math self-concepts than boys (e.g., Skaalvik and Skaalvik, 2004; Niepel et al., 2020) and thus develop less positive attitudes and affects toward math (e.g., Else-Quest et al., 2010; Goetz et al., 2013; Schurtz et al., 2014; Arens et al., 2017).

A prominent theory predicting these relations is Eccles' expectancy-value theory—a comprehensive model for the explanation of achievement-related choices and behaviors (EVT; Eccles-Parsons et al., 1983; Wigfield and Eccles, 2000; Eccles, 2009). EVT was originally developed to help explain gender differences in the likelihood of studying math and science. Among others, it assumes that stereotypes shared within one culture, such as beliefs about gender roles, affect students' self-concepts, and consequently their subject-specific task values and other achievement-related outcomes. However, EVT also assumes that students' perceptions of these stereotypes significantly account for the stereotypes' impact on students' self-concepts. In line with this assumption, several studies have shown that the influence of the math-related gender stereotype favoring boys in math on students' math self-concepts depends on students' beliefs in this stereotype (e.g., Nosek et al., 2002; Kurtz-Costes et al., 2008; Evans et al., 2011; Steffens and Jelenec, 2011; Passolunghi et al., 2014). More specifically, these studies revealed that girls tend to show lower math self-concepts, whereas boys typically have higher math self-concepts, the more they believe in this stereotype. Furthermore, some studies have shown that the effect of math-related gender stereotypes can even be reversed in favor of girls if students—against cultural conventions—are convinced that girls would be more competent in math than boys (e.g., Passolunghi et al., 2014).

To sum up, the stereotype endorsing that math would be a typically male domain does not affect each student's math self-concept in the same way. Rather, girls' and boys' beliefs regarding the validity of this stereotype are central determinants for its influence on their math self-concepts. Based on these findings, the present study further examines how students' beliefs in the gender stereotype favoring boys in math affect their math self-concepts by considering, for the first time, the potential influence of shared beliefs about this stereotype in students' classrooms.

Impact of Classmates' Gender Stereotypes on Students' Self-Concepts

Besides the impact of students' individual gender stereotypes, previous research has found that students' self-concepts are also

affected by gender stereotypes held by significant others. These studies have dealt with the influence of parents' and teachers' beliefs (e.g., Jacobs and Eccles, 1992; Bouchey, 2004; Gunderson et al., 2012; Rowley et al., 2013; Muntoni and Retelsdorf, 2019). For example, Jacobs and Eccles (1992), analyzing longitudinal data, found that the math-related gender stereotypes of mothers influenced their perceptions of their children's math abilities in such a way that mothers with a strong belief in the stereotype favoring boys in math enhanced their perceived abilities of their sons but devalued their perceived abilities of their daughters. In turn, these ability perceptions affected the children's own math self-concepts, beyond students' actual gender and their teachers' beliefs about their abilities. These findings are also in accord with EVT, which emphasizes the role of socializers' beliefs and predicts that these beliefs, such as those about gender stereotypes, affect students' self-concepts even beyond students' own beliefs about gender stereotypes.

Unlike the relatively high number of studies examining the impact of parents' and teachers' gender stereotypes on students' math self-concepts, the impact of classmates' gender stereotypes on students' math self-concepts has not been examined so far. Nevertheless, such an influence seems plausible, given that peers also represent important socializers for students, especially during adolescence (e.g., Berndt, 1979; Hartup, 1996; Espelage et al., 2003; Brown, 2011). In particular, previous research has shown that peers can be of high importance for imparting behavior connoting appropriateness based on gender (e.g., Lamb et al., 1980; Zucker and Bradley, 1995; Bussey and Bandura, 1999; Ruble et al., 2007). Moreover, several studies have found that students' individual beliefs and values can be significantly affected by those of their classmates (e.g., Ryan, 2001; Bouchey, 2004; Frenzel et al., 2010; Studsrød and Bru, 2011). For example, with regard to math, Bouchey (2004) showed in a cross-sectional study that classmates' ratings of students' math ability were positively related to students' math self-concepts, after controlling for students' math achievement. Besides, Frenzel et al. (2010) found in a longitudinal study that students' math interest was higher, the more value their classmates expressed toward math. These authors also noted that classmates can be assumed to play an important role in the formation of students' achievement-related beliefs and values, especially in Germany, as students in the German school system stay within the same group of students across most subjects within a school year.

More specific evidence for the assumption that students' math self-concepts might be influenced by their classmates' math-related gender stereotypes stems from two longitudinal studies, in which data collected in Germany were re-analyzed. In the one study, Salikutluk and Heyne (2017) investigated how classmates' gender norms impact on students' math achievement. They found that girls performed worse in classes where traditional gender norms were strongly present, whereas girls' and boys' math achievement did not differ in classes where traditional gender norms were low or absent. In the other study, Muntoni et al. (2021) examined the relations between reading-related gender stereotypes and reading self-concepts. As already stated in the Introduction, they found that boys developed lower reading self-concepts, the more their classmates believed in the stereotype favoring girls in reading, whereas classmates' beliefs in this stereotype did not affect girls' reading self-concepts. Similar findings also emerged for students' reading self-efficacy, reading motivation, and reading achievement.

Taken together, the results of both studies suggest that high subject-specific gender stereotypes shared within the classroom might negatively impact on the stereotyped group. However, it should be noted that the gender norms examined by Salikutluk and Heyne (2017) did not refer to school subjects, but particularly addressed the question of whether men should use violence to defend their families. Thus, it is unclear whether Salikutluk and Heyne's findings would be replicated if gender norms (or gender stereotypes) referred to math. In particular, it is worth noting that students' individual gender norms in Salikutluk and Heyne's study were negatively related to math achievement not only for girls but also for boys—presumably because a strong belief that men should use violence might go along with more antisocial behavior at school and thus with lower math achievement for boys. Moreover, it is questionable to what extent the effects of gender norms on students' math achievement correspond to those on their math self-concept, given that the gender gap in math self-concept is significantly stronger than in math achievement (e.g., Niepel et al., 2020).

In contrast to Salikutluk and Heyne (2017), Muntoni et al. (2021) investigated the impact of classmates' subject-specific gender stereotypes on students' self-concepts more specifically. Notwithstanding this, it cannot be taken for granted that their results would generalize to the math domain. This is especially true because the stereotyped gender groups in the domains of reading and math differ from each other. For example, an important difference between stereotypes relating to boys' reading competence versus girls' math competence is that boys, in fact, perform worse in reading, whereas the gender difference in students' math performance is at least very small [e.g., Organisation for Economic Co-operation and Development (OECD), 2020]. Thus, one could speculate that classmates' subject-specific gender stereotypes affect boys' reading self-concepts more strongly than girls' math self-concepts because the stereotype favoring girls in reading is objectively more tenable. Aside from that, it is worth mentioning that the contextual effect on boys' reading self-concepts found by Muntoni et al. (2021) strongly resulted from an absence of the effect of boys' individual reading-related gender stereotypes on their reading self-concepts. However, concerning the math domain, such a finding would contradict the various findings on the impact of students' individual beliefs in the stereotype favoring boys in math on their math self-concepts (e.g., Passolunghi et al., 2014). This also makes it necessary to investigate whether Muntoni et al.'s (2021) findings can be generalized to the domain of math.

To summarize, it seems likely that classmates' math-related gender stereotypes affect students' math self-concepts beyond their individual gender stereotypes. Nevertheless, this is an empirical question, which has not yet been addressed in any study. The present study aims to close this research gap.

THE PRESENT RESEARCH

This research is the first to investigate the relations between students' and their classmates' math-related gender stereotypes and students' math self-concepts. Its main purpose is to examine the influence of classmates' gender stereotypes on students' self-concepts. Thus, for the first time, it aims to test whether Muntoni et al.'s (2021) much-noticed findings concerning the relations between classmates' reading-related gender stereotypes and students' reading self-concepts would generalize to the domain of math. Moreover, this study seeks to dive further into the question as to what extent students' individual beliefs concerning math-related gender stereotypes affect their math self-concepts by examining these relations, separately for girls and boys, after controlling for the relations between gender stereotypes and self-concepts at the class level.

Based on the theoretical reflections and empirical findings presented in the previous sections, I assumed to find a negative relation between girls' individual beliefs in the gender stereotype favoring boys in math and their math self-concepts (*Hypothesis 1a*). On the contrary, I assumed to find a positive relation between boys' individual beliefs in this stereotype and their math self-concepts (*Hypothesis 1b*). Furthermore, I expected that girls' math self-concepts showed a negative relation to their classmates' beliefs in the gender stereotype favoring boys in math (*Hypothesis 2*), given that previous research suggests that high subject-specific gender stereotypes shared within the classroom might negatively impact on the stereotyped group (Salikutluk and Heyne, 2017; Muntoni et al., 2021). That is, I assumed that classmates' math-related gender stereotypes would show a negative relation to girls' math self-concepts, after controlling for students' individual differences in their math-related gender stereotypes. I left it as an open research question whether classmates' beliefs in the gender stereotype favoring boys in math would also relate to boys' math self-concepts. For example, whereas some studies have found that stereotypes questioning the ability of an outgroup can lead to performance boosts in the ingroup ("stereotype lift"; e.g., Walton and Cohen, 2003), other studies have found that they can decrease the performance in the ingroup ("choking under pressure"; e.g., Cheryan and Bodenhausen, 2000). Nevertheless, given that Muntoni et al. (2021) found no significant effect of classmates' beliefs in the stereotype favoring girls in reading on girls' reading self-concepts, I considered it as likely that boys' math self-concepts would not significantly relate to their classmates' beliefs in the stereotype favoring boys in math.

I tested my hypotheses in a large sample of secondary school students from Germany. To account for potential alternative explanations, I also tested the relations between students' math-related gender stereotypes and math self-concepts after controlling for students' math grades and age. I controlled for students' math grades, as students form their subject-specific self-concepts especially based on their grades. In particular, previous research has shown that students' math self-concepts show significantly stronger relations to their math grades than to their results from standardized math tests (e.g., Wolff et al., 2019b; Möller et al., 2020). I took into account students' age since students' math self-concepts usually decrease with increasing age (e.g., Wolff et al., 2020b; Orth et al., 2021). I expected to find support for all stated hypotheses even after controlling for the covariates.

MATERIALS AND METHODS

Sample

The sample consisted of N = 1,424 students (age: M = 15.1, SD = 2.01; 56.2% female, 42.6% male, 1.2% not specified) between Grade 7 and Grade 13. These students attended 90 classes of 11 secondary schools in the German federal state of Schleswig-Holstein. The number of classes per school ranged from 2 to 14 with an average of about 8 classes per school. The sample stemmed from a larger project with the major aim to examine comparison effects in the process of students' self-concept formation (Wolff et al., 2021). The schools were recruited by direct requests to individual school offices. Participating classes were selected by school administrators. In many cases, there was direct contact with specific teachers at the schools who offered to participate in the study, particularly with classes they taught themselves. The participation was voluntary and the informed consent of the parents was required if students were underage. A lack of informed parental consent was the main reason why students did not participate in the study. It mostly resulted from the fact that the students had not handed over the parent letter in advance of the study.

Procedure

The data collection took place in the spring of 2018. The students answered paper-and-pencil questionnaires during regular school lessons. The constructs were measured in the following order: math self-concept, math-related gender stereotype, math grade, and demographics (age and gender). Approval for the whole procedure was obtained by the local ministry of education.

Measures

Math Self-Concepts

Students' math self-concepts were measured using six items: (1) "With a number of things in math, I immediately know: I will never understand this," (2) "Although I try my best, math is hard for me," (3) "I simply have no natural aptitude in math," (4) "I would much rather do math if the subject were not so difficult," (5) "Math does not come naturally to me," (6) "It comes easily to me to understand tasks and solve problems in math." These items had already been used successfully in contemporary self-concept research (e.g., Wolff et al., 2019a). The students responded to all items on a 6-point Likert scale ranging from 1 = *strongly disagree* to 6 = *strongly agree*. The negatively phrased items were reverse coded in the way that higher scores indicated higher self-concepts. The reliability of the scale according to Geldhof et al. (2014) was high at the within-level (α = 0.92) and the between-level (α = 0.97). Moreover, invariance tests provided evidence for the invariance of the scale across gender groups (see **Table 1**).

TABLE 1 | Measurement invariance of math self-concept between gender groups.

Model	Equality constraints	χ^2	*df*	*p*	CFI	TLI	RMSEA
1	Baseline	179.54	18	<0.001	0.996	0.993	0.113
2	Thresholds	183.46	36	<0.001	0.996	0.997	0.076
3	Thresholds and loadings	161.19	41	<0.001	0.997	0.998	0.065

The table shows the pooled results over m = 50 imputed data sets. They stem from single-level analyses in MPlus in which the complex modeling procedure (type = complex) was used to correct the estimated standard errors for the nested data structure of students in classes. The self-concept items were treated as categorical indicators and measurement invariance was tested according to Svetina et al. (2020). In Model 1, the indicators were allocated to one factor, but the thresholds and loadings were estimated freely across the groups. In Model 2, the thresholds were constrained to be equal across the groups. In Model 3, the thresholds and loadings were constrained to be equal across the groups. Measurement invariance is supported since the model fit improves with increasing equality constraints. CFI, comparative fit index; TLI, Tucker-Lewis index; RMSEA, root mean square error of approximation. N = 1,424 (n = 800 girls, n = 607 boys, n = 17 not specified).

Gender Stereotypes

Students' beliefs in the stereotype endorsing that math would be a typically male subject were measured using three items: (1) "Boys are simply more gifted at math," (2) "If there was a typical boy subject, math would be one," (3) "Math is a subject that is usually more fun for boys." These items had been developed by Pohlmann (2005). The students responded to all items on a 6-point Likert scale ranging from 1 = *strongly disagree* to 6 = *strongly agree*. The reliability of the scale (Geldhof et al., 2014) was high at the within-level (α = 0.90) and the between-level (α = 0.99).

Grades

The students reported their math grades from their latest report cards. Previous research has shown that self-reports of grades in the German school system are sufficiently reliable (e.g., Dickhäuser and Plenter, 2005). All grades were coded according to the German 15-point grading system, which ranges from 0 = *insufficient* to 15 = *perfect*. This grading system is mainly used at the upper secondary level in Germany, which was also the case in the present study. When teachers assigned grades according to the 6-point grading system, ranging from 1 = *excellent* to 6 = *insufficient* (as the case in most of the lower classes in the sample of the present study), I converted these grades into the 15-point system, using the official transformation key, according to which grade 1 equals 14 points, grade 2 equals 11 points, grade 3 equals 8 points, grade 4 equals 5 points, grade 5 equals 2 points, and grade 6 equals 0 points. I preferred this transformation as it did not lead to any loss of information. Nevertheless, I note that the findings of this study fully replicated if transforming the grades from the 15-point system to the 6-point system instead (i.e., 13−15 points to grade 1, 10−12 points to grade 2, etc.).

Statistical Analyses

The statistical analyses were similar to Muntoni et al. (2021). I conducted multilevel analyses in MPlus 8.4 (Muthén and Muthén, 2017), with students (within-level) being clustered in classes (between-level). More specifically, I specified doubly latent multiple group two-level structural equation models to examine whether students' math self-concepts were affected by their individual math-related gender stereotypes and the average math-related gender stereotypes within their classes. In these models, students' gender stereotypes were estimated as latent variables at the within- and between-level, which allowed controlling for measurement and sampling errors (Marsh et al., 2009). Since group membership (i.e., gender) was included as a within-level grouping variable (because each class consisted of girls and boys), the between-level data were not independent between the within-level groups. To account for this dependency, I applied multilevel mixture models, in which a latent class variable indicating the group membership was specified (Asparouhov and Muthén, 2012). Thus, a latent class could be set up at the within-level and the group membership variable was specified as a perfect indicator of the latent class variable (Muntoni et al., 2021). To handle missing values (on average, 2.2% of the data were missing per variable), I applied multiple imputation, including m = 50 imputed data sets (Graham et al., 2007).

Overall, I calculated two models. In Model 1, I only took students' gender stereotypes (independent variable) and self-concepts (dependent variable) into consideration. In Model 2, I additionally controlled for students' math grades and age (control variables). In both models, I also included 10 dummy variables, indicating students' affiliation to 1 of 11 schools, which allowed me to take account of the three-level data structure. For testing Hypotheses 1a and 1b, I examined whether the effects of students' gender stereotypes on their math self-concepts at the within-level were significantly negative for girls and significantly positive for boys. For testing Hypothesis 2, I examined whether contextual effects of class-average gender stereotypes on students' math self-concepts occurred. To this end, I calculated additional parameters indicating whether the effects of gender stereotypes on self-concepts at the between- and within-level were significantly different from each other. This was necessary because the variables which appeared at both levels were implicitly group-mean centered. Accordingly, the effects of class-average gender stereotypes on math self-concepts at the between-level were no direct estimates of the contextual effects (Marsh et al., 2009). As suggested in Hypothesis 2, the contextual effects should be significantly negative for girls.

I calculated Tymms' (2004) Δ to facilitate the interpretation of the effect sizes. For this purpose, I used the formula $\Delta = (2 \times B \times SD_{predictor})/\sigma$, where B is the unstandardized regression coefficient, $SD_{predictor}$ is the standard deviation of the predictor variable (for the contextual effect: at the between-level), and σ is the total standard deviation of the outcome variable (Marsh et al., 2009). Tymms' Δ can be interpreted similar to

Cohen's (1988) *d*. Thus, $|\Delta|$ = 0.2 represents a small effect, $|\Delta|$ = 0.5 a moderate effect, and $|\Delta|$ = 0.8 a large effect.

RESULTS

Preliminary Analyses

Table 2 presents the descriptive statistics. In line with previous research, boys showed higher math self-concepts compared to girls (ΔM = 0.43, β = 0.16, $p < 0.001$), whereas boys' and girls' math grades did not significantly differ from each other (ΔM = −0.07, β = −0.01, p = 0.71). Boys also held a slightly stronger belief in the stereotype favoring boys in math (ΔM = 0.19, β = 0.08, p = 0.02). Moreover, boys' math-related gender stereotypes were positively related to their math self-concepts (r = 0.18, $p < 0.001$) and math grades (r = 0.12, $p < 0.01$), whereas girls' math-related gender stereotypes were negatively related to their math self-concepts (r = −0.26, $p < 0.001$) and math grades (r = −0.21, $p < 0.001$). For both genders, older students showed lower math grades (both r = −0.14, $p < 0.01$). In addition, older girls showed slightly stronger beliefs in the stereotype favoring boys in math compared to younger girls (r = 0.13, $p < 0.01$) and older boys showed slightly lower math self-concepts compared to younger boys (r = −0.15, $p < 0.01$). The correlations between students' math self-concepts and math grades were strongly positive for girls (r = 0.61, $p < 0.001$) and boys (r = 0.58, $p < 0.001$). The intraclass correlation coefficients (ICCs), indicating the proportion of total variance that was accounted for by between-class variance, were 0.05 or higher for all four variables. In particular, the ICC of 0.11 found for students' beliefs in the stereotype favoring boys in math is noteworthy, as it indicated that students of the same class showed a substantial agreement in their belief in this stereotype. Furthermore, this value suggested that it was appropriate to examine the relations between students' math-related gender stereotypes and their math self-concepts using multilevel analyses.

