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How hard did you try? A scoping review of the literature on effort investment in math

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Like most high-level human skills, such as reading or playing the piano, learning math requires thousands of hours of effort. Despite its importance, research on effort in math remains limited. This scoping review examines the literature on effort in math, focusing on individual variables (i.e., sex, age, skills, attitudes) and contextual factors (i.e., teacher involvement, parental support, SES, cultural differences) that influence effort investment in math. It explores how effort contributes to math achievement, predicts gains over time, and mediates the effects of affective factors, showing how positive attitudes enhance performance through increased effort and how lack of effort mediates the negative impact of math anxiety. The review highlights the foundational role of effort in fostering positive attitudes and emotions in math and offers strategies to motivate students to invest effort in math learning.

KEYWORDS

math, effort, achievement, performance, attitudes, anxiety

1 Introduction

Mathematical competence is essential across many areas of life. Poor math skills are associated with negative outcomes such as reduced employment prospects post-graduation (Durrani and Tariq, 2012), limited promotion opportunities (Parsons and Bynner, 1997), lower salaries (Dougherty, 2003), and poor financial decision-making (Agarwal and Mazumder, 2013). Furthermore, the difficulties with certain math concepts, such as fractions and probability, has been shown to predict lower performance in health and social decision-making (Reyna and Brainerd, 2007). Beyond the individual level, mathematics plays a critical role in national economic strength. The United States is currently facing a shortage of students and professionals in Science, Technology, Engineering, and Mathematics (STEM) fields (Boggs et al., 2024). Addressing the root causes of math underachievement and nurturing talent in these areas is vital for maintaining economic competitiveness and national security. Like other complex human skills such as reading or playing the piano, developing proficiency in math requires thousands of hours of dedicated cognitive effort. Despite the crucial importance of effort in academic success, and particularly in mathematical achievement (Duckworth, 2016), to the best of our knowledge, there has been no comprehensive review of the individual and contextual factors that influence effort investment in math, or of how effort contributes to achievement and gains in math over time. This paper aims to fill this gap in literature. We begin by outlining our literature search method (Section 2) and the conceptualization of effort (Section 3), then review evidence on why studying effort in math is important (Section 4). We examine individual variables (Section 5) and contextual factors (Section 6) that influence effort investment in math, followed by a discussion of effort as a possible mechanism mediating between affective factors and math achievement (Section 7). We also explore how effort contributes to the development of positive attitudes and emotions toward math (Section 8).

Finally, we present strategies to motivate students to invest effort in math learning (Section 9), a conclusion (Section 10) and a discussion of some limitations and future directions (Section 11). See Table 1 for a summary of all the studies.

2 Method: literature search

We conducted a comprehensive search for studies examining effort investment in mathematics using several electronic databases, including APA PsycINFO, PubMed, ProQuest Dissertations & Theses, Taylor & Francis Online, and Google Scholar. A broad range of keyword combinations was used to capture relevant literature, including terms such as "effort," "engagement," "perseverance," "persistence," "grit," "math," and "mathematics." Boolean operators "OR" and "AND" were used to expand and refine the search. To be included in the review, studies had to meet the following criteria: (1) be written in English, and (2) focus specifically on effort in mathematics, as compared to other fields (i.e., reading; academic performance broadly defined). No restrictions were placed on the year of publication, population being studied, or the geographic location of the study. The screening process began with a review of titles and abstracts to assess initial relevance, followed by full-text reading of potentially eligible studies to determine final inclusion. The primary search was conducted between February and May 2024, with additional studies included thereafter on a case-by-case basis based on their relevance.

3 Conceptualization and measurement of effort in math

Effort is commonly defined as the mental energy or attentional resources voluntarily allocated to a task (Kahneman, 1973). Researchers have measured effort in various ways, depending on the instrument used, the populations studied, and the specific research question addressed. Most studies have relied on self-report measures, asking participants to indicate how much effort they invest in different math tasks or situations (e.g., Trautwein et al., 2006a; Trautwein, 2007; Trautwein and Lüdtke, 2007, 2009; Xu, 2018). For example, some studies asked participants to report the effort they invested during a test (O'Neil et al., 1995), sometimes quantified as a percentage (Cole et al., 2008). Others assessed agreement with statements related to homework compliance (e.g., "I always try to complete my mathematics homework") and persistence (e.g., "Even if my mathematics homework is difficult, I do not give up quickly"; Trautwein et al., 2009). Similarly, Balfanz and Byrnes (2006) asked students questions like: "How hard are you working in math class?" In addition to student self-reports, some studies have gathered teacher assessment of student effort. For example, teachers were asked to compare a child's effort to that of peers ("Compared to other children, how hard have this child tried in each activity area listed below?" (Upadyaya and Eccles, 2015; see also Brisson et al., 2017; Mägi et al., 2010).