Hypotheses Testing

Table 3 presents the results of the multilevel analyses. Model 1 tested the effects of students' math-related gender stereotypes on their math self-concepts without considering control variables. As predicted in Hypothesis 1, girls' individual math-related gender stereotypes showed a negative effect on their math self-concepts (B = −0.26, $p < 0.001$, Δ = −0.43), whereas this effect was positive for boys (B = 0.21, $p < 0.001$, Δ = 0.35). Moreover, as predicted in Hypothesis 2, there was a negative contextual effect on girls' math self-concepts (B = −0.38, $p \leq 0.05$, Δ = −0.23), implying that classmates' math-related gender stereotypes were negatively related to girls' math self-concepts, after controlling for individual differences in gender stereotypes. The contextual effect on boys' math self-concepts was non-significant (B = 0.07, p = 0.78). Model 2 demonstrated that these relations also persisted after controlling for students' math grades and age. Whereas the negative effect of girls' individual math-related gender stereotypes on their math self-concepts (B = −0.15, $p < 0.001$, Δ = −0.24)

TABLE 2 | Means, standard deviations, bivariate correlations, and intraclass correlations [with 95% confidence intervals] of the manifest variables.

Variables	M_{girls}	M_{boys}	SD_{girls}	SD_{boys}	$r_{math\ self-concept}$	$r_{gender\ stereotype}$	$r_{math\ grade}$	r_{age}	ICC
Math self-concept	**3.85 [3.72, 3.97]**	**4.27 [4.14, 4.40]**	**1.38 [1.33, 1.43]**	**1.28 [1.21, 1.34]**	–	**0.18 [0.10, 0.27]**	**0.58 [0.52, 0.64]**	**−0.15 [−0.24, −0.06]**	**0.05 [0.02, 0.08]**
Gender stereotype	**2.73 [2.58, 2.87]**	**2.92 [2.78, 3.06]**	**1.25 [1.20, 1.31]**	**1.27 [1.21, 1.33]**	**−0.26 [−0.34, −0.19]**	–	**0.12 [0.04, 0.21]**	0.08 [−0.02,0.18]	**0.11 [0.07, 0.14]**
Math grade	**8.43 [8.12, 8.74]**	**8.36 [8.05, 8.67]**	**3.03 [2.87, 3.18]**	**3.10 [2.87, 3.30]**	**0.61 [0.56, 0.66]**	**−0.21 [−0.29, −0.13]**	–	**−0.14 [−0.23, −0.05]**	**0.09 [0.05, 0.12]**
Age	**15.21 [14.76, 15.66]**	**14.95 [14.52, 15.37]**	**2.05 [1.80, 2.26]**	**1.94 [1.70, 2.15]**	−0.09 [−0.18, 0.01]	**0.13 [0.04, 0.23]**	**−0.14 [−0.23, −0.05]**	–	**0.90 [0.87, 0.92]**

The table shows the pooled results over m = 50 imputed data sets. The means, standard deviations, and bivariate correlations stem from a single-level analysis in MPlus in which the complex modeling procedure (type = complex) was used to correct the estimated standard errors for the nested data structure of students in classes. The correlations below the diagonal refer to the subsample of girls. The correlations above the diagonal refer to the subsample of boys. The intraclass correlation coefficients (ICCs) indicate the proportion of total variance that is accounted for by between-class variance. They stem from additional multilevel analyses. Math self-concept and gender stereotype had a possible range of 1 = strongly disagree to 6 = strongly agree. Math grade had a possible range of 0 = insufficient to 15 = perfect. Bold values are significantly different from zero ($p < 0.05$). N = 1,424 (n = 800 girls, n = 607 boys, n = 17 not specified).

TABLE 3 | Unstandardized regression coefficients, standard deviations, and Tymms' Δ [with 95% confidence intervals] of the multilevel analyses predicting students' math self-concept.

	Model 1						**Model 2**					
	Girls			**Boys**			**Girls**			**Boys**		
Variables	***B***	***SD***	**Δ**	***B***	***SD***	**Δ**	***B***	***SD***	**Δ**	***B***	***SD***	**Δ**
Within-level												
Gender stereotype	**−0.26 [−0.35, −0.16]**	**1.13 [1.06, 1.19]**	**−0.43 [−0.59, −0.27]**	**0.21 [0.11, 0.30]**	**1.13 [1.06, 1.19]**	**0.35 [0.19, 0.51]**	**−0.15 [−0.22, −0.07]**	**1.13 [1.06, 1.19]**	**−0.24 [−0.37, −0.11]**	**0.13 [0.06, 0.21]**	**1.13 [1.06, 1.19]**	**0.24 [0.10, 0.37]**
Math grade	–	–	–	–	–	–	**0.28 [0.25, 0.31]**	**2.93 [2.79, 3.06]**	**1.19 [1.07, 1.31]**	**0.24 [0.21, 0.27]**	**2.93 [2.79, 3.06]**	**1.12 [0.98, 1.26]**
Age	–	–	–	–	–	–	0.09 [−0.01, 0.19]	**0.65 [0.56, 0.73]**	0.09 [−0.01, 0.18]	−0.06 [−0.19, 0.08]	**0.65 [0.56, 0.73]**	−0.06 [−0.19, 0.08]
Between-level												
Gender stereotype	**−0.63 [−0.99, −0.28]**	**0.40 [0.33, 0.47]**	**−0.38 [−0.59, −0.17]**	0.28 [−0.22, 0.79]	**0.40 [0.33, 0.47]**	0.17 [−0.14, 0.48]	**−0.58 [−0.95, −0.21]**	**0.40 [0.33, 0.46]**	**−0.34 [−0.56, −0.13]**	−0.03 [−0.52, 0.46]	**0.40 [0.33, 0.46]**	−0.02 [−0.33, 0.29]
Math grade	–	–	–	–	–	–	0.08 [−0.06, 0.22]	**0.90 [0.67, 1.08]**	0.11 [−0.08, 0.29]	−0.04 [−0.27, 0.19]	**0.90 [0.67, 1.08]**	−0.06 [−0.39, 0.27]
Age	–	–	–	–	–	–	−0.05 [−0.10, 0.01]	**1.91 [1.70, 2.10]**	−0.13 [−0.29, 0.03]	−0.07 [−0.16, 0.03]	**1.91 [1.70, 2.10]**	−0.20 [−0.48, 0.08]
Contextual effect												
Gender stereotype	**−0.38 [−0.76, −0.00]**	**0.40 [0.33, 0.47]**	**−0.23 [−0.46, −0.00]**	0.07 [−0.44, 0.59]	**0.40 [0.33, 0.47]**	0.05 [−0.27, 0.36]	**−0.44 [−0.82, −0.05]**	**0.40 [0.33, 0.46]**	**−0.26 [−0.48, −0.03]**	−0.16 [−0.67, 0.34]	**0.40 [0.33, 0.46]**	−0.10 [−0.42, 0.22]

The table shows the pooled results over m = 50 imputed data sets. Tymms' (2004) Δ was calculated using the formula $\Delta = (2 \times B \times SD_{predictor})/\sigma$*, where B is the unstandardized regression coefficient,* $SD_{predictor}$ *is the standard deviation of the predictor variable (for the contextual effect: at the between-level), and σ is the total standard deviation of math self-concept (Model 1: σ = 1.35 for girls, σ = 1.32 for boys; Model 2: σ = 1.37 for girls, σ = 1.27 for boys). Both models also included 10 dummy variables at the between-level, indicating students' affiliation to 1 of 11 schools (not depicted). Bold values are significantly different from zero (p < 0.05). N = 1,424 (n = 800 girls, n = 607 boys, n = 17 not specified).*

and the positive effect of boys' individual math-related gender stereotypes on their math self-concepts ($B = 0.13$, $p < 0.001$, $\Delta = 0.24$) were slightly reduced, the negative contextual effect on girls' math self-concepts was even slightly stronger ($B = -0.44$, $p = 0.03$, $\Delta = -0.26$). The contextual effect on boys' math self-concepts was still non-significant ($B = -0.16$, $p = 0.53$). Students' individual math grades showed strong positive effects on their math self-concepts (girls: $B = 0.28$, $p < 0.001$, $\Delta = 1.19$; boys: $B = 0.24$, $p < 0.001$, $\Delta = 1.12$). The effects of math grades at the between-level and of age at both levels were non-significant (all $|B| \leq 0.09, p \geq 0.07$).

DISCUSSION

The present research substantially extends our knowledge of the relations between subject-specific gender stereotypes and self-concepts. For the first time, I investigated how students' individual and their classmates' math-related gender stereotypes affect girls' and boys' math self-concepts. In line with my hypotheses, and with findings from previous research (e.g., Nosek et al., 2002; Steffens and Jelenec, 2011; Passolunghi et al., 2014), I found that girls showed lower math self-concepts, the more they believed in the stereotype favoring boys in math, whereas boys showed higher math self-concepts, the more they believed in this stereotype. Furthermore, and most central for this research, I found a negative contextual effect of classmates' beliefs in the stereotype favoring boys in math on girls' math self-concepts. Thus, girls attending classes in which students strongly believed in the stereotype that math would be a typically male domain showed lower math self-concepts than girls attending classes in which the students did not believe in this stereotype, after controlling for individual gender stereotypes. The contextual effect of classmates' beliefs in the stereotype favoring boys in math on boys' math self-concepts was close to zero and indicated that classmates' shared beliefs in this stereotype do not significantly affect boys' math self-concepts.

Theoretical Implications

The findings of this research have important theoretical implications as they further support the role of classmates as significant socializing peers. Specifically, it was shown that girls' math self-concepts were lower the more their classmates believed in the stereotype favoring boys in math. In contrast, boys' math self-concepts were not related to the gender stereotypes shared in students' classrooms. Remarkably, both the significant contextual effect on girls' math self-concepts and the non-significant contextual effect on boys' math self-concepts found in the present research were in accord with the results of Muntoni et al. (2021), who found a negative contextual effect of shared reading-related gender stereotypes, endorsing that reading would be a typically female domain, on boys' reading self-concepts, but not on girls' reading self-concepts. Taken together the results of both studies, it seems that gender stereotypes shared in the classroom negatively affect the self-concepts of students of the stereotyped gender group, whereas they do not affect the self-concepts of students of the non-stereotyped gender group.

Muntoni et al. (2021) had already speculated, when they compared the effects of gender stereotypes between the domains of math and reading, "that the underlying processes are rather similar" (p. 190). Nevertheless, an empirical test of this assumption seemed indicated, especially because math-related gender stereotypes are even less tenable than reading-related gender stereotypes, according to differences in girls' and boys' performance in standardized math and reading tests: Whereas girls, in fact, do not perform significantly worse in math than boys (which also corresponds to the similar math grades found for girls and boys in the present study), they still outperform boys in reading [e.g., Organisation for Economic Co-operation and Development (OECD), 2020]. It would, therefore, also have been plausible if girls' math self-concepts had not been related to shared math-related gender stereotypes in the present study, although Muntoni et al. (2021) found a negative effect of shared reading-related gender stereotypes on boys' reading self-concepts.

However, the findings of the present study suggest that the impact of math-related gender stereotypes on girls' math self-concepts may be even stronger than the impact of reading-related gender stereotypes on boys' reading self-concepts. This is due to the fact that the contextual effect on girls' math self-concepts occurred beyond the negative effect of girls' individual math-related gender stereotypes on their math self-concepts, whereas the contextual effect on boys' reading self-concepts in Muntoni et al.'s (2021) study, which was similarly strong as the contextual effect on girls' math self-concepts in the present study, occurred along with a non-significant effect of boys' individual reading-related gender stereotypes on their reading self-concepts. More precisely, Muntoni et al. (2021) examined two models. In the first model, they only controlled for demographics. In this model, they found positive effects of girls' individual reading-related gender stereotypes on their reading self-concepts and negative effects of boys' individual reading-related gender stereotypes on their reading self-concepts, but no contextual effects. The contextual effect on boys' reading self-concepts was only shown in the second model, in which the authors additionally controlled for prior reading self-concepts. Yet, in this model, the effects of gender stereotypes at the within-level were non-significant. The fact that the present research revealed simultaneous effects of students' individual and shared gender stereotypes on their self-concepts constitutes an important difference to Muntoni et al.'s (2021) results. Although the results of both studies suggest that shared gender stereotypes have specific effects on the self-concepts of the stereotyped group, it seems that there are also some differences in the mechanisms of how gender stereotypes affect students' self-concepts in the domains of math and reading.

Practical Implications

The findings of this research are of high practical importance as they illustrate, more differentiated than in previous research, how girls' math self-concepts are impaired by math-related gender stereotypes. On the one hand, it was demonstrated that girls show lower math self-concepts, the more they believe in the stereotype favoring boys in math. This finding was

already known from prior studies (e.g., Passolunghi et al., 2014). However, in the present study, it was shown for the first time that these relations also hold in multilevel analyses. On the other hand, the present research revealed that math-related gender stereotypes shared in the classroom negatively relate to girls' math self-concepts, after controlling for girls' individual math-related gender stereotypes. To the best of my knowledge, this finding has not been shown in any prior empirical study yet. To conclude, the math-related gender stereotype endorsing that math would be a typically male domain is not only incompatible with empirical findings that showed no substantial differences in girls' and boys' math performance [e.g., Organisation for Economic Co-operation and Development (OECD), 2020]. It also seems to be disadvantageous for girls in two ways. Teachers are, therefore, advised to avoid the emergence of gender stereotypes and to remove existing stereotypes whenever possible. In particular, this applies if gender stereotypes manifest themselves in the classroom and thus affect students' self-concepts (see, e.g., Frawley, 2005, for interventional strategies).

It is worth noting that the effects of students' individual and shared math-related gender stereotypes found in the present study were only small—similarly to the effects of students' individual and shared reading-related gender stereotypes found by Muntoni et al. (2021). Nevertheless, it seems likely that these effects will have a substantial impact over time and could even become a self-fulfilling prophecy. Several studies have demonstrated that students' academic self-concepts are not only formed based on their prior achievements but also affect their subsequent achievements to a substantial degree (e.g., Marsh and Craven, 2006; Wolff et al., 2020b). If girls' math self-concepts suffer from math-related stereotypes, this can consequently impair their future math performance. In particular, girls might then be prone to believe that they indeed perform worse in math than boys, with the result that their math self-concepts and achievements could further worsen—and that they might decide against a career in math, science, technology, or engineering, even though they have the potential to succeed in these disciplines.

Strengths, Limitations, and Directions for Future Research

The present research has some limitations that should be discussed in greater depth. A first limitation is its cross-sectional design. Accordingly, the findings of this study allow us to make conclusions about how students' math-related gender stereotypes are related to their math self-concepts measured at a certain point in time, but not to changes in these self-concepts across time. Future research should, therefore, aim to examine how individual and shared math-related gender stereotypes relate to changes in students' self-concepts. In particular, it would seem worthwhile to conduct such investigations during phases of school transitions, which have shown to come along with significant changes in students' self-concepts (e.g., Wigfield et al., 1991; Wolff et al., 2020c), given that these changes might also result from changes in gender stereotypes shared within the classroom. Moreover, it would be advisable for future research to measure students' gender stereotypes (and other covariates) some time before the self-concepts as such a design would be more suitable to allow an approximation to causal conclusions than the simultaneous assessment of these constructs.

A second limitation of the present study can be seen in the fact that the classes were selected by the school administrators, rather than chosen randomly. Accordingly, the examined sample was not representative. However, this limitation seemed acceptable since the aim of this research was not to examine gender stereotypes and self-concepts in a representative student sample, but the relations between these constructs at the individual and class level. For this purpose, the analyzed data seemed quite suitable as they showed several favorable characteristics. For example, the internal consistencies of the self-concept scale and the scale assessing students' gender stereotypes were very high, the ICC of students' gender stereotypes was also high, and the number of missing values was very low. Beyond that, the data were collected in the year 2018, specifically for the present study. Given that gender stereotypes have changed across the decades (e.g., Eagly et al., 2020), this up-to-datedness of the analyzed data can be seen as a strength of this study.

A third limitation of the present research is its restriction to the investigation of the relations between students' subject-specific gender stereotypes and self-concepts in the domain of math. For this reason, it was not possible to test whether Muntoni et al.'s (2021) findings, which referred to these relations in the domain of reading, would have replicated within the present sample. Moreover, it was not possible to examine the interplay between gender stereotypes and self-concepts in different subjects. For example, numerous studies examining the relations between students' math and verbal achievements and self-concepts have demonstrated that students' achievement in one domain negatively affects their self-concept in the other domain, after controlling for achievement in the other domain (Möller et al., 2020). It would be conceivable that similar results also emerged for the relations between math and verbal gender stereotypes and self-concepts. Hence, future research should investigate the relations between math- and reading-related gender stereotypes and self-concepts within the same sample.

Finally, a limitation of the present research involves the fact that students' stereotypes were only measured through self-reports. It is conceivable that students' implicit gender stereotypes (shared in the classroom) affect their self-concepts beyond what is explicitly expressed. This seems particularly plausible considering that previous studies have found some gender-specific differences in the existence of explicit and implicit gender stereotypes, although the results were somewhat inconsistent (e.g., Steffens and Jelenec, 2011; vs. Passolunghi et al., 2014; see also Nosek et al., 2002). Researchers should thus feel encouraged to measure students' subject-specific gender stereotypes using both explicit and implicit measures in future research. Furthermore, it would seem worthwhile to supplement explicit self-concept measures with implicit measures of subject-specific self-concepts (e.g., Wolff et al., 2020a), given that gender stereotypes, especially if measured implicitly, might affect students' self-concepts especially at an unconscious level.

CONCLUSION

The present research provided new significant insights into the interaction of gender and gender stereotypes in the formation of students' academic self-concepts. For the first time, it was shown that not only students' individual math-related gender stereotypes but also the math-related gender stereotypes shared in their classrooms affect students' math self-concepts. By analogy with Muntoni et al. (2021), who found a negative contextual effect of classmates' shared reading-related gender stereotypes on boys' reading self-concepts, this research revealed a negative contextual effect of classmates' shared math-related gender stereotypes on girls' math self-concepts. Taken together, it seems that stereotyped gender groups suffer from both individual and shared gender stereotypes. Given this, it is to be hoped that gender stereotypes favoring girls or boys in a certain domain will continue to decrease in the future.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the Local Legislation and Institutional Requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

FW designed the study, prepared the research materials, organized the data collection, conducted the analyses, and wrote the manuscript.

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Mindsets and Self-Concepts About Self-Regulated Learning: Their Relationships With Emotions, Strategy Knowledge, and Academic Achievement

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Being a self-regulated learner and believing that deliberate strategy use might be an effective way of overcoming learning challenges is important for achieving academic success. Learners' self-theories about their abilities might explain why some students are more inclined to engage in self-regulated learning (SRL) than others. This study aims to investigate the relationships between students' mindsets and self-concepts about SRL and their correlation with enjoyment, boredom, strategy knowledge, and academic achievements. As covariates, we included gender, age, and academic track. We surveyed 244 students (46.3% female) from the lower secondary school level with a mean age of 14.57 years. The results revealed that mindsets about SRL support more adaptive learning emotions (i.e., higher enjoyment and lower boredom) and positively relate to students' strategy knowledge. The students' self-concepts about SRL are positively related to their enjoyment and academic achievements. Gender-specific differences between the students revealed a disadvantage for the boys, who had lower self-concepts about SRL, lower strategy knowledge, and lower academic achievements in comparison to the girls. Furthermore, the study also revealed that students in the lower academic track adhered more to a fixed mindset about SRL and had lower strategy knowledge than their peers in the higher academic track. Finally, we found an indirect relationship between mindset about SRL and academic achievement via self-concepts about SRL. Overall, our results emphasize the importance of students' mindsets and self-concepts about SRL for their learning and academic achievements.

Keywords: implicit theories, mindsets, self-concept, self-regulated learning, strategy knowledge, metacognition, emotion

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INTRODUCTION

Self-regulated learners are agents of their learning. They know when and how to use strategies effectively to overcome challenges, they are reflective, motivated, and strategic, and they believe that abilities in self-regulated learning (SRL) will help them succeed in school and beyond (Pressley et al., 1987). However, some students do not believe that strategies are necessary for learning or

that they might be an effective way of overcoming learning challenges. Instead, they believe that if a person has high abilities, one does not need deliberate strategies to master obstacles (Hertel and Karlen, 2020). Students might also believe that they do not have sufficient abilities in SRL and therefore do not apply strategies. Learners' self-theories about their abilities play an essential role in the context of academic learning and can explain different patterns of emotions, motivation, strategy use, persistence in SRL, response to challenges and setbacks, and academic achievement (Dweck and Leggett, 1988; Efklides, 2011; Karlen et al., 2019; Lawson et al., 2019). Vosniadou et al. (2020) argued that it might be beneficial to examine beliefs not as isolated units but as connected to other beliefs and to other cognitive and emotional structures. Therefore, forming a belief system, which is critical for learners perception, and interpretation of the learning context and prediction of their learning behavior (for an overview of beliefs about SRL see Lawson et al., 2019). Two core self-theories about abilities are learners' implicit theories about the nature of abilities (mindsets) as trait-like (fixed mindset) or malleable (growth mindset) and their self-theories about the level of one's abilities, also called self-concept (Dweck and Leggett, 1988; Bong and Skaalvik, 2003). These beliefs represent independent but related components of individuals' self-related implicit beliefs that are related to various motivational and cognitive effects such as better emotional, motivational, and metacognitive self-regulation or adaptive management of challenges (Ommundsen et al., 2005; Pekrun, 2006; King et al., 2012; Van der Beek et al., 2017; Yeager and Dweck, 2020).

Individuals can hold different mindsets and self-concepts about different abilities (Gunderson et al., 2017). The literature that focuses on mindsets and self-concepts about SRL is still scarce and requires further examination (Chen et al., 2020; Hertel and Karlen, 2020). Our study builds upon existing empirical work that links motivational and affective aspects of learning to SRL and students' academic achievement (Burnette et al., 2013). Focusing on mindsets and self-concepts about SRL may offer a key to understanding how much learners are inclined to engage in SRL and, in turn, develop their SRL competencies (Efklides, 2011; Vosniadou et al., 2020). So far, little is known about self-theories about SRL and their possible relationship to enjoyment or boredom in learning. This study focuses on boredom and enjoyment, as researchers showed that these emotions are of particular relevance for students' learning and academic achievement (Camacho-Morles et al., 2021). Hence, this paper aims to examine the role of students' mindsets and self-concepts about SRL concerning their enjoyment and boredom about learning, strategy knowledge, and academic achievement.

MINDSETS AND SELF-CONCEPTS ABOUT SELF-REGULATED LEARNING

Individuals can hold different self-theories about their abilities, which create a system of meaning that affects how individuals approach academic situations, how they perceive their knowledge and abilities, how they self-regulate their learning, and how they interpret and respond to challenges within such situations (Bong and Skaalvik, 2003; Efklides, 2011; Lawson et al., 2019; Yeager and Dweck, 2020). By following Carol Dweck's social cognitive theory (Dweck and Leggett, 1988), we focus on students' implicit theories (mindsets) about the nature of their abilities as trait-like (fixed mindsets) or malleable (growth mindsets). Students who adhere to a fixed mindset believe that their abilities are relatively pre-determined, like a fixed talent that is incapable of developing. Accordingly, they are more likely to demonstrate maladaptive learning behaviors such as withdrawing when challenges arise, engaging in procrastination, and avoiding expending effort and negative evaluations of their abilities since these could indicate that they possess low levels of talent (Burnette et al., 2013; Haimovitz and Dweck, 2017). In contrast, students who adhere to a growth mindset tend to perceive learning situations as opportunities to grow and expand their competencies. Thus, mindsets are associated with individual differences in academic achievements. However, two meta-analyses recently revealed small effect sizes between implicit theories of intelligence and academic achievement (Costa and Faria, 2018; Sisk et al., 2018). Mindsets may indirectly affect academic achievement since they foster more adaptive learning behaviors (Burnette et al., 2013; Karlen et al., 2019). By transferring implicit theories of intelligence to an SRL context, students who adhere to a growth mindset about SRL assume that competencies in SRL can be learned and improved through practice, effort, and training. In contrast, students who adhere to a fixed theory about SRL suppose that SRL competencies are relatively stable over time and are related to a given talent (Hertel and Karlen, 2020). Mindsets about SRL are relevant since learning and engaging in SRL can be a strenuous process that requires perseverance and an adaptive way of dealing with challenges. Moreover, having a strategic repertoire is not a guarantee that one will select and use those strategies wisely. Thus, a highly developed repertoire might not always support learning as it is expected to Carr and Taasoobshirazi (2017) and Parkinson and Dinsmore (2018). It is more important to believe that with practice and experience, strategies will become more effective. SRL requires not only a broad strategy repertoire and knowledge about those strategies but also self-confidence and the belief that with practice, time, and effort, SRL will increase academic achievement (Efklides, 2011). In this respect, mindsets are significant for students who wish to gain competencies in SRL and are also addressed in SRL training sessions and interventions (Chen et al., 2020; Hertel and Karlen, 2020).

Self-concept beliefs are relatively stable, multidimensional, and hierarchical cognitive representations of one's perceived level of academic abilities in general and in different academic domains (Bong and Skaalvik, 2003). These mental representations of individuals' abilities include self-descriptions and self-evaluations (Brunner et al., 2010). One's self-concept is formed through past experiences and comparisons and is continually reinforced by evaluative inferences (Möller et al., 2020). Self-concepts about various domains positively associate with persistence, positive emotions about learning, effort, strategy use, and academic achievements in those domains, as well as long-term educational attainments (Gogol et al., 2017;

Möller et al., 2020). However, people differ from each other in terms of their self-concepts. They can have different self-concept levels in different domains (Brunner et al., 2010). Learners also might differ from each other in terms of their self-concepts about SRL. In contrast to individuals with low self-concepts about SRL, individuals with high self-concepts about SRL are convinced that they are good at SRL and can achieve their desired learning goals through strategic learning.

Mindsets and self-concepts typically demonstrate weak correlations (Ommundsen et al., 2005; Cury et al., 2006; Kornilova et al., 2009). They are largely independent of each other since individuals who adhere to fixed or growth mindset can have high or low self-concepts in a specific domain. We know from various studies that mindsets and self-concepts make independent contributions that explain adaptive and maladaptive behaviors, even after controlling for each other (Ommundsen et al., 2005). For self-concepts, slightly stronger relationships have been found between students learning behaviors and various emotional, motivational, and cognitive outcomes than between implicit theories and these same factors (Ommundsen et al., 2005; Kornilova et al., 2009; Priess-Groben and Hyde, 2017). However, Dweck and Leggett (1988) suggested in their theoretical model that mindsets take on a protective function for students' self-concepts. Students who adhere to a growth mindset might see mistakes as feedback regarding skills that are not yet sufficiently available but can be developed. Thus, failures will likely not damage their self-concepts as much as they would for students who adhere to a fixed mindset. For example, Robins and Pals (2002) reported that students who adhere to a fixed mindset experience a decline in self-esteem (a self-concept-related construct) during college, whereas students who adhere to a growth mindset increase their self-esteem.

MINDSETS, SELF-CONCEPTS, AND EMOTIONS IN SELF-REGULATED LEARNING

Achievement emotions are linked to achievement-related activities and outcomes and comprise subjective feelings and psychological, cognitive, expressive, and motivational components (Pekrun, 2006). Based on Pekrun's (2006) control-value theory and Eflikdes' (2011) "metacognitive and affective model of self-regulated learning," mindsets and self-concepts function as motivational resources that are essential antecedents for emotions in academic learning and guide SRL processes (Gogol et al., 2017; Van der Beek et al., 2017; Bakadorova et al., 2020). Mindsets and self-concepts refer to a control-related appraisal component, which influences the regulation of emotions (Pekrun, 2006; Efklides, 2011). Accordingly, the perception that one controls the learning process and its outcomes should promote enjoyment and reduces boredom while learning (Pekrun and Stephens, 2010). Students who adhere to growth mindsets see success as controllable and, thus, would rather perceive enjoyment. In contrast, the lack of control that students who adhere to a fixed mindset might experience in challenging situations is associated with the experience of anxiety or boredom while learning (King et al., 2012; Lou and Noels, 2020). In their meta-analysis, Burnette et al. (2013) found a negative link between a growth mindset about intelligence and negative emotions, which means that students with a growth mindset experience fewer negative emotions about learning. From a theoretical and empirical perspective, one can expect to see a similar correlational pattern between self-concepts and achievement emotions. Students should enjoy learning when they judge themselves as being competent enough to master a learning task. In contrast, boredom should result when perceived competence and control are low. Empirical findings support those theoretical assumptions and showed that students who feel competent in a domain perceive a higher level of control over learning and achievement activities, which leads to higher enjoyment and less boredom (Pekrun and Stephens, 2010; Van der Beek et al., 2017).

MINDSETS, SELF-CONCEPTS, EMOTIONS, AND THEIR RELATIONSHIP TO STRATEGY KNOWLEDGE

Successful self-regulated learners are characterized by broad strategy repertoires, a high level of strategy knowledge, joy of learning, and motivation that supports in-depth and persistent SRL (Pressley et al., 1987; Pekrun et al., 2002). Besides motivation and beliefs that support the use of strategies, learners particularly need metacognitive knowledge to process achievement tasks and situations in a goal-oriented manner (Karlen et al., 2014; Ben-Eliyahu and Linnenbrink-Garcia, 2015; Lawson et al., 2019). Metacognition has been broadly defined as knowledge about cognition and the regulation and monitoring of cognitive functions (Flavell et al., 2002; Pintrich, 2002). On the one hand, this conceptualization includes executive metacognitive skills that are related to planning, monitoring, and regulating one's activities. On the other hand, it refers to learners' knowledge about their information-processing skills, the nature of tasks, and strategies for coping with such tasks (Paris et al., 1983; Pressley et al., 1987). Strategy knowledge comprises declarative knowledge (i.e., knowing about the existence of strategies), procedural knowledge (i.e., knowing about how a strategy can be effectively used), and conditional knowledge (i.e., knowing when and why strategies are useful for completing a specific task) (Paris et al., 1983). Thus, strategy knowledge includes knowledge about the effectiveness of a strategy, the range of its appropriate applications, and how to use it to accomplish various tasks (Pressley et al., 1987). Researchers have linked strategy knowledge to the effective use of strategies and higher achievement in various domains (Händel et al., 2013; Maag Merki et al., 2013).

Efklides (2011) has included mindsets, self-concepts, and emotions at the personal level that set goal-directed top-down and bottom-up SRL processes and are closely linked to student's metacognition. The relationship between mindsets and SRL has predominantly been investigated using mindsets about intelligence. In comparison to those who adhere to a growth mindset about intelligence, students who adhere to a fixed theory of intelligence are more likely to fail to employ metacognitive

skills, which leads to higher levels of procrastination, worse time management, the decreased use of strategies, negative emotional regulation, and failure (Burnette et al., 2013; Yan et al., 2014). Initial research groups recently linked mindsets to SRL. Chen et al. (2020) found that mindsets about SRL, which they called "strategic mindsets," positively relate to the use of metacognitive strategies and academic achievement. Hertel and Karlen (2020) compared the predictive powers of mindsets about intelligence and mindsets about SRL regarding SRL. They found that mindsets about SRL more strongly relate to students' learning goals, self-reported strategy use, and strategy knowledge than mindsets about intelligence do.

So far, the specific link between students' self-concepts about SRL and their SRL has not been examined. Nevertheless, when focusing on students' academic self-concepts, researchers have found empirical evidence that supports a positive relationship between academic self-concepts and SRL. Bakadorova et al. (2020) found that high school students' academic self-concepts positively associate with emotional engagement (enjoyment of learning) and behavioral school engagement (i.e., involving a student's persistence in accomplishing tasks, attention during a lesson, or effort expended). In a study that was conducted with first graders, Roebers et al. (2012) reported that the students' domain-specific self-concepts were substantially associated with metacognitive monitoring. Finally, in a study that was conducted with kindergarteners, Compagnoni and Losenno (2020) found that their academic self-concepts positively related to their behavioral self-regulation.

Researchers have suggested that emotions can have a profound and long-term influence on students' metacognition because they favor engagement in SRL and the use of different strategies (Perry et al., 2001; Pekrun and Stephens, 2010). Several studies have demonstrated that while positive emotions such as enjoyment promote the use of in-depth strategies and students' engagement in metacognitive processes (i.e., the activation of strategy knowledge and self-evaluation), negative, deactivating emotions such as boredom promote maladaptive SRL (Pekrun et al., 2002; Ben-Eliyahu and Linnenbrink-Garcia, 2015; Chatzistamatiou et al., 2015). Regulating negative emotions (e.g., boredom) and supporting positive emotions (e.g., enjoyment) should thus facilitate successful SRL and support long-term engagement in SRL (Pekrun et al., 2002; Ben-Eliyahu and Linnenbrink-Garcia, 2015). Empirical research also indicates that emotions are a significant aspect of successful learning processes that lead to higher academic achievement (Camacho-Morles et al., 2021). For example, Perry et al. (2001) showed in their longitudinal study that students with higher academic control reported less course boredom, were more motivated, used more strategies, and obtained higher course grades. Researchers assume that SRL mediates the effects of emotions on academic achievement (Ben-Eliyahu and Linnenbrink-Garcia, 2015).

GENDER, AGE, AND ACADEMIC TRACK AS COVARIATES OF SELF-REGULATED LEARNING

When focusing on students' genders, researchers have observed null or mixed gender differences in domain-general mindsets about intelligence (Compagnoni et al., 2019; Warren et al., 2019). Hertel and Karlen (2020) found no correlation between gender and mindsets about the malleability of SRL in a sample of university students. However, they discovered that girls more strongly believe that SRL is relevant for academic success in universities (i.e., mindsets about the relevance of SRL). Concerning self-concepts, gender-specific differences depend mainly on a subject's social attributions (i.e., math self-concepts are higher for male students) and might vary from domain to domain (Lauermann et al., 2019). However, researchers have repeatedly demonstrated that girls have higher strategy knowledge than boys and are thus more successful in SRL (Händel et al., 2013; Maag Merki et al., 2013), which might also positively influence their self-concepts about SRL over long periods. Concerning students' emotions, existing evidence has demonstrated that boys report less enjoyment and more boredom about learning than girls do (Pekrun et al., 2017; King and dela Rosa, 2019). As they age and experience more extended schooling, older students are more likely to report less enjoyment about learning and higher boredom than younger students are (Perry et al., 2001). Students in certain countries (e.g., Germany or Switzerland) are assigned to different types of schools with different academic requirements at the lower secondary level. Thus, students finish compulsory school in different academic tracks. One can expect students in a track with lower academic requirements to ascribe more of a fixed mindset and to have lower strategy knowledge than students in a track within higher academic requirements (Händel et al., 2013; Warren et al., 2019).

AIMS AND HYPOTHESES OF THE PRESENT STUDY

Theoretical concepts highlight how students' mindsets and self-concepts affect their emotions, engagement, and development in learning in general and in specific in SRL (Dweck and Leggett, 1988; Efklides, 2011). However, the literature that focuses on mindsets and self-concepts about SRL is still scarce. We aim to provide new insight into how more domain- or content-specific mindsets and self-concepts about SRL are related to each other (Research question 1). We specifically aim to examine the relationship between students' mindsets and self-concepts about SRL with their enjoyment, boredom, and strategy knowledge (Research question 2). Finally, we investigate how mindsets and self-concepts about SRL influence students' academic achievements when taking students' emotions and strategy knowledge into account (Research question 3). Based on the literature review presented in the previous sections, we hypothesized that mindsets and self-concepts about SRL would demonstrate a small but positive correlation (Hypothesis 1). We expected to find that mindsets and self-concepts about SRL would positively relate to enjoyment (Hypotheses 2a), negatively relate to boredom (Hypotheses 2b), and positively relate to strategy knowledge (Hypotheses 2c). Furthermore, we expected enjoyment to positively relate to strategy knowledge (Hypotheses 2d) and boredom to negatively relate to strategy knowledge (Hypotheses 2e). Finally, we expected students' mindsets and self-concepts about SRL to enhance their

academic achievements because these facilitate students' strategy knowledge (Hypothesis 4).

METHODS

Participants

The participants were lower secondary school students ($N = 244$; 46.3% female) from 13 different classes from one school district situated in a rural area in the German-speaking part of Switzerland. School principals decided that every class should participate in this survey. Therefore, participation was mandatory for all the classes. However, the parents had to consent before the study was conducted, and students were allowed to withdraw from the online survey at any time. Out of 281 students forty-one decided not to participate in this study.