Other approaches have used behavioral indicators such as time on task. This includes time spent on math homework (e.g., Suárez et al., 2019; Singh et al., 2002; Schmitz and Skinner, 1993) or time spent preparing for math tests outside of class (e.g., Benedict and Anderton, 2004; Saville et al., 2006). Some researchers consider these measures more objective than self-reports (Berger, 2009). Relatedly, effort has also been measured by the number of math problems attempted or solved within a given time frame (e.g., Medway and Venino, 1982; Trautwein and Lüdtke, 2009). Finally, some studies have assessed effort through task selection, specifically, participants' tendency to choose more challenging and cognitively demanding math problems or their willingness to solve math problems instead of playing games (Milyavskaya et al., 2021).

A key challenge in synthesizing this literature is the use of different terms to describe the same underlying construct—a phenomenon known as the *jangle fallacy* (Lawson and Robins, 2021). To address this, we included in our review all the studies that focused on effort in math, even if they used alternative terms such as homework compliance and persistence (Trautwein et al., 2009; Trautwein and Lüdtke, 2009), working hard in math (Balfanz and Byrnes, 2006) or grit (e.g., Yu et al., 2021).

4 Why is it important to study effort in math?

Research has consistently shown that the amount of effort individuals invest in a subject or task predicts their performance. For example, effort investment has been found to predict students' American College Testing (ACT) scores across subjects including Math, Social Studies, and English (Cole et al., 2008). Similarly, effort investment has been linked to high academic achievement in high-school students, as measured by grade point average (GPA) (Schwinger et al., 2009) and to expected end-of-course letter grades among college students (Wolters and Hussain, 2015). Bowman et al. (2015) showed that effort predicted increases in GPA from spring to the fall semesters in undergraduate students.

When focusing specifically on math, similar patterns emerge. Mägi et al. (2010) examined longitudinal associations between effort and math achievement in Estonian secondary students. They found that teacher-rated effort and math grades were concurrently associated at both time points. Moreover, effort at Time 1 predicted effort at Time 2, which in turn predicted math grades at Time 2, highlighting the importance of sustained effort. Xu et al. (2021) similarly found that effort at Time 1 predicted standardized math scores at Time 2, and vice versa, suggesting a reciprocal relationship between effort and achievement. However, neither Mägi et al. (2010) nor Xu et al. (2021) directly examined whether effort at Time 1 predicted *gains* in math achievement over time (i.e., changes in performance from Time 1 to Time 2; Merkley et al., 2017). This limitation was addressed by Trautwein (2007), whose longitudinal study with secondary German students showed that homework effort at Time 1 positively predicted math grades and test scores at Time 2, even after controlling for initial performance. These findings were later replicated by Trautwein et al. (2009). Collectively, these studies demonstrate that effort in math is not only associated with concurrent performance but also with performance gains over time.

Beyond its direct link to achievement, effort in math is also important because it may mediate the relationship between affective variables (e.g., attitudes; anxiety) and math achievement (Singh et al., 2002; Cole et al., 2008; Trautwein et al., 2009; Demir-Lira et al., 2020; Suárez-Pellicioni et al., 2021). Additionally, some research suggests

TABLE 1 Summary of the literature on the role of individual and contextual variables explaining effort investment in math.