In Switzerland, lower secondary schools are usually divided into two or three different school types with different academic tracks (performance-based levels). In our school district, students are grouped into two different academic tracks based on their elementary school report cards. The highest track is for the most gifted children and prepares students for university entrance. The low-medium track includes two groups of students, preparing them either for vocational education and training or continuing education in upper secondary schools. Most of the students who participated (71.3%) attended the low-medium academic track (students mixed into one class), and 28.7% attended the highest academic track, which roughly corresponded to the distribution of students to academic tracks (school type) in Switzerland. Lower secondary school lasts 3 years (seventh [$n = 88$], eighth [$n = 83$], and ninth [$n = 73$] grade). Students were, on average, $M = 14.57$ years old ($SD = 0.94$). Most students (87.6%) reported that both parents or one parent were born in Switzerland, while a few (12.4%) reported that neither of their parents were born in Switzerland. A majority of the students (85.1%) reported speaking the instructional language at home (Swiss German or German), followed by Portuguese with 2.9%, English and other languages with each 2.5%, Albanian with 2.0%, and Serbian and Turkish with each 1.2%. Only a small number of students reported speaking French, Italian, or Spanish, with each 0.8%. A minimal amount of the students did not indicate any language (0.8%).

Measures

All students who participated in the study completed an online survey during class time. The average time to complete the questionnaire ($M = 26.37$ min., $SD = 6.68$; without instruction time was well within the allowed timeframe of one lesson (45 min). The questionnaire was written in German, as it is the official instructional language. Throughout the questionnaire, we used the term "self-organized learning" instead of the term "self-regulated learning" as students were more familiar with the first term. In Switzerland, the term self-organized learning has become more established in schools. It is a pedagogical term that includes our understanding of the scientific term SRL. Nevertheless, both terms are used synonymously. The descriptive statistics and internal reliabilities for each variable are presented in **Table 1**.

Mindsets About Self-Regulated Learning

We used a validated scale from Hertel and Karlen (2020) to assess the students' mindset about SRL. The scale included three items that incorporated a five-fold scale [sample item: "Everyone has a certain ability to self-organize their learning, and this… (1) cannot be changed to (5) can be changed"]. Higher values represented stronger endorsements of a growth mindset, meaning that higher values indicated that the students more strongly believed in the malleability of SRL.

Self-Concepts About Self-Regulated Learning

The students' self-concepts about SRL were assessed using a three-item scale (Karlen et al., 2020). The scale consists of three items (sample item: "I am good at self-organizing my learning"). Each item was scored on a six-point scale from 1 (*does not apply at all*) to six (*entirely true*). A higher score indicated a higher self-concept about SRL.

Enjoyment and Boredom About Learning

Enjoyment and boredom about learning were measured using the Achievement Emotions Questionnaire (AEQ), which was developed by Pekrun et al. (2011). As the number of items in the questionnaire was limited, we used fewer items than what the original instruments included. Four items were used to assess enjoyment (sample item: "I enjoy acquiring new knowledge"), and four items were used to assess boredom (sample item: "I find learning to be rather boring"). Answers were provided on a six-point scale from 1 (*does not apply at all*) to 6 (*entirely true*).

Strategy Knowledge

The students' strategy knowledge was assessed using a newly developed vignette test that outlines a fictitious learning situation in which students are asked to describe their intended approaches to processing a given task. The vignette test is based on similar procedures that have successfully and validly captured strategy knowledge using a vignette or scenario-based procedure (e.g., Händel et al., 2013; Maag Merki et al., 2013). With such tests, not the frequency of strategy use across different learning situations is measured, but students' knowledge about the use of strategies for completing a specific learning task (Schuster et al., 2020). Such vignette tests make it possible to test learners' spontaneous recall of strategies in a relatively short time. These tests have higher validity than, for example, questionnaires measuring the retention of strategies because they are contextualized and instead measure the qualitative use of strategies than the frequency of strategy use in general (Wirth and Leutner, 2008).

The vignette test includes a typical school learning situation, which requires the use of different learning strategies: "Imagine a class is about to complete a major exam. Therefore, the teacher gives the class a great deal of content to learn for the next 2 weeks. What could the students do to make sure that their learning for the exam goes well? Please describe all your tricks and pieces of advice for learning successfully." The students' descriptions, provided in an open-response format, were analyzed using a developed coding manual based on the categorization of strategies developed by Weinstein and Mayer (1986). Thus, the category system for coding the students'

TABLE 1 | Descriptive statistics, internal reliabilities, and correlations.

Variables	Cronbach's α	*n*	*M*	*SD*	Range	1	2	3	4	5	6	7	8	9
1. Mindsets about SRL	0.68	244	3.75	0.74	1.67–5.00	-	0.19**	0.26***	−0.19**	0.21**	0.14*	−0.07	−0.08	−0.15*
2. Self-concepts about SRL	0.87	244	4.30	1.05	1.00–6.00		-	0.26**	−0.21***	0.21**	0.32***	−0.21***	−0.12	−0.04
3. Enjoyment	0.90	243	3.37	1.09	1.00–6.00			-	−0.73***	0.31***	0.24***	−0.25***	−0.21***	−0.10
4. Boredom	0.79	244	3.24	1.03	1.25–6.00				-	−0.18*	−0.20**	0.26***	0.29***	0.15*
5. Strategy knowledge	-	225	3.47	2.07	0.00–10.00					-	0.31***	−0.43***	−0.16*	−0.28***
6. Academic achievement	-	244	4.58	0.44	3.55–5.60						-	−0.33***	−0.13	−0.13
7. Gender[a]	-	244	-	-	-							-	0.18**	0.15*
8. Age	-	244	14.57	0.94	12.83–17.00								-	0.27***
9. Academic track[b]	-	244	-	-	-									-

M, mean, SD, standard deviation.
[a]*Female = 1; male = 2.*
[b]*Higher academic track = 1; lower academic track = 2.*
*$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

described strategies contained three main categories: cognitive strategies, metacognitive strategies, and resource management strategies. These main categories were further refined by the differentiation developed by Wild and Schiefele (1994). A distinction was made among cognitive learning strategies between rehearsal, organization, and elaboration strategies. For metacognitive strategies, we differentiated between planning, monitoring, reflection, and regulation strategies. The resource management strategies were divided into internal (emotions, motivation, effort, attention, time management) and external (help-seeking, learning environment, peer learning) resource management strategies.

The students' answers were coded according to the strategies that they recalled (quantitative approach) and the specific instructions that they provided for the practical use of these strategies (qualitative approach). All of the named strategies had to include a reference to the learning situation. For example, if a cognitive strategy that was related to the learning situation was mentioned (e.g., "I suggest using a text-marking strategy"), the students received one point. Moreover, if they also provided a suggestion that was related to the strategy's quality of use, a further point was awarded (e.g., "I suggest the text-marking strategy: the students should first read the paragraph, ask a question, and then highlight the answer"). Students received zero points if they did not mention any strategy. All points across all categories were added together to calculate the total score. There was no point limit. The maximum points to be achieved varied depending on the number of strategies each student named.

Two independent coders with expertise in SRL double-coded a subsample of the students' answers ($N = 25$). This subsample corresponded to approximately 10% of the total sample. Subsequently, Cohen's kappa was used to determine the observer agreement. Interrater reliability was good, with Cohen's $\kappa = 0.87$.

Academic Achievement

We assessed the students' levels of academic achievement using a mean score (i.e., their grade point averages) based on their subject-specific grades. We obtained the students' official grades from their report cards. As reflected by several report card grades, the averaged measure of the student's academic achievement is a reliable indicator of their overall school performance. In Switzerland, grades range from one to six; six indicate outstanding performance, and one indicates poor performance. Thus, higher numbers represented higher levels of academic achievement.

Analysis

The data were analyzed using descriptive and correlational analyses that utilized SPSS Version 26 and Mplus 8.2 (Muthén and Muthén, 1998-2007). To make full use of the data, we applied the full information likelihood method (FIML). This procedure allowed us to include all available information to estimate the models. The average rate of missing values per variable was 1.13% (range: 0.0–7.8%). The maximum likelihood estimator (MLR) was used to ensure robustness to non-normality. First, to explore the dimensionality and the reliability of the scales of mindsets and self-concept about SRL, we performed a confirmatory factor analysis (CFA) with latent variables. Second, we conducted a path analysis to examine the relationship between all variables. To improve the number of free parameters in accordance with sample size ratios and increase the parameter estimates' stability, we used manifest variables instead of latent variables. Thanks to this approach, our path model met the minimal assumptions regarding the ratio of free parameters per case (Kline, 2016). We included gender, age, and academic track as covariates. The model fit indices were interpreted using several model fit indicators (Schermelleh-Engel et al., 2003): χ^2/df ratio value (should be lower than 3), the root mean square error of approximation (RMSEA, should be lower than 0.06), the comparative fit index (CFI, should be higher than 0.95), and the standardized root mean square (SRMR, should be lower than 0.08). The indirect effects were examined using a bias-corrected bootstrapping procedure (MacKinnon et al., 2004). Since bootstrapping is not yet available for MLR estimation in Mplus, maximum likelihood (ML) was used to estimate the indirect effects.

RESULTS

First, to examine the relationship between mindset and self-concept about SRL, a two-dimensional model with two correlated latent factors was specified (see **Figure 1**). This two-dimensional CFA model indicated immediately acceptable fit values [$\chi^2_{(8)} = 15.049$, $p = 0.06$, $\chi^2/df = 1.881$, CFI = 0.980, RMSEA = 0.060, and SRMR = 0.024]. As expected, the results indicated that the two self-theories about SRL are discriminatory and moderately related.

Second, the descriptive statistics and correlations between all the variables are outlined in **Table 1**. As expected, students' mindsets and self-concepts about SRL correlated positively with enjoyment, strategy knowledge, and academic achievement and correlated negatively with boredom. All the antecedents for academic achievement demonstrated significant positive relationships (mindset about SRL, self-concepts about SRL, strategy knowledge, and enjoyment) or negative relationship (boredom).

Based on theoretical assumptions and previous findings (Pekrun, 2006; Efklides, 2011), a path model was performed on the data to investigate the relationships between the variables in this study. All modeled paths are displayed in the model as no paths were removed (see **Figure 2**). The path model directly demonstrated an excellent fit to the data: $\chi^2_{(7)} = 2.459$, $p = 0.930$, $\chi^2/df = 0.351$, CFI = 1.000, RMSEA = 0.000, and SRMR = 0.017. Mindsets about SRL positively related to self-concepts about SRL, enjoyment, and strategy knowledge. When students believed that SRL competencies are malleable they enjoyed learning at school more and had increased knowledge about strategies. In turn, mindsets about SRL negatively correlated with boredom, meaning that the students who adhered to a growth mindset about SRL found learning less boring than students who did not adhere to a growth mindset. The higher the students' self-concepts were about SRL, the more they reported that they enjoyed learning. In contrast, there was no significant correlation between self-concepts about SRL and boredom. Furthermore, students' self-concepts about SRL positively related to academic achievement. As expected, students' strategy knowledge also positively related to their academic achievement. Finally, whereas enjoyment positively related to strategy knowledge, boredom did not significantly correlate with strategy knowledge.

In terms of the covariates, female students reported higher self-concepts about SRL, gained higher strategy knowledge, reported higher enjoyment and lower boredom, and had higher levels of academic achievement than male students did. As expected, no gender differences were found for mindsets about SRL. Students from the lower academic track reported that they adhered more to a fixed mindset about SRL and demonstrated lower strategy knowledge than their peers from the higher academic track did. Finally, the older the students were, the less they reported enjoying learning at school and the more they reported higher levels of boredom. Altogether, all the variables within the model explained $R^2 = 0.21$ ($p < 0.001$) of the variance in academic achievement.

We tested the mediation effects by examining the indirect effects of mindsets and self-concepts about SRL on enjoyment, strategy knowledge, and academic achievement. We conducted 1,000 bootstraps. The total direct, total indirect, and specific indirect effects are outlined in **Table 2**. The results revealed four significant indirect effects. When students more strongly endorse a growth mindset about SRL, they demonstrated higher strategy knowledge due to their higher self-concepts about SRL. Furthermore, when students more strongly endorsed a growth mindset about SRL, they experienced higher levels of academic achievement due to their higher self-concepts about SRL. Additionally, the higher the students' self-concepts were, the higher their strategy knowledge was due to their enjoyment of learning. Finally, the higher the students' perceived enjoyment of learning was, the higher their levels of academic achievement were due to their higher levels of strategy knowledge.

DISCUSSION

This study focused on two crucial self-theories about abilities that represent independent but related components of individuals' belief systems about SRL, which affect how individuals approach academic situations, how they perceive their knowledge and their abilities and respond to challenges within such situations (Dweck and Leggett, 1988). Mindsets and self-concepts create a system of meaning that sets goal-directed top-down and bottom-up SRL processes in motion and, thus, is the source of different SRL trajectories, emotions, motivation, and differences in academic achievement (Efklides, 2011; Burnette et al., 2013). In this study, we have assessed students' mindset and self-concept about SRL. We explored the relationship between students' mindsets and self-concepts about SRL and enjoyment, boredom, strategy knowledge, and academic achievement while controlling for students' genders, ages, and academic track. Overall, the results revealed that students' mindsets and self-concepts about SRL positively relate directly or indirectly to their enjoyment, strategy knowledge, and academic achievement. In the following sections, according to our research questions and hypotheses, we discuss this study's findings in more detail and draw conclusions for practice.

Our first research question addressed the relationship between mindsets and self-concepts about SRL. Our results revealed that the students' mindsets and self-concepts about SRL were separate but positively interrelated constructs, which confirmed our first hypothesis. Students with a growth mindset about SRL reported higher self-concepts about SRL than students with a fixed mindset about SRL. A possible explanation for this finding is that students with growth mindsets tend to perceive learning situations as opportunities to grow and expand their competencies (Dweck and Leggett, 1988). They consider failures and mistakes that they experience while learning and applying strategies to be feedback for their SRL, which can be developed through further practice. In contrast, students with a fixed mindset about SRL see SRL failures as a threat to their perceived competence in SRL. Thus, mindsets about SRL might also take on a protective function for students' self-concepts about SRL.

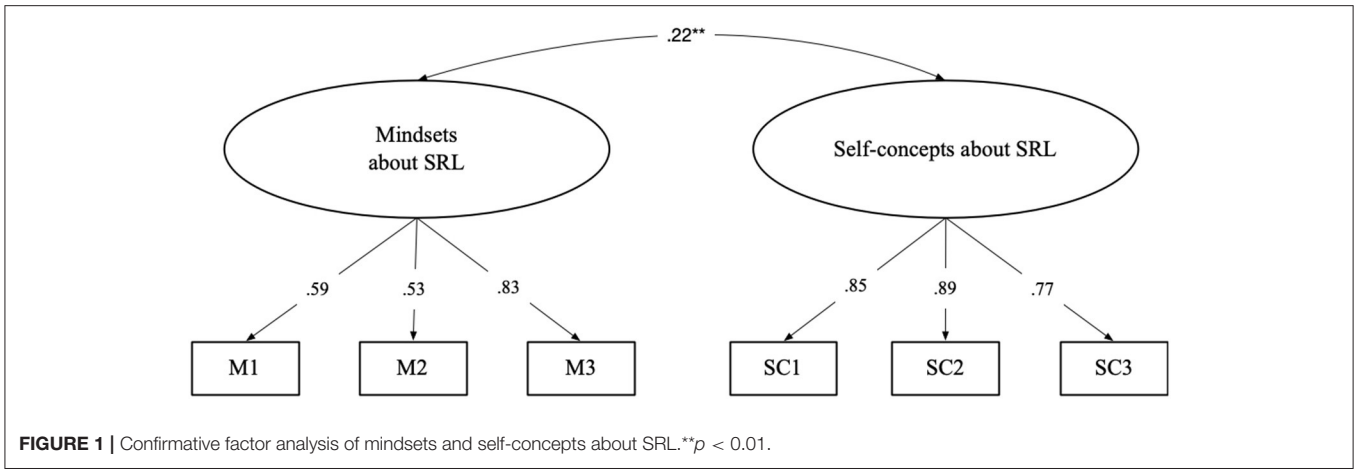

FIGURE 1 | Confirmative factor analysis of mindsets and self-concepts about SRL.$^{**}p < 0.01$.

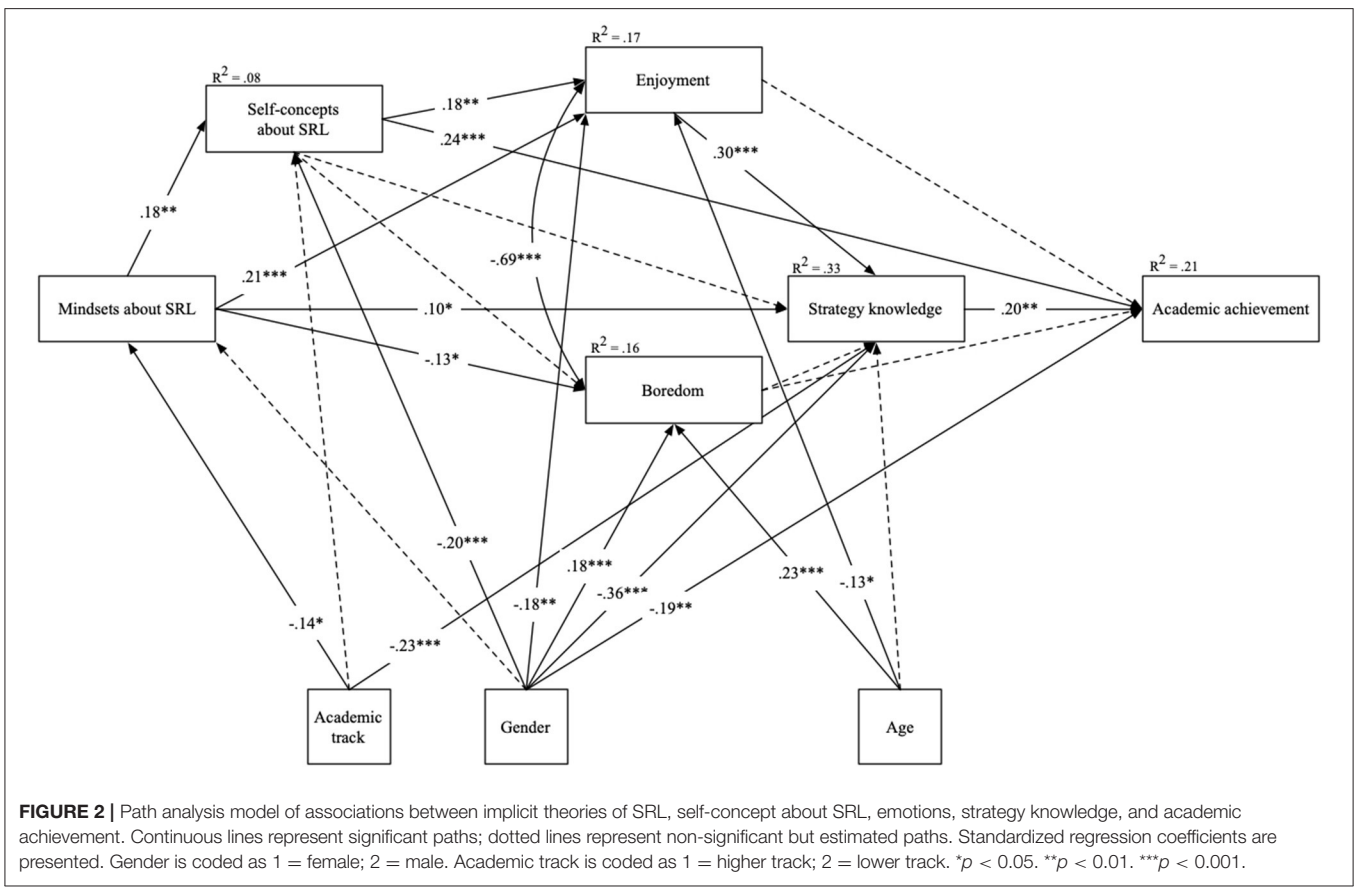

FIGURE 2 | Path analysis model of associations between implicit theories of SRL, self-concept about SRL, emotions, strategy knowledge, and academic achievement. Continuous lines represent significant paths; dotted lines represent non-significant but estimated paths. Standardized regression coefficients are presented. Gender is coded as 1 = female; 2 = male. Academic track is coded as 1 = higher track; 2 = lower track. $^{*}p < 0.05$. $^{**}p < 0.01$. $^{***}p < 0.001$.

However, researchers need to conduct longitudinal studies to investigate this assumption.

Our second research question focused on the relationship between mindsets and self-concepts about SRL, emotions, and strategy knowledge. We expected that mindsets and self-concepts about SRL would positively relate to enjoyment (Hypothesis 2a), negatively relate to boredom (Hypothesis 2b), and positively relate to strategy knowledge (Hypothesis 2c), which we were mostly able to confirm. The students' mindset about SRL positively related to strategy knowledge. This relationship can be explained using findings from other studies that have demonstrated that students with a growth mindset about intelligence more frequently implement strategies, demonstrate higher engagement in strategic behavior, and possess higher metacognitive awareness than students with a fixed mindset (Burnette et al., 2013; Yan et al., 2014). These learning behaviors support students' development of strategy knowledge (Karlen and Compagnoni, 2017; Chen et al., 2020; Hertel and Karlen,

TABLE 2 | Total effect, total indirect effects and specific indirect effect of mindsets about SRL, self-concept about SRL, enjoyment, strategy knowledge, and academic achievement.

Hypothesized effects	Observed effects	
	Estimates	SE
Mindsets > enjoyment		
Total effect M > EJ	**0.240**	**0.064**
Total indirect effect M > EJ	0.031	0.017
Specific indirect		
M > SC > EJ	0.031	0.017
Mindsets > strategy knowledge		
Total effect M > SK	**0.140**	**0.051**
Total indirect effect IT > SK	**0.054**	**0.023**
Specific indirect		
M > EJ > SK	**0.061**	**0.024**
Self-concepts > strategy knowledge		
Total effect SC > SK	0.090	0.055
Total indirect effect SC > SK	0.031	0.020
Specific indirect		
SC > EJ > SK	**0.052**	**0.025**
Mindsets > academic achievement		
Total effect M > AA	**0.098**	**0.029**
Total indirect effect M > AA	**0.098**	**0.029**
Specific indirect		
M > SC > AA	**0.039**	**0.019**
M > SK > AA	0.016	0.012
M > SC > SK > AA	0.002	0.001
M > EJ > SK > AA	0.002	0.003
M > SC > EJ > SK > AA	0.001	0.001
Self-concepts > academic achievement		
Total effect SC > AA	**0.252**	**0.059**
Total indirect effect SC > AA	0.029	0.018
Specific indirect		
SC > SK > AA	0.011	0.017
SC > EJ > SK > AA	0.010	0.006
Enjoyment > academic achievement		
Total effect EJ > AA	0.105	0.084
Total indirect effect EJ > AA	**0.054**	**0.027**
Specific indirect		
EJ > SK > AA	**0.054**	**0.027**

Standardized effects are shown; statistical significance was determined using 1,000 bootstraps. Bold print for significant total effect, total indirect effects, and indirect effects. M, mindsets about SRL; SC, self-concepts about SRL; EJ, enjoyment; SK, strategy knowledge; AA, academic achievement.

2020). Mindsets and self-concepts about SRL both positively related to enjoyment about learning, and mindsets about SRL also reduced boredom. These results align with Pekrun's (2006) control-value theory, which assumes that beliefs and self-concepts are important antecedents for emotions because they increase an individual's perception of being in control of the learning process (Pekrun and Stephens, 2010).

Our second research question focused also on the association between emotions and strategy knowledge. We expected enjoyment to positively correlate to strategy knowledge (Hypothesis 2d) and boredom to negatively correlate to strategy knowledge (Hypothesis 2e). Our results only confirmed the positive relationship between enjoyment and strategy knowledge. A possible explanation for this finding might be that positive emotions such as enjoyment influence SRL more strongly than negative emotions such as boredom do (Pekrun et al., 2002). Students might also build up strategy knowledge with less use of strategy, but it is more effective when students show deliberate strategy practice because students enjoy learning. Additionally, the importance of students' enjoyment of learning is highlighted by the results that we found regarding how mindsets and self-concepts about SRL indirectly impact strategy knowledge via enjoyment. Moreover, we found that enjoyment mediated the effects of students' self-concepts about SRL on strategy knowledge. Our results align with several researchers' findings that stresses the importance of emotions as a relevant component of students' SRL (Pekrun et al., 2002). These results point out that in the promotion of SRL, it is also essential to support adaptive emotions and the regulation of negative emotions (Ben-Eliyahu and Linnenbrink-Garcia, 2015). Self-theories about abilities that support control and value of learning might play a crucial role here (Pekrun, 2006).

However, we do not know whether successful or less successful SRL might have influenced students' emotions about learning. Emotions affect students' SRL and achievement, but related experiences of success and failure can in turn influence students' emotions (Pekrun et al., 2017). Determining this fact would require a longitudinal analysis of the interplay between these processes. This might be an interesting question for future studies.

Our third question investigated whether students' mindsets and their self-concepts about SRL indirectly or directly relate to academic achievement. The results revealed that students with a growth mindset and higher self-concepts about SRL reached higher academic achievement than their peers who adhered to a fixed mindset and possessed lower self-concepts, which aligned with Hypothesis 4. Self-concepts about SRL related directly to academic achievement. This finding supports existing results that have demonstrated the significance of self-concepts for academic achievement in school (Lauermann et al., 2019; Möller et al., 2020). The effect of mindsets about SRL on academic achievement was indirect, so this study also contributes to a growing body of evidence that has demonstrated that mindsets may have mainly indirect or small direct impacts on students' academic achievements (Costa and Faria, 2018; Sisk et al., 2018). In line with this, other researchers have demonstrated that a growth mindset positively affects beneficial learning factors such as motivation, the perseverance of effort, and SRL, all of which are essential antecedents of academic achievement (Burnette et al., 2013; Priess-Groben and Hyde, 2017; Karlen et al., 2019). However, we found that mindset about SRL did not significantly affect academic achievement via strategy knowledge. Integrating further SRL variables could therefore be important for future studies on this topic. It may be important to examine the relationship between mindset, SRL, and performance by including further SRL variables.

By focusing on the results that concern the covariates in our study, we can discuss some interesting results. Our results revealed that the girls reported higher self-concepts about SRL and obtained greater strategy knowledge than the boys did. These results also confirm findings from previous studies that have repeatedly demonstrated that girls have more strategy knowledge than boys do for different age groups (Händel et al., 2013; Maag Merki et al., 2013). Researchers have demonstrated that self-concepts give rise to SRL behaviors during learning and thus support the acquirement of strategy knowledge (Roebers et al., 2012; Bakadorova et al., 2020), which creates favorable learning conditions for girls, at least concerning SRL. However, we need further studies that investigate a possible reciprocal relationship between successful SRL and the development of students' self-concepts about SRL.

Gender-specific differences were also found for emotions. Our results are consistent with existing evidence that demonstrates that boys report less enjoyment and more boredom about learning than girls do (King and dela Rosa, 2019). These emotional differences might exist because the boys reported lower self-concept about SRL, which leads to gender-linked appraisals that are related to learning (Pekrun, 2006). In other words, the difference in perceived competence provides a lower expectation of control and success, which in turn might negatively influence male students' emotions about learning. Further, our results revealed that boys obtained lower grades at school than girls. They not only perceived lower competence in (self-regulated) learning, they were also less successful than girls, which both might explain emotional differences. In line with this assumption, Pekrun et al. (2017) showed reciprocal effects between emotions and academic achievement. However, due to our cross-sectional design, we cannot make any statements on reciprocal effects.

This study also revealed that the students in the lower academic track were at risk in two ways. On the one hand, when compared with students in the higher academic track, they more frequently reported having a fixed mindset about SRL, which confirmed previous results concerning how at-risk students have a relatively fixed view of mindsets of intelligence (Warren et al., 2019). Simultaneously, we also found that academic track as a factor negatively correlated with strategy knowledge, which means that the students from the lower academic track possessed less strategy knowledge than their peers in the more academically demanding track did. This finding could be one possible explanation for why students in lower academic tracks may have more difficulties in school since both mindsets and strategy knowledge relate to academic achievement (Händel et al., 2013).

Practical Implications

This study's findings have implications for interventions that are designed to support students' SRL in classrooms. When designing and conducting SRL training sessions in classes, researchers and educators should consider and encourage growth mindsets about SRL (Hertel and Karlen, 2020). Fixed theorists may have strategies in their repertoire but may not use them. This may occur because they think that smart people do not need strategies or because they become defensive when learning becomes challenging. In this context, teachers' feedback might play an important role by attributing effort to strategy use rather than ability (Rattan et al., 2012). In line with conceptual change research in the context of SRL an important step toward producing some change in learners' implicit belief is to make them explicit and make them the subject of discussion and reflection in learning (Lawson et al., 2019; Vosniadou et al., 2020). Our results also demonstrate that students in the lower academic track adhere to a fixed mindset about SRL and possess lower strategy knowledge than their peers in the higher academic track do. Interventions that focus on mindsets have proven to be particularly relevant for low-performing and disadvantaged students and represent an important contribution to increasing equality and educational opportunities for those students (Binning et al., 2019). Therefore, low-performing students could especially benefit from combined training that focuses on mindsets about SRL and SRL. Finally, our results demonstrate that boys can represent an at-risk group concerning the promotion of self-concepts about SRL and strategy knowledge in comparison to girls. To strengthen their self-concepts about SRL (male), students need to experience success in SRL. Helping students maximize control and value in SRL may benefit their learning and academic achievements. For example, teachers could explicitly provide strategies to help students improve their control and overcome challenges and support students' SRL or to provide adaptive support to students in SRL. Simultaneously, that notion that everyone can overcome challenges with effort and strategies could support higher control and value and, thus, support emotions that encourage SRL (Pekrun, 2006). Overall, it could be particularly beneficial if SRL training not only fosters strategies but also supports beliefs that might be consistent with SRL theory. A growth mindset classroom could support the notion that everyone can progress with effort, that the deliberate use of strategies and academic failures are an important part of everyone's learning process.

Limitations

This study's first limitation was that nearly all the variables were measured simultaneously and that all the results are correlational. Grades (academic achievement) were obtained afterward from students' semester report cards. However, these grades represented students' school performances from their last semester. Our path analysis model was estimated based on previous empirical and theoretical assumptions about the relationships between all the involved variables (Pekrun, 2006; Efklides, 2011). The relationships between the variables could also be modeled differently. For example, when measuring proximal influencing factors for self-concepts, one should consider the reciprocal relationship between self-concepts and academic achievement (Möller et al., 2020). One must also recognize that this study's results came from a non-experimental field study with a rather small sample, which might explain the observed relatively low effects. These restrictions limit the generalizability of our results; another verification by a larger sample is needed. Finally, we focused on two key emotions (enjoyment and boredom) that have been identified as

being particularly relevant to students' learning (Pekrun et al., 2017). However, other essential emotions relate to students' learning (e.g., anger, hope, etc.). Therefore, future studies might focus on a broader range of emotions and expand our knowledge about the relationship between self-beliefs, emotions, and SRL.

CONCLUSION

This study confirms that students' mindsets and self-concepts about SRL create a belief system that is important to students' enjoyment and boredom, strategy knowledge, and academic achievement. Overall, our results revealed that investigating students' mindsets and self-concepts about SRL and their relationships with other SRL variables might be worthwhile. Mindsets and self-concepts about SRL have the potential to contribute to a better understanding of why students might be inclined to engage in goal-directed SRL processes such as the activation of strategy knowledge or the regulation of emotions. It might also be essential to identify beliefs that are not consistent with SRL (Vosniadou et al., 2020), which might stand in the way of applying strategies, enjoying learning, and developing strategy knowledge. Students who think SRL is a malleable ability and belief that they have enough competencies in SRL to overcome challenges might be more likely to seek out opportunities to apply strategies.

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 human participants were reviewed and approved by University of Applied Sciences and Arts Northwestern Switzerland. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

YK led in writing the manuscript, conceived the study, and collected and analyzed the data. CH conceived the study, collected and prepared the data, provided critical feedback, and revised the manuscript. AL evaluated the strategy knowledge test, coded the students' answers, and proofread the manuscript. FS evaluated the strategy knowledge test, coded the students' answers, provided critical feedback, and revised the manuscript. All authors contributed to the manuscript and approved the submitted version.

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Mindsets and Neural Mechanisms of Automatic Reactions to Negative Feedback in Mathematics in Elementary School Students

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Neuroscientific research regarding mindsets is so far scarce, especially among children. Moreover, even though research indicates the importance of domain specificity of mindsets, this has not yet been investigated in neuroscientific studies regarding implicit beliefs. The purpose of this study was to examine general intelligence and math ability mindsets and their relations to automatic reactions to negative feedback in mathematics in the Finnish elementary school context. For this, event-related potentials of 97 elementary school students were measured during the completion of an age-appropriate math task, where the participants received performance-relevant feedback throughout the task. Higher growth mindset was marginally associated with a larger P300 response and significantly associated with a smaller later peaking negative-going waveform. Moreover, with the domain-specific experimental setting, we found a higher growth mindset regarding math ability, but not general intelligence, to be associated with these brain responses elicited by negative feedback regarding errors in math. This suggests that it might be important to address domain-specific and even academic-domain-specific beliefs in addition to general mindsets in research and practice.

Keywords: mindsets, implicit theories, math ability, feedback error-related negativity, P300, feedback

INTRODUCTION

Mindsets are defined as implicit beliefs individuals hold about basic human abilities and attributes, such as intelligence or personality (Dweck, 2006). They exist on a spectrum from fixed mindsets, which refer to believing that specific human attributes are static and unchangeable, to growth mindsets, which refer to believing that these attributes are malleable and can be shaped and developed with effort. Mindsets can be understood as meaning systems, which have an organizing function when it comes to people making sense of the world, interpreting their experiences, and planning their behavior (Dweck et al., 1995).

These meaning-making systems develop in constant interaction with the perceived environment of the person. Furthermore, while research among children suggests that during elementary school years, mindsets might still be in the process of development as organizational frameworks, they are nonetheless already related to achievement-related cognition and behaviors in theoretically predictable ways in the second half of elementary school (Kinlaw and Kurtz-Costes, 2007). The role of mindsets has been widely investigated in the educational context as they were shown to be related to various motivational and behavioral variables, including the way students handle academic setbacks and challenges (Blackwell et al., 2007; Aditomo, 2015). Namely, people with a fixed mindset are more prone to interpret their setbacks by attributing them to the lack of a rather stable ability when compared to people with a growth mindset, who rather attribute setbacks to the lack of effort (Dweck et al., 1995; Dweck, 2006). These differences in the interpretation of events can then lead to differences in the subsequent ways of coping with setbacks and the students' psychological wellbeing. Growth mindset has been linked to students' higher resilience, psychological wellbeing, and school engagement, which seem to be at least partly explained by the enhanced resilience (Zeng et al., 2016). Thus, it can be inferred that a better understanding of these implicit beliefs could be used to support students in their learning with regard to not only their academic achievement, but also their psychological wellbeing.

Mindsets are conceptually domain specific (Dweck et al., 1995), and it has been suggested that even though there seems to be a certain generality across mindsets regarding different domains, the specific domains of implicit beliefs are still distinguishable (Schroder et al., 2016). The general factor and domain-specific facets of mindsets were also apparent regarding their relations to psychological outcomes. Namely, specific mindsets specifically predicted the variance of psychological symptoms in that same domain, yet general mindset still moderately predicted the variance of symptoms in specific domains (Schroder et al., 2016). While Schroder et al. (2016) focused on distinguishing domain-specific mindsets regarding mental health, the research has previously focused on differentiating broader domains, such as intelligence, personality, and morality (Hughes, 2015).

Regarding the domain of intelligence, most of the research done on mindsets has focused on general intelligence without differentiating between possible subdomains of implicit beliefs, such as academic-domain-specific mindsets. Yet, recent research has also examined academic domain specificity of mindsets and shown that these beliefs can be distinguished between different academic domains already among first graders and that at least starting from teenage years they relate differently to academic-domain-specific motivation and achievement (Gunderson et al., 2017). Academic-domain-specific mindsets seem to predict outcomes in that specific academic domain better than general intelligence beliefs or mindsets regarding another domain (Gunderson et al., 2017; Costa and Faria, 2018).