The role of	Publication	Population	Location	Measure of effort	Main finding
Individual variables					
Sex	Song et al. (2019)	8th and 9th grade students	South Korea	A three-item survey (e.g., "When studying mathematics, I skip all the hard parts") was used to assess students' use of effort avoidance strategies. Participants rated their agreement with each statement on a 7-point Likert scale ranging from 1 ("strongly disagree") to 7 ("strongly agree")	Male students were more likely than female students to report engaging in effort avoidance when learning mathematics
	Smith et al. (2013)	1st year STEM graduate students	United States	Comparative ratings: Participants responded to four custom-developed items designed to assess their perceptions of effort and ability relative to their peers. The items included: 1. "Compared with other students, how much effort do you expend in your field of study?" 2. "Compared with other students, to what extent do you find the material and work in your field challenging?" 3. "Compared with other students, to what extent does your field come easily and naturally to you?" 4. "Compared with other students, how much energy does it take you to succeed in your field?" Responses were recorded on a 5-point Likert scale ranging from 1 ("a lot less") to 5 ("a lot more") Absolute ratings: Participants also completed three items assessing their own effort and ease in their field of study: 1. "How much energy does it take you to succeed in your field?" 2. "How much effort do you expend in your field?" 3. "To what extent does your field come easily and naturally to you?" (reverse scored) These were rated on a 5-point Likert scale Additionally, participants rated a peer of their choice using three parallel items: 1. "It takes a lot of energy for ____ to succeed in this field" 2. "____ expends a lot of effort in this field" 3. "This field comes easily and naturally to _____" These peer ratings were also measured on a 5-point Likert scale	Compared to male students in STEM graduate programs, female students perceived themselves as needing to invest more effort than their peers to succeed. This heightened perception of effort was associated with a reduced sense of belonging and diminished motivation among women
	Espinoza et al. (2014)	Secondary school math teachers	United States	Effort beliefs were measured using the attributional bias instrument, which asked teachers to explain students' success and failure in mathematics by selecting between effort-based and ability-based explanations. Each teacher evaluated four students from their class: one high-achieving and one low-achieving boy, and one high-achieving and one low-achieving girl. For each student, teachers responded to two scenarios—one depicting academic success and one depicting failure—by choosing from four possible explanations. Each scenario included two effort-related options (e.g., "the student asked for help" or "rushed through the assignment") and two ability-related options (e.g., "the student mastered the material" or "struggled with math"). Teacher responses were then coded as either effort or ability attributions	At baseline (Time 1), teachers demonstrated a gendered attributional bias: they attributed girls' success in mathematics to effort twice as often as they did for boys (66% for girls vs. 33% for boys)
	Greene et al. (1999)	High school students	United States	Effort in math class was assessed using a self-report measure consisting of two items, yielding a Cronbach's alpha of 0.82, indicating good internal consistency. The specific items used in the measure were not reported	Males and females may interpret the stereotype that math is a male domain differently. Females who struggle might believe their difficulties reflect a lack of ability, leading them to see effort as useless. Males, on the other hand, may think that needing effort signals low ability, since they are supposed to be good at it
	Matteazzi et al. (2021)	High school students	Italy	Effort was measured by the number of hours and minutes students dedicated daily to studying mathematics	A significant positive correlation was observed between time spent studying math at home and math achievement among male high school students, whereas no such relationship was found for female students

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TABLE 1 (Continued)

The role of	Publication	Population	Location	Measure of effort	Main finding
Age	Trautwein et al. (2006a)	5th, 7th, and 9th grade students		Homework compliance was assessed using a four-item scale (e.g., "I often copy math homework from others at school"), with responses recorded on a 4-point Likert scale ranging from "completely disagree" (1) to "completely agree" (4)	Results indicated a decline in math homework effort with age, as ninth-grade students reported lower levels of effort compared to fifth-grade students
	Upadyaya and Eccles (2015)	Kindergarteners, 1st and 3rd grade students and their teachers	United States	Teacher-rated effort was measured using a two-item survey: (1) "Compared to other children, how much innate ability or talent does this child have in each of the following areas?" and (2) "Compared to other children, how hard does this child try in each activity area listed below?" with math and reading as the specified domains. Teachers responded using a seven-point Likert scale ranging from "very little/not at all hard" (1) to "a lot/very hard" (7)	Results showed a decline in teacher-rated math effort as children grew older
Math skill	Helwig et al. (2001)	3rd and 5th grade students	United States	Teacher-rated effort was assessed using a single-item measure: "Please rate the amount of effort this student puts into the subject area of mathematics." Teachers responded on a 5-point Likert scale ranging from "almost no effort" (1) to "very large effort" (5)	A positive correlation was found between teacher-rated math skills and teacher-rated student effort in mathematics
	Xie et al. (2013)	Middle school students	United States	Effort was quantified using a performance ratio, calculated by dividing the number of successfully completed math topics by the total number of topics attempted within the Assessment and Learning in Knowledge Spaces (ALEKS) platform	A significant interaction between ability and effort was observed, indicating that students who exerted high effort outperformed those with low effort, regardless of their ability level
	Fisher et al. (2012)	Preschoolers (average age of 4.39 years at Time 1)	United States	Children were videotaped while participating in an educational math activity. After being invited to engage with the materials, the experimenter stepped away, allowing the children to interact independently. The video recordings were later coded for two behavioral indicators—*Time on Task* and *Goal-Directed Play*—which align with the study's conceptualization of effort. However, it is important to note that the original authors categorized these measures under the broader construct of interest • Time on task: Defined as the total duration during which the child actively interacted with the stimulus