Recently, there has been a growing interest in neuroscientific research on mindsets in order to gain a better comprehension of the mechanisms with which they associate with different behavioral outcomes. The so far scarce research conducted in this field has shown that there are differences in the event-related brain potentials (ERPs) between adults with growth and fixed mindsets (Mangels et al., 2006; Moser et al., 2011). ERPs are time-locked fluctuations of voltage recorded with electroencephalogram (EEG) regarding a certain event, for example, the presentation of a stimulus or execution of a response, such as the press of a button (Woodman, 2010; Kappenman and Luck, 2011). ERPs have been used for decades in research regarding perception and attention (Woodman, 2010; Kappenman and Luck, 2011). State-of-the-art instruments are mobile, so that the recordings can be performed in various environments, such as schools. The method has great temporal accuracy, thus enabling the observation of voltage fluctuations elicited by unfolding neural processes with great precision. This makes it possible to test hypotheses regarding rapid processing of information, which would otherwise be unobservable with using only behavioral methods. The opportunity to inspect the neural processes associated with perception and cognition of setbacks, such as errors and negative feedback, has made the technique useful also for researchers investigating the underlying mechanisms of mindsets (Tirri and Kujala, 2016).

Most of the ERP studies done on mindsets have focused on examining error-related ERPs in speeded reaction time tasks (Moser et al., 2011; Schroder et al., 2014, 2017). More specifically, they have explored error-related negativity (ERN) and error positivity (Pe), which are associated with adaptive behavioral adjustments following errors. ERN is a negative deflection that is elicited when an error is made (Gehring et al., 2011). It is maximal at midline frontocentral scalp locations and peaks at around 100 ms after an erroneous button press. The ERN is assumed to reflect processes involved in the evaluation of the need for control and its implementation (Gehring et al., 2011). Another ERP that has been explored to be elicited by errors is Pe. Pe is a slow positive-going waveform observed to follow the ERN in case of erroneous responses in speeded reaction time tasks. Pe has a more diffuse scalp distribution than ERN, and its maximum amplitude has in general been observed between 200 and 400 ms post-response (Overbeek et al., 2005). Pe has also been observed as a waveform consisting of two positive deflections, which have been termed as early Pe and late Pe (van Veen and Carter, 2002; Moser et al., 2011; Schroder et al., 2014). Even though the functional significance of Pe is still poorly known, the available data seem to suggest that it is mainly associated with error-awareness and the motivational significance of the committed error (Overbeek et al., 2005). Furthermore, for a more comprehensive understanding of the elicited brain responses, exploration of behavioral adjustment and their associations with the ERPs are suggested (Schroder and Moser, 2014). The widely used and recommended behavioral measure to study post-error adjustment and its associations

Abbreviations: ERN, error-related negativity; ERP, event-related potential; FRN, feedback error-related negativity; GEN, general intelligence mindset; LN, late negativity; LP, late positivity; MATH, math ability mindset; Pe, error positivity; PCA, post-correct accuracy; PEA, post-error accuracy; RT, reaction time.

with ERPs is post-error accuracy (PEA), which refers to the accuracy of the trials following errors. Other regularly reported behavioral adjustment measures are reaction times (RTs), including post-error RTs in relation to post-correct RTs referred to as post-error slowing (PES), but this has been differently interpreted and depends on task-specific parameters and, thus, has not been considered as reliable as PEA concerning post-error adjustment (Schroder and Moser, 2014). Importantly, ERN and Pe responses have been shown to relate to adaptive behavioral adjustments following errors (Torpey et al., 2011).

Exploring ERN and Pe and their associations with mindsets has resulted in informative findings. Namely, Moser et al. (2011) found higher growth mindset regarding general intelligence to be associated with higher PEA on a speeded reaction time task and a larger early and late Pe amplitude. They also found Pe to be positively correlated with PEA with Pe mediating the relationship between mindset and post-error performance.

Schroder et al. (2014) observed the effect of experimentally induced mindsets on ERPs. Differently from Moser et al. (2011) though, they found no association between early Pe and mindsets and demonstrated that late Pe was more positive in the fixed mindset condition than in the growth condition. They found smaller late Pe to be associated with enhanced stimulus processing ERP responses. Thus, Schroder and colleagues suggested that individuals in the growth mindset condition having a smaller late Pe prioritized stimulus processing instead of response processing. Regarding post-error behavior, though, they found no significant relationships between either of the Pe responses and PEA.

The only study in this field that has been conducted on children, as far as we know, found a higher growth mindset regarding general intelligence to be associated with a larger Pe difference between error and correct trials (Schroder et al., 2017). They also found that the relationship between mindset and PEA differed significantly between children with large versus small Pe difference amplitudes. Namely, growth mindset was associated with higher PEA in children with small Pe amplitudes, but not in children with large Pe amplitudes.

None of the previously mentioned studies have found mindsets to be associated with other post-error behavioral data than PEA, such as post-error reaction times (RTs) in speeded reaction time tasks. Neither have they found associations between mindsets and overall RTs or accuracy in the tasks used (Moser et al., 2011; Schroder et al., 2014, 2017).

Even though most of the ERP studies on mindsets have explored error-related brain responses, as far as we know, there is one study that focused on examining ERP responses elicited by feedback (Mangels et al., 2006). Indeed, negatively and positively displaced deflections have been observed to be elicited by performance-relevant feedback in addition to error commission. Namely, a negative deflection similar to ERN has been observed after presentation of feedback indicating incorrect performance, independent of the modality of the feedback (Miltner et al., 1997). Although this deflection has been observed to peak later than ERN, namely, between 200 and 350 ms after the onset of the feedback stimulus, it shares a similar scalp distribution (Miltner et al., 1997; Walsh and Anderson, 2012). As this ERP seems to result from cognitive processes associated with external feedback, it has been termed feedback-related negativity (FRN). Earlier research on error- and feedback-related ERPs has suggested that FRN appears to reflect the same neural process as ERN – a more generic neural process regarding initial detection of an outcome that is worse than expected (Miltner et al., 1997; Holroyd and Coles, 2002).

In addition to the negatively displaced FRN response, a positive-going waveform P300 has been found to be elicited by performance-relevant feedback. P300 response, which peaks approximately 300–600 ms after the eliciting stimulus, is not exclusive to negative feedback but is being generated when perceptual stimulus discrimination occurs and is thought to reflect the processing of attention-demanding stimulus more generally (Polich, 2007). It has initially been observed in oddball tasks, where it is elicited by infrequent target stimuli (Polich, 2007). P300 has later been suggested to be a canonical waveform, consisting of two subcomponents that reflect information processing: an earlier peaking P3a with maximum amplitude over frontal and central areas and a subsequent longer lasting P3b with a more parietal scalp distribution (Polich, 2007). P3a is sensitive to the novelty and rarity of the stimulus and is thought to index attention processes related to frontal working memory (Polich, 2007). It is sensitive to expectancy, with the response being the largest to unexpected stimuli (Butterfield and Mangels, 2003; Mangels et al., 2006; Polich, 2007). The subsequent longer lasting P3b subcomponent is thought to index memory processes (Polich, 2007). P300 seems to signal unexpected changes relevant for behavioral adjustment and has been assumed to reflect attentional processes, with larger amplitude associated with more and smaller amplitude less attentional resources being available for the processing of the stimulus (Polich, 2007). P300 amplitude has also been associated with learning from feedback. Namely, the amplitude of the feedback-locked P300 was shown to be larger for initial errors that were answered correctly in the subsequent retest when compared to initial errors that were not corrected in the retest (Butterfield and Mangels, 2003; Mangels et al., 2006; Ernst and Steinhauser, 2012). Interestingly, the positive-going ERP elicited after error commission – Pe – has been suggested to reflect similar neurocognitive processes to the ones reflected in P300. Namely, both Pe and P300 have been assumed to be involved in conscious processing of motivationally significant events (Ridderinkhof et al., 2009).

In the ERP study on mindsets that explored feedback-related brain responses, Mangels et al. (2006) used a general knowledge task and found differences in ERPs between growth- and fixed-minded participants. Namely, they observed differences regarding immediate performance feedback on the accuracy of the response and regarding learning-relevant feedback, which provided the correct answer to the previously presented question. Regarding performance feedback, fixed-minded participants had an enhanced anterior frontal P300 (peaking between 360 and 400 ms after the onset of the feedback stimulus) at Fz electrode site when compared to growth-minded participants. The authors suggested this to reflect fixed-minded participants' heightened attention to performance feedback. Namely, they also found a larger anterior

frontal P300 amplitude to be associated with endorsement of performance goals. Additionally, the results also indicated that a greater P300 amplitude at FCz was associated with higher error correction on the immediate subsequent retest. A greater P300 amplitude has been associated with better subsequent error correction in other studies as well (Butterfield and Mangels, 2003; Ernst and Steinhauser, 2012). The only FRN difference found between growth- and fixed-minded participants was a larger amplitude in the growth mindset group in case of expected errors. Regarding the behavioral measures, growth-minded participants performed better than fixed-minded participants on a surprise retest of initially inaccurately answered questions. Considering this and the fact that there were differences in the learning-relevant feedback-related ERPs between the growth and fixed mindset groups, the authors suggested that possibly there is greater attention allocation to learning-relevant feedback among growth-minded participants.

Even though the results from these neuroscientific studies focusing on mindsets are somewhat controversial and lack replication, they seem to still consistently refer to differences in the ERPs between growth- and fixed-minded individuals. It is important to take into consideration that almost all of the above-mentioned results have been found in a single study not yet having been replicated, which leaves them tentative and in need for additional confirmative findings. Moreover, exploration of feedback-related ERPs and their associations with mindsets have been especially rare and, as far as we know, have not previously been studied in children. Furthermore, academic domain specificity of mindsets has not yet been investigated in neuroscientific studies regarding implicit beliefs. The current study, which is part of the "Copernicus – Changing Mindsets about Learning: Connecting Psychological, Educational and Neuroscientific Evidence" project, aims to address this gap by examining general intelligence and academic-domain-specific, more specifically math ability mindsets, and their relations to automatic reactions to performance-relevant feedback in mathematics in the Finnish elementary school context. The academic domain of mathematics was chosen since achievement in mathematics is often believed to depend more on an uncontrollable innate ability when compared to achievement in other domains, for example, social sciences and languages (Gunderson et al., 2017; Costa and Faria, 2018). Additionally, students seem to consider mathematics to be one of the most important and difficult school subjects (Dundar et al., 2014). In the current study, elementary school students completed an age-appropriate math task that provided performance-relevant feedback throughout the task, while their ERPs and performance were recorded. We focused on exploring FRN and P300, which, as mentioned earlier, have been in the focus of neuroscientific research on reactions to feedback. FRN and P300 below refer to their difference amplitudes between negative and positive performance-relevant feedback in the math task.

Taking into account the findings from the previous studies described above, we expected to find:

1. no relationship between overall accuracy on the task and mindsets (both general intelligence and math ability), since no previous study found such a relationship (Mangels et al., 2006; Moser et al., 2011; Schroder et al., 2014, 2017);
2. no relationship between RTs and mindsets (both general intelligence and math ability), since no previous study found such a relationship (Moser et al., 2011; Schroder et al., 2014, 2017);
3. a stronger endorsement of growth mindset (both regarding general intelligence and math ability) to be related to higher PEA, since growth mindset has been associated with better self-regulatory processes in case of failure and behavioral adjustment after setbacks (Moser et al., 2011; Burnette et al., 2013);
4. the association between math ability mindset and PEA in the math task to be stronger than the one between general intelligence mindset and PEA, since academic-domain-specific beliefs predict outcomes in that specific academic domain better than general intelligence beliefs or mindsets regarding another domain (Gunderson et al., 2017; Costa and Faria, 2018);
5. no relationship between FRN and mindsets (both general intelligence and math ability), since significant associations with the negative deflection following errors or negative feedback have not been found (Mangels et al., 2006; Moser et al., 2011; Schroder et al., 2014, 2017);
6. mindsets (both regarding general intelligence and math ability) to be associated with the P300 amplitude, since mindsets have previously been shown to associate with feedback-related P300 amplitude (Mangels et al., 2006);
7. the association between math ability mindset and P300 in math task to be stronger than the one between general intelligence mindset and P300 in math task, since academic-domain-specific beliefs have been shown to predict outcomes in that specific academic domain better than the beliefs regarding general intelligence or another domain (Gunderson et al., 2017; Costa and Faria, 2018);
8. P300 amplitude to be associated with PEA, since the previous studies have shown P300 to be associated with attentional resources directed toward the stimulus (Polich, 2007) and to predict subsequent error correction (Butterfield and Mangels, 2003; Mangels et al., 2006; Ernst and Steinhauser, 2012).

MATERIALS AND METHODS

Participants

The participants of our study were 97 third-grade students (46 girls, 46 boys, and 5 did not report their gender; M_{age} = 8.94 years, SD_{age} = 0.43) from two Finnish public elementary schools. Both schools are located in the Helsinki metropolitan area, one in a low socioeconomic status (SES) area and the other in a medium SES area (Vilkama et al., 2014).

Materials

Mindset Measures

In order to measure the participants' general intelligence mindset, an instrument including the four Entity Theory items from

the Implicit Theories of Intelligence Scale (Dweck, 1999) was used. The original scale consists of four Entity Theory statements (e.g., *You have a certain amount of intelligence, and you cannot really do much to change it*) and four Incremental Theory statements (e.g., *You can always substantially change how intelligent you are*). Following Dweck's recommendations, the latter ones were not included in the current questionnaire as these items are not reliable due to social desirability, and thus, using Entity Theory statements is a standard practice in this research area (Dweck, 1999). For measuring participants' math ability mindset, the same four Entity Theory statements from the Implicit Theories of Intelligence Scale were adapted to be math ability specific. Participants indicated how much they agreed with each statement by marking one of the six circles that varied in size ranging from *not at all* to *really a lot*, which mapped to a 6-point Likert-type scale. Higher scores indicate a greater endorsement of growth mindset. The internal consistencies of the instruments were acceptable (general intelligence mindset Cronbach's $\alpha = 0.75$; math ability mindset Cronbach's $\alpha = 0.79$).

Math Task

The participants' ERPs to feedback in mathematics were recorded during the completion of an age-appropriate math-specific two-alternative choice task (**Figure 1**). Each trial of the task consisted of a math calculation with one number missing from the calculation that was presented at a central location on the computer monitor for 3000 ms. After this, either a correct or wrong answer appeared in the place of the missing number at most for 3000 ms. During this 3000 ms response window, the participants were instructed to press one of the two buttons on a response box with their dominant hand in order to indicate whether they thought the number appearing in the calculation was the correct answer or not. The participant's response was followed by the bolded correct answer on the monitor (in case of a correct equation on the screen) or by the incorrect answer changing to a correct one (in case of an originally incorrect equation on the screen) for 3000 ms. In case of an incorrect response, a feedback tone of 100 ms followed immediately in order to ensure that the participant was aware of having made a mistake. In case the participant did not press any button during the 3000 ms response window, a time-out message appeared in the center of the monitor for 3000 ms before the next trial. The task consisted of a practice block (5 correct equation trials and 5 incorrect equation trials) to ensure that the participants had understood the task. According to the participants' performance during the practice block, they were subsequently administered an easier (0–5 trials answered correctly) or more difficult version (6–10 trials answered correctly) of the actual task in order to ensure that the calculations in the task would be challenging enough but not too difficult for the participants. The actual task consisted of two blocks (47 trials in the first block and 46 trials in the second block) making up a total of 93 trials. The 93 trial calculations (48 correct equations and 45 incorrect equations) were presented in a random order for each participant. The children were allowed a 5- to 10-min refreshment pause between the blocks. The positions of the two buttons on the response box were alternated every second experimental day in order to avoid possible motor response confounds in the aggregated data (Grootswagers et al., 2017).

Procedure

The children's participation in this study was voluntary, and parental, school principals', municipal officials' written consents were obtained. The children and their parents were informed about the study procedures and their right to cancel their participation at any moment of the study and measurements.

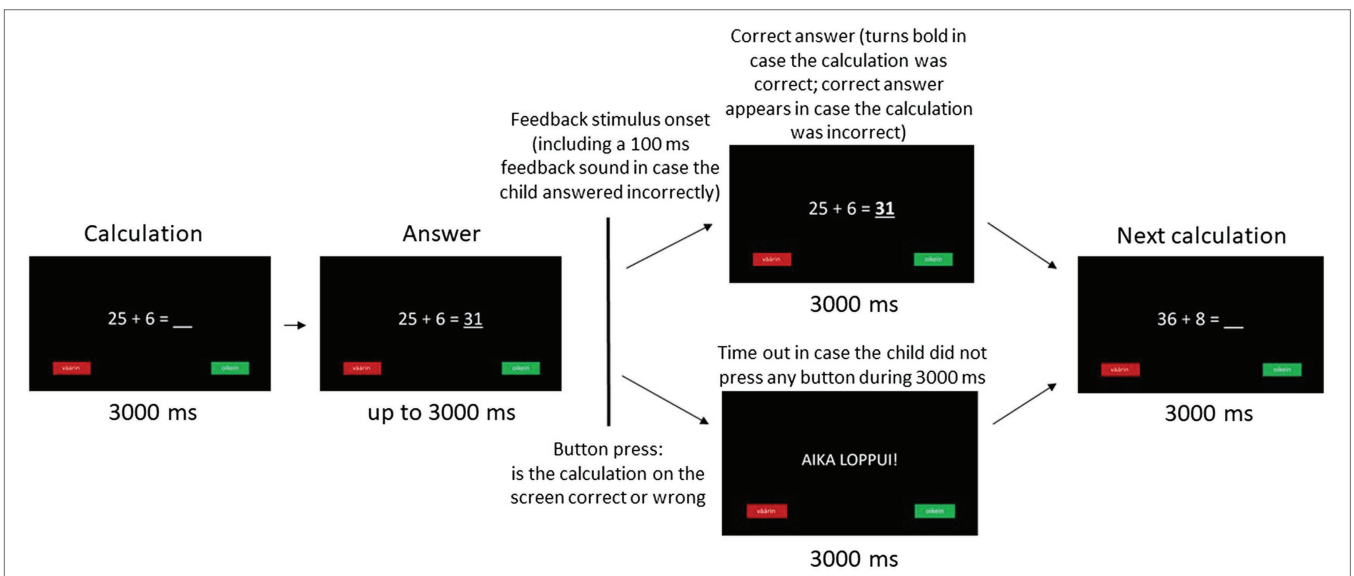

FIGURE 1 | Math task.

The research project for the study was reviewed and approved beforehand by the University of Helsinki Ethical Review Board.

The questionnaire regarding general intelligence and math ability mindset was administered to the participants by a researcher as part of a longer questionnaire during their regular school hours. The researcher read each question and response options out loud as the participants correspondingly filled in the electronic questionnaire behind laptops or tablets provided by the school. The procedure lasted approximately for 40 min.

The experiment, including the math task and psychophysiological recording, was conducted by one to two experimenters in a separate room at the school premises during regular school hours. Before the experiment, the children were briefed about the process of the experiment and reminded of their right to cancel their participation at any moment. After completing the task, the children were compensated with sweets and stickers for their participation. The whole procedure lasted approximately 1 h and 15 min per participant.

Data Recording and Processing

Continuous electroencephalographic activity was recorded with portable equipment (BrainVision QuickAmp amplifier) using 32 Ag-AgCl active electrodes (ActiCap, Brain Products, Germany). Electrolyte gel (Signa Gel, Bio-Medical Instruments, Inc., Warren, MI) was used at each electrode. The data were recorded with BrainVision Recorder at 250 Hz sampling rate. Recording reference was Fpz or FCz depending on the size of the used cap.

After recording, the EEG data were processed with MATLAB R2019a software (Mathworks, Natick, MA) with EEGLAB 19.0 toolbox. The signal was band-pass filtered with cutoffs of 0.1 Hz and 30 Hz and segmented into epochs beginning 200 ms before button press and continuing for 750 ms following button press. In addition to visual inspection, artifactual epochs were rejected by detecting abnormal trends and abnormal spectra, and eye movement artifacts were removed using independent component analysis (Delorme and Makeig, 2004). The data were subsequently re-referenced to the mean of the mastoid electrodes.

Feedback-locked ERPs were calculated relative to a −150 to −50 ms baseline window, which was also approximately −150 to −50 ms pre-response (button press) as the time difference between the button press and feedback stimulus onset was only a few milliseconds. In order to obtain feedback-related ERPs regarding participants' authentic decisions about the accuracy of the math calculations and in order to exclude trials with accidental button presses, all trials where the RT was less than 300 ms post-stimulus (the answer appearing in the place of the missing number of the equation on the screen) were left out from the analyses (Thomas et al., 1981). Also, time-out trials were excluded from further analyses. Additionally, to ensure reliable averages of ERPs, a minimum of six trials was considered necessary for each participant for both error and correct trials in order to calculate the averages (Pontifex et al., 2010). The average number of correct trials included in the further analyses was 42 (min 20, max 71) and the number of error trials was 27 (min. 6, max 53) per participant. Subsequently, the averaged ERPs for correct trials were subtracted from the averaged ERPs for error trials and the aggregated amplitude curve was visually inspected in order to determine the time windows for ERPs to be quantified. Additionally, topographical maps from these time windows were created and visually inspected to determine electrode sites where ERPs were maximal. Accordingly, feedback-locked grand average ERPs for three electrode sites along the scalp midline (Fz, Cz, and Pz) were calculated.

The first negative peak was observed at 50–200 ms after the onset of the feedback stimulus, and taking into account the experimental design of the study, it was presumably affected by the N1 response elicited by the negative feedback sound on error trials (**Figure 2**). Additionally, preliminary analyses showed no associations between this first negative peak and mindsets or behavioral data, and consequently, it was excluded from further analyses. A subsequent negatively displaced response, which peaked between 200 and 360 ms after feedback stimulus onset, was identified as FRN (**Figures 2**, **3**). FRN was assessed as mean difference amplitude over 50 ms time window around each participant's negative peak between latencies 200 and 360 ms. P300 was calculated as mean difference amplitude over 50 ms time window around each participant's positive peak between latencies 250 and 500 ms after feedback stimulus onset. We also observed one later emerging negative deflection peaking between 360 and 625 ms after feedback stimulus onset and one later emerging positive deflection peaking between 500 and 725 ms after feedback stimulus onset. We termed the negatively displaced response as late negativity (LN) and the positively displaced response as late positivity (LP) due to their latencies. LN was assessed as mean difference amplitude over 100 ms time window around each participant's negative peak between latencies 360 and 625 ms, and LP was calculated as mean difference amplitude over 50 ms time window around each participant's positive peak between latencies 500 and 725 ms after feedback stimulus onset.

In order to estimate the consistency of these observed brain responses, split-half reliabilities using Spearman-Brown coefficient for each observed response at midline electrode sites for correct and error trials were computed (Hajcak et al., 2017). The first 14 correct and error trials were included for computing the internal reliabilities as including more has been shown to result in only slight enhancement in the reliability coefficient while losing subjects due to the lack of sufficient number of accepted trials (Hajcak et al., 2017). As some participants had less than 14 artifact-free trials, the number of trials included in the calculations for internal reliabilities was smaller than 14 in the case of these participants. All of the split-half reliability coefficients for each ERP component for correct and error trials at the three electrode sites were above 0.74, which indicates a sufficient reliability of these responses (all of the split-half reliability coefficients can be found in the **Supplementary Table S1**).

Behavioral measures from the math task included overall accuracy, RTs, post-error and post-correct RTs, and accuracy. PEA was calculated as sum of the number of correct answers following error trials divided by sum of number of all answers following error trials. Post-correct accuracy (PCA) was calculated, respectively, using the sum of number of correct answers following correct trials.

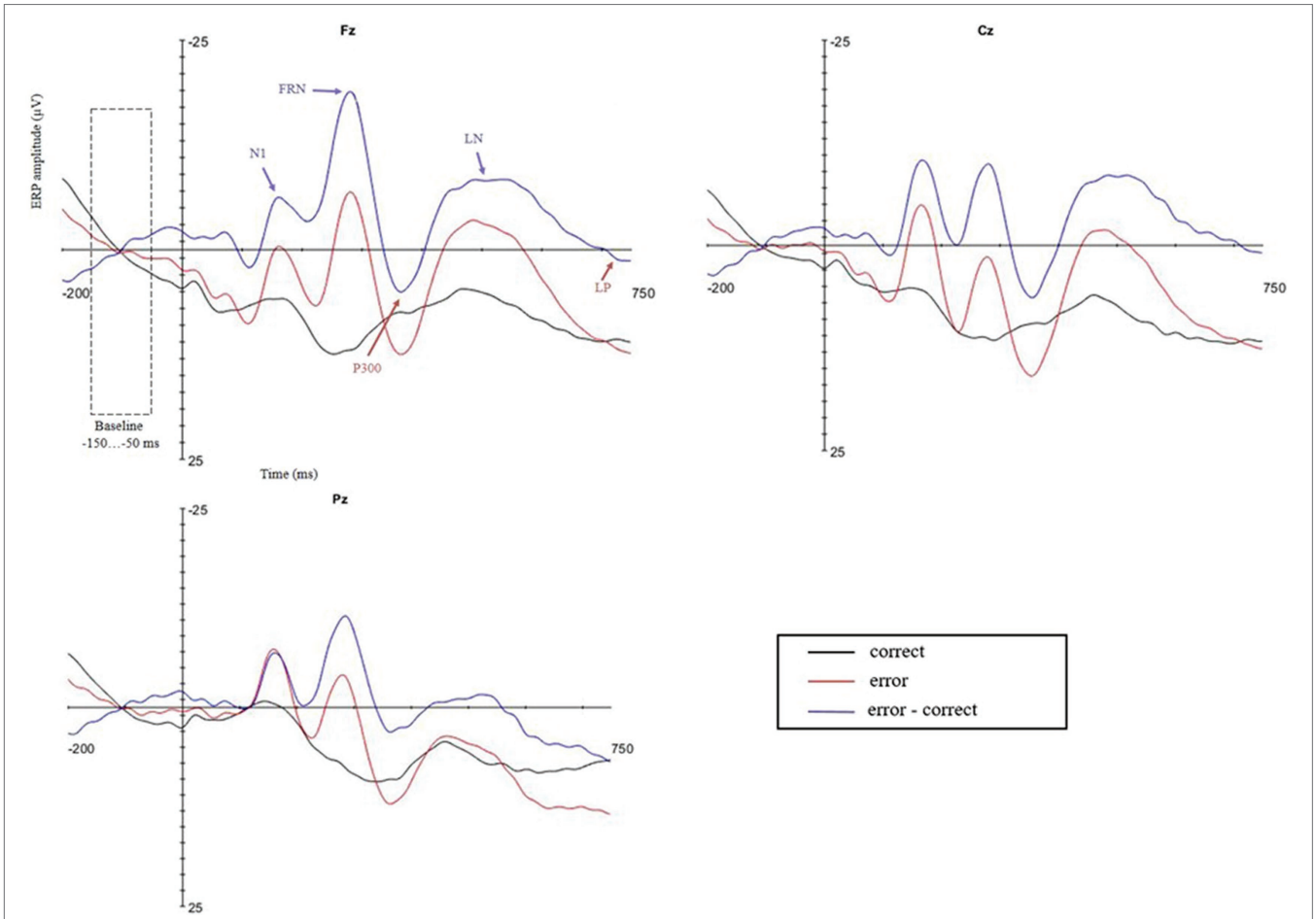

FIGURE 2 | Feedback-locked waveforms for positive and negative feedback trials at frontal Fz, central Cz, and parietal Pz electrodes with indicated baseline and ERP time windows: N1, FRN, P300, LN, and LP. The 0 point on the time scale represents the feedback stimulus onset. Analyzed ERP amplitudes were collected based on individual peak latencies: FRN within the 200–360 ms, P300 within the 250–500 ms, LN within the 360–625 ms, and LP within the 500–725 ms time window after feedback stimulus onset.

TABLE 1 | Descriptive statistics of questionnaire and behavioral variables.

Variable	*M* (*SD*)	Minimum, Maximum
General intelligence mindset	3.66 (1.19)	1.00, 6.00
Math ability mindset	4.16 (1.20)	1.25, 6.00
Overall accuracy (%)	60.7 (10.8)	38.1, 88.8
PEA (%)	60.3 (12.2)	30.0, 94.1
PCA (%)	61.1 (11.3)	38.5, 92.0
RT (ms)	1701 (286)	983, 2189
EH RT (ms)	1767 (307)	934, 2275
CH RT (ms)	1675 (288)	1035, 2229
Post-EH CH RT (ms)	1713 (312)	1029, 2278
Post-CH CH RT (ms)	1651 (295)	1015, 2325
Post-error slowing (%)	104.4 (13.0)	64.9, 143.5

EH, error hit; CH, correct hit.

Data Analyses

First, descriptive statistics of mindset, behavioral and ERP variables were calculated (**Tables 1, 2**), and the normality of data distribution was visually inspected. As the variables were normally distributed, Pearson correlation was used to examine the relationships between the study variables (correlations can be found in the **Supplementary Table S2**). Subsequently, the data were checked to ensure that other assumptions for general linear modeling in addition to normality were satisfied. In case the assumption of sphericity was not satisfied, Greenhouse-Geisser correction was used. After this, repeated-measures analyses of variance (rANOVAs) were conducted on behavioral measures in order to check for the differences between error and correct trials, and subsequently, the scores of general intelligence mindset (GEN) and math ability mindset (MATH) were entered into the rANOVAs as continuous predictors to explore the main effects of mindsets and interactions between mindsets and behavioral measures.

Regarding ERPs, in order to first check for the differences between error and correct trials, paired-samples *t*-tests were conducted to examine whether the error and correct trial ERP amplitudes were significantly different from each other. Subsequently, rANOVAs or, when appropriate, univariate ANOVAs (UNIANOVAs) were conducted on ERP measures, including GEN and MATH scores as continuous predictors

TABLE 2 | ERP components: paired-samples *t*-test results along with descriptive statistics for mean error trial, correct trial, difference amplitudes, and peak latencies.

ERP components	Electrode site	Error trial *M* (*SD*) in μV	Correct trial *M* (*SD*) in μV	Paired-samples *t*-test		Error minus correct	
				t(96)	*p*	Amplitude *M* (*SD*) in μV	Peak latency *M* (*SD*) in ms
FRN	Fz	−6.29 (19.41)	11.21 (19.07)	−14.90	0.000	−17.81 (11.55)	277 (20)
	Cz	0.74 (18.58)	10.81 (18.58)	−8.99	0.000	−9.99 (9.94)	279 (24)
	Pz	−4.11 (16.67)	6.72 (18.02)	−9.77	0.000	−7.21 (8.92)	280 (27)
P300	Fz	12.70 (20.62)	7.70 (21.29)	3.81	0.000	6.23 (12.64)	373 (42)
	Cz	16.70 (19.59)	10.14 (19.89)	4.79	0.000	7.93 (12.97)	365 (43)
	Pz	13.17 (16.71)	9.04 (19.27)	3.51	0.001	6.22 (12.41)	393 (49)
LN	Fz	−5.79 (20.61)	4.82 (23.43)	−7.82	0.000	−11.97 (13.49)	526 (70)
	Cz	−2.91 (20.31)	7.34 (22.14)	−7.53	0.000	−11.85 (13.26)	513 (71)
	Pz	1.67 (19.14)	5.58 (20.83)	−2.91	0.004	−6.02 (12.72)	500 (79)
LP	Fz	10.37 (26.77)	10.15 (24.13)	0.12	0.906	3.03 (18.47)	643 (77)
	Cz	12.49 (25.14)	11.10 (22.73)	0.80	0.429	3.56 (17.40)	643 (72)
	Pz	16.03 (24.95)	7.39 (21.30)	4.45	0.000	9.49 (18.79)	641 (70)

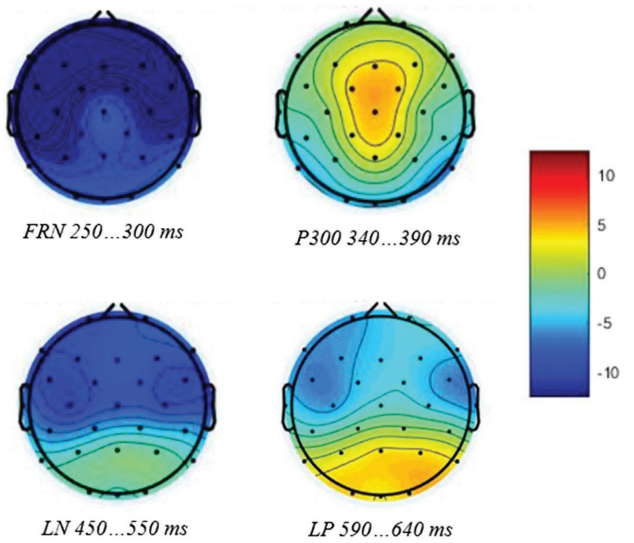

FIGURE 3 | Scalp distribution maps for FRN and P300 (above), and LN and LP (bottom) amplitude differences between negative and positive feedback trials.

in order to assess the main effects of mindsets and interactions between mindsets and responses. In order to explore the relationships between ERP responses and post-error behavioral measures, rANOVAs or, when appropriate, UNIANOVAs on ERP measures, including PEA as continuous predictor, were conducted. In case of significant effects, follow-up analyses were conducted to aid with the interpretation of the results.

RESULTS

Mindsets

As expected, a wide range of mindset endorsements was observed with most participants' mindset scores falling between fixed and growth extremes (**Table 1**). Next, the relationship between GEN and MATH was examined. A significant, intermediate correlation between GEN and MATH was observed (r = 0.41, p < 0.01).

Behavioral Data

The descriptive statistics of behavioral data from the two-choice task are presented in **Table 1**. On average, the participants were correct on 60.7% (*SD* = 10.8%) of the trials (excluding time-out trials) with the average accuracy on the completion of the easier version of the task (N = 37) being 57.7% (*SD* = 8.8%) and the accuracy for the more difficult version (N = 60) being 62.6% (*SD* = 11.5%). Regarding Hypothesis 1, the overall accuracy was not related to mindsets in either of the difficulty levels of the task (p > 0.09). RTs on error trials (M = 1767 ms) were significantly longer than RTs on correct trials (M = 1675 ms) [$F(1,96)$ = 24.05, p < 0.001, η^2 = 0.20]. Concerning Hypothesis 2, when mindsets were entered into the rANOVA as continuous predictors, there were no significant effects (all rANOVA results can be found in the **Supplementary Table S3**).

Regarding post-error behavioral data, post-error RTs on subsequent correct trials (M = 1713 ms) were significantly longer than post-correct RTs on following correct trials (M = 1651 ms) [$F(1,96)$ = 8.59, p = 0.004, η^2 = 0.08], indicating a PES effect. When mindsets were entered into the rANOVA as continuous predictors, there were no significant effects (**Supplementary Table S3**). There was no significant difference between PEA (M = 60.3%) and PCA (M = 61.1%). Regarding Hypotheses 3 and 4, there were no significant effects when mindsets were entered into the rANOVA as continuous predictors (**Supplementary Table S3**).

Feedback-Related ERPs

Feedback-Related Negativity

Feedback-related negativity was the second negative deflection after the N1 (**Figure 2**). According to the paired-samples *t*-test, error and correct trial FRN amplitudes differed significantly from each other at all three electrode sites, indicating a significant difference between error trial and correct trial responses (**Table 2**). In order to test Hypothesis 5, FRN was then analyzed using rANOVA, including FRN difference amplitudes from three electrode sites (Fz, Cz, and Pz) with GEN and MATH as continuous predictors. The main effect of GEN was not significant, and neither

was the interaction between GEN and electrode site (**Supplementary Table S3**). The main effect of MATH was not significant, and neither was the interaction between MATH and electrode site (**Supplementary Table S3**). However, a main effect of electrode site emerged [$F(1.67,156.48) = 5.10$, $p = 0.01$, $\eta^2 = 0.05$], with post-hocs indicating that FRN was larger at Fz than Cz or Pz electrodes ($p < 0.001$).

P300

According to the paired-samples *t*-test, error and correct trial P300 amplitudes differed significantly from each other at all three electrode sites, indicating a significant difference between error trial and correct trial responses (**Table 2**). In order to test Hypotheses 6 and 7, P300 was then analyzed using rANOVA, including P300 difference amplitudes from three electrode sites (Fz, Cz, and Pz) with GEN and MATH added as continuous predictors. The main effect of GEN was not significant, and neither was the interaction between GEN and electrode site (**Supplementary Table S3**). The main effect of MATH approached significance [$F(1,94) = 3.49$, $p = 0.07$, $\eta^2 = 0.04$], indicating that higher growth mindset regarding math ability was marginally associated with larger P300 difference amplitude [with lower quartile scores (3.5) P300: mean at $Fz = 5.01$ μV, mean at $Cz = 6.58$ μV, mean at $Pz = 4.79$ μV; with higher quartile scores (5.25) P300: mean at $Fz = 8.24$ μV, mean at $Cz = 10.14$ μV, mean at $Pz = 8.56$ μV]. The interaction between MATH and electrode site was not significant (**Supplementary Table S3**). Additionally, no significant main effect of the electrode site emerged, indicating that there was no difference in the P300 at the three electrode sites (**Supplementary Table S3**).

Late Negativity

According to the paired-samples *t*-test, error and correct trial LN amplitudes differed significantly from each other at all three electrode sites, indicating a significant difference between error trial and correct trial responses (**Table 2**). LN was then analyzed using rANOVA, including LN difference amplitudes from three electrode sites (Fz, Cz, and Pz) with GEN and MATH as continuous predictors. The main effect of GEN was not significant, and neither was the interaction between GEN and electrode site (**Supplementary Table S3**). The main effect of MATH was significant [$F(1,94) = 4.61$, $p = 0.03$, $\eta^2 = 0.05$], indicating that higher growth mindset regarding math ability was associated with smaller LN difference amplitude [with lower quartile scores (3.5) LN: mean at $Fz = -13.43$ μV, mean at $Cz = -13.61$ μV, mean at $Pz = -7.68$ μV; with higher quartile scores (5.25) LN: mean at $Fz = -9.57$ μV, mean at $Cz = -8.98$ μV, mean at $Pz = -3.24$ μV]. The interaction between MATH and electrode site was not significant (**Supplementary Table S3**). Additionally, no significant main effect of the electrode site emerged, indicating that there was no difference in the LN at the three electrode sites (**Supplementary Table S3**).

Late Positivity

According to the paired-samples *t*-test, error and correct trial LP amplitudes differed significantly from each other only at Pz electrode site, indicating a significant difference between error trial and correct trial responses only at the parietal site (**Table 2**). LP was then analyzed using UNIANOVA, including LP difference amplitude from the parietal electrode site with GEN and MATH added as continuous predictors. The effects of GEN and MATH were not significant (**Supplementary Table S3**).

Brain-Behavior Relationships

In order to examine brain-behavior relationships, rANOVA on FRN was conducted with PEA added as a continuous predictor. There was no significant main effect (**Supplementary Table S3**), but a significant interaction between PEA and electrode site emerged [$F(1.61,153.28) = 4.61$, $p = 0.02$, $\eta^2 = 0.05$], indicating that PEA was differently associated with FRN at different electrode sites. However, subsequent separate UNIANOVA analyses for each electrode revealed that these associations were not significant [$F(1,95) \leq 3.17$, $p \geq 0.08$, $\eta^2 \leq 0.03$].

Subsequently, in order to test Hypothesis 8, rANOVA on P300 with PEA added as a continuous predictor was conducted. There was no significant main effect (**Supplementary Table S3**), but a significant interaction between PEA and electrode site emerged [$F(1.62,153.42) = 4.53$, $p = 0.02$, $\eta^2 = 0.05$], indicating that PEA was differently associated with P300 amplitudes at different electrode sites. However, subsequent separate UNIANOVA analyses for each electrode revealed that these associations were not significant [$F(1,95) \leq 2.03$, $p \geq 0.16$, $\eta^2 \leq 0.02$].

Next, rANOVA on LN with PEA added as a continuous predictor was conducted. There was neither significant main effect nor interaction between PEA and electrode site (**Supplementary Table S3**).

Finally, UNIANOVA on LP with PEA added as a continuous predictor was conducted. The main effect of PEA was significant [$F(1,95) = 11.37$, $p = 0.001$, $\eta^2 = 0.11$], indicating that higher PEA was associated with larger LP amplitude at the parietal electrode site [with lower quartile scores of PEA (52%) LP amplitude mean at $Pz = 5.31$ μV; with higher quartile scores of PEA (68%) LP amplitude mean at $Pz = 13.34$ μV].

DISCUSSION

The neuroscientific research on mindsets, especially among children, is still scarce, and none of the previous studies in this field has taken academic domain specificity of mindsets into account. We aimed to address this gap, and thus in the current study, we examined the relations of general intelligence and academic-domain-specific, more specifically math ability mindsets to automatic reactions to negative feedback in mathematics in Finnish elementary school students. We found P300, the positive deflection thought to index attention processes related to working memory, to be marginally associated with mindsets and LN, a later peaking negatively displaced response, to be significantly associated with mindsets, while for FRN, the negative deflection reflecting initial detection of outcome valence, and for LP, a positive-going waveform with later latency, no such association was found. More specifically, we found

that a larger P300 amplitude and a smaller LN amplitude elicited by negative feedback in math were associated with higher growth mindset regarding math ability (in the case of P300 this association being only marginal), but not with mindset regarding general intelligence. As associations between academic-domain-specific mindsets and ERPs elicited by feedback in the corresponding domain had previously not been explored, the results of this study offer new insight for understanding the complexity and specificity of mindsets in action.

Mindsets

The moderate positive correlation between general intelligence and math ability mindset suggests that these mindsets are related, but still separable from one another, which is consistent with the previous research. Namely, it has been suggested that there are a general factor and domain-specific facets to mindsets (Dweck et al., 1995; Schroder et al., 2016).

Behavioral Data

Confirming our expectations in Hypothesis 1, the overall accuracy in the math task was not related to mindsets. This is consistent with the previous studies (Mangels et al., 2006; Moser et al., 2011; Schroder et al., 2014, 2017). Longer RTs on error trials, when compared to RTs on correct trials, are inconsistent with the results of the previous studies using a speeded reaction time task (Moser et al., 2011; Schroder et al., 2014, 2017). This is probably due to the differences between the tasks used in the previous studies and the current one. Unlike the previous research, we did not employ a simple speeded-response task, but required the participant to calculate prior to their response instead of simply reacting to the stimulus as fast as possible. The longer RT on error trials in our study could indicate that it was more demanding for the participants to calculate their answers on those trials or that they were more hesitant regarding their answers on error trials. Confirming Hypothesis 2 and consistently with earlier studies, mindsets did not have any significant effects on RTs (Moser et al., 2011; Schroder et al., 2014, 2017).

Regarding post-error behavioral data, the post-error RTs on the following correct trials were significantly longer than the post-correct RTs on the following correct trials, indicating a PES effect, which is consistent with the previous studies using a speeded reaction-time error-monitoring task (Moser et al., 2011; Schroder et al., 2014, 2017). Again, mindsets did not have any significant effects on post-error RTs, which is also in line with the previous studies (Moser et al., 2011; Schroder et al., 2014, 2017).

Consistently with the previous studies, there was no difference between PEA and PCA (Moser et al., 2011; Schroder et al., 2014, 2017). Inconsistently with our expectations in Hypotheses 3 and 4, mindsets had no significant effects on PEA, which is compatible with one previous study (Schroder et al., 2014) but inconsistent with others, where higher growth mindset was either marginally (Schroder et al., 2017) or significantly associated with higher PEA relative to PCA (Moser et al., 2011).

Thus, consistently with earlier research, we did not find associations between behavioral data and mindsets, but inconsistently with some earlier studies, we found no association between mindsets and PEA, either. According to the mindset theory, for someone with a fixed mindset, a failure or making a mistake rather refers to the lack of their natural ability needed to succeed, as opposed to seeing it as an indication of the need to imply more effort or a different strategy (Molden and Dweck, 2006). This can subsequently lead fixed-minded individuals to avoid challenges and give up when facing failure (Molden and Dweck, 2006). Theoretically, it could be expected for a higher growth mindset to be associated with higher PEA as the growth-minded person would see an error and the performance-relevant feedback in this case as a sign of the need to implement more effort and focus on the following trials. Nevertheless, this was not the case, which possibly suggests that the task used in the current study demanded more than simply applying more effort or focus in order to succeed as it was not a regular speeded reaction time task, but a more demanding and complex math calculation task. Additionally, the previous research has also shown that learning goals and effort attributions mediate the relationship between growth mindset and adaptive post-failure behavior without a direct significant effect between the mindset and behavior (Smiley et al., 2016). Thus, it could also be speculated that in the case of a more complex task, as the one used in this study, the participating growth-minded children did not attribute their mistakes simply to their lack of effort.

Feedback-Related ERPs

Feedback-Related Negativity

We observed a negatively displaced FRN response with maximal amplitude difference at Fz following negative feedback, peaking between 200 and 360 ms after feedback stimulus onset. This frontally maximal negative deflection following negative feedback is compatible with earlier research on performance-relevant feedback-related ERPs (Miltner et al., 1997; Butterfield and Mangels, 2003; Mangels et al., 2006). Regarding Hypothesis 5 concerning the relationship with mindsets, there were no significant associations between FRN and mindsets, which is compatible with the previous research (Mangels et al., 2006). The study by Mangels et al. (2006) is, as far as we know, the only earlier study focusing on associations between mindsets and feedback-related ERPs, while most of the neuroscientific research on mindsets has examined error-related ERPs in speeded reaction time tasks (Moser et al., 2011; Schroder et al., 2014, 2017). These studies explored ERN, the negative-going waveform following the commission of errors, and found no relationship between mindsets and this negative deflection associated with initial error detection (Moser et al., 2011; Schroder et al., 2014, 2017). Earlier research on error- and feedback-related ERPs and corresponding equivalent dipole analysis has suggested that FRN appears to reflect the same neural process as ERN (Miltner et al., 1997). Thus, consistently with the previous research, our results suggest that mindsets are not related to the initial detection of the outcome valence itself.

P300

In addition to FRN, we observed P300, a positive deflection peaking between 250 and 500 ms after the onset of the feedback

stimulus. This positive deflection following feedback is compatible with the previous research on feedback-related ERPs (Butterfield and Mangels, 2003; Mangels et al., 2006; for review, see Glazer et al., 2018). P300 amplitude did not differ between the midline recording sites, which might be due to its more frontal P3a and more parietal P3b subcomponents overlapping (Polich, 2007). Regarding Hypothesis 6 concerning the associations with mindsets, the P300 amplitude was only marginally associated with mindsets. Earlier research exploring the relationships between mindsets and feedback-related ERPs found a greater frontally maximal P300, possibly reflecting the P3a subcomponent, to be associated with fixed mindset and endorsement of performance goals (Mangels et al., 2006). This association was thought to indicate the greater salience of the negative performance feedback among fixed-minded participants. Interestingly, in our study, the direction of this association, though not reaching statistical significance, indicated a larger P300 amplitude to be associated with higher growth mindset. Hence, our marginally significant result does not comply with the findings of Mangels et al. (2006). It is important to mention, though, that in the study by Mangels et al. (2006), this frontally maximal P300 response was elicited by performance-relevant feedback stimulus, but in our study, performance-relevant feedback was presented simultaneously with corrective feedback. Thus, in this case, a larger P300 could indicate more attentional resources engaged in the processing of the corrective feedback stimulus. Complying with this speculation, Schroder et al. (2014) found larger P300 to incongruent trials among the participants in the growth mindset induction group when compared to the fixed mindset induction group. These results could indicate greater attention allocation to stimulus processing after growth mindset induction. Additionally, error-related ERP studies have found higher growth mindset to be associated with a larger Pe response elicited by errors in a speeded reaction time task (Moser et al., 2011; Schroder et al., 2017). These results have been interpreted as growth-minded individuals allocating more attention to errors with Pe mediating the effect of growth mindset on post-error adjustment (Moser et al., 2011). Thus, taking into account the findings of Schroder et al. (2014) and that Pe and P300 have been suggested to reflect similar processes involved in conscious processing of motivationally significant events (Ridderinkhof et al., 2009), the results of the present study regarding the amplitude of P300 seem to comply with these previous findings.

Additionally, regarding Hypothesis 7, the domain-specific experimental design of the current study provided informative findings concerning the academic domain specificity of mindsets. Namely, a larger P300 amplitude elicited by negative feedback in math was marginally associated with higher growth mindset regarding math ability, but the association between the P300 amplitude and mindset regarding general intelligence did not approach significance. Even though these findings only approached statistical significance, it could possibly refer to the importance of not only domain but also academic domain specificity of mindsets (Gunderson et al., 2017; Costa and Faria, 2018).

Late Negativity

In addition to the FRN and P300, we observed a negative-going waveform following the P300 response and peaking between 360 and 625 ms after feedback stimulus onset. Regarding the topographical distribution of this response, the LN amplitudes did not differ at the midline electrode sites. Such a late negative-going waveform, as far as we know, has not previously been reported in feedback-related ERP studies. Interestingly, in our study, this LN amplitude was associated with mindsets. Namely, higher growth mindset in math ability was associated with a smaller LN difference amplitude elicited by feedback in the math task. It is important to highlight that the effect size for this association was small, indicating that math ability mindset only explains a very small percentage of the variance in the amplitudes of the LN response. Nevertheless, this significant association, although small in effect size, was observed only in the case of mindsets regarding math ability. Namely, general intelligence mindset had no association, not even a marginal one, with the LN amplitude during the math task. When examining the latencies of P300 and LN observed in the current study and taking into account the later peaking and longer lasting character of the P3b subcomponent of the P300 canonical waveform, it could be speculated that the positive-going P3b, associated with memory processes, could be overlapping with the subsequent negative-going LN response. In this case, a smaller LN difference amplitude could possibly reflect a greater latent P3b difference amplitude. As we found a greater P300 difference amplitude to be marginally associated with a growth mindset in math ability, the significant association with a smaller LN amplitude could possibly reflect the underlying association between growth mindset in math ability and a greater latent P3b difference amplitude. Nevertheless, these results are novel and as such a LN elicited by feedback has not been observed in the previous studies, this association remains to be explored by future research.

Late Positivity

The other late deflection following performance feedback was a positive-going waveform emerging at the parietal site after the LN response and peaking between 500 and 725 ms after feedback stimulus onset. This type of a later emerging positive waveform has not previously been reported in feedback-related ERP research focusing on mindsets (Mangels et al., 2006). A later sustained positive-going centro-parietal ERP beginning at around 500–600 ms and possibly continuing for several seconds after stimulus onset has been examined in the context of reward processing assumed to reflect sustained attention toward and elaborative processing of emotionally and motivationally salient stimuli (Weinberg and Hajcak, 2011; Pornpattananangkul and Nusslock, 2015; for review, see Glazer et al., 2018). It could be speculated that this late positive-going waveform observed in the current study could reflect sustained attention to and further processing of the feedback stimulus. Regarding the relationship with mindsets, though, there were no significant associations observed with the LP response. Thus, it remains unclear, which processes this later emerging positive waveform reflects in the context of feedback processing.

Brain-Behavior Relationships

PEA did not have a significant main effect regarding FRN, which is consistent with the suggestion that FRN codes outcome valence and that the need for behavioral adjustment is not its core feature (Von Borries et al., 2013). Not complying with our expectations in Hypothesis 8, PEA did not have a significant association with the P300 amplitude. This is contradictory to earlier findings that found corrective feedback-related P300 to be larger for initial errors that were answered correctly in the subsequent retest (Butterfield and Mangels, 2003; Mangels et al., 2006; Ernst and Steinhauser, 2012). In the present study, though, the corrective and performance-relevant feedback were presented simultaneously; thus, the P300 amplitude in the current study reflects attention not only toward the learning-relevant stimulus, but also toward the performance-relevant stimulus. Additionally, in the present study, behavioral adjustment was not measured using a retest enabling the assessment of the later accuracy of initial errors, but simple PEA. Thus, instead of reflecting the attentional resources directed at the specific learning-relevant stimulus, higher PEA in this design could rather reflect general heightened attention toward the overall task following errors and the accompanying feedback.

There were no associations between PEA and LN. Regarding the positive-going LP, though, PEA had a significant effect. Namely, higher PEA was associated with larger LP at the parietal site. This suggests that the observed LP could reflect heightened and sustained attention on the task following errors. A later emerging positive deflection following negative feedback has been linked to subsequent behavioral adjustment also in earlier studies (San Martín et al., 2013; Von Borries et al., 2013; for review see Glazer et al., 2018). Thus, the found association between LP and PEA seems to support the assumption of LP reflecting attention to motivationally salient stimuli coupled with subsequent behavioral adjustment (Glazer et al., 2018).

Limitations

As our study explored only general intelligence mindsets and mindsets about a single academic domain – math – regarding the reactions while completing a math-specific task, it has limitations that should be addressed in the future. To make more reliable conclusions regarding academic domain specificity of mindsets in action, the experimental design should compare several different academic-domain-specific mindsets, for example, math ability and writing ability mindsets, and their relations to automatic reactions to feedback in math-specific and writing-specific tasks. Another option could be including an additional task, performance on which would be associated with general intelligence. Such a design would enable comparing general intelligence and math ability mindsets, and their relations to automatic reactions to feedback in general intelligence and math-specific tasks. Also, the inclusion of a feedback sound in case of an inaccurate response is a considerable limitation of the current study, making it more challenging to compare positive and negative feedback-related ERPs. Yet, in our study, we prioritized to study the reactions to feedback that would be clear and could not be perceived as ambiguous by the participants. Thus, the decision to use the feedback sound was made to make the participants clearly aware of their errors and the valence of the feedback.

Additionally, the design of the current study limits the exploration of the performance-relevant feedback-related ERPs separately from the ERPs related to corrective learning-relevant feedback. This limits the interpretation of the results of the current study. In the future, performance-relevant and corrective feedback could be presented separately in order to be able to differentiate between the ERPs elicited by performance-relevant feedback stimulus and learning-relevant feedback stimulus.

Another limitation to address concerns the mindset measures, which were self-report questionnaires. Using self-report questionnaires among this age group might be problematic regarding understanding of the questions and self-reflection necessary to answer them (Borgers et al., 2000). In the future, the assessments of teachers and parents could additionally be used regarding mindset measures.

Conclusion

To conclude, our results suggest that mindsets about math ability might be linked to attentional processing of the feedback received regarding performance in the domain of math. These results suggest that domain specificity of mindsets might matter when it comes to the complex interaction of implicit beliefs and feedback in the process of interpretation and meaning making by the student. Namely, mindsets regarding specific domains possibly play a bigger role in eliciting automatic reactions to feedback in the corresponding domains when compared to more general mindsets. Moreover, even though earlier research has shown domain-specific and general mindsets to have a general factor in addition to domain-specific aspects, our results regarding automatic reactions to feedback suggest that it might be important to address domain-specific and even academic-domain-specific beliefs in addition to general mindsets when planning interventions and looking for ways to support students' learning. Nevertheless, these observed changes in ERP amplitudes associated with mindsets in the current study were not associated with subsequent behavioral adjustment and the changes in ERP amplitudes associated with improved subsequent performance were not associated with mindsets. Thus, even though the results regarding the observed automatic reactions suggest that domain specificity of mindsets could matter in the process of meaning making and interpretation by the student, the ways in which these beliefs and their interactions with processing feedback get translated into behavioral outcomes are not so straightforward. Thus, these math ability- and other academic-domain-specific mindsets and their role in students' behavioral outcomes in the corresponding academic domains call for further research.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Helsinki Ethical Review Board in the Humanities and Social and Behavioral Sciences. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

IP, MHuo, TK, SL, EK, and KT planned the experimental design. IP, MHuu, and KK collected and pre-processed the data. IP and TL conducted the analyses. IP, TL, MHuu, KK, MHuo, TK, SL, EK, and KT wrote the paper. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

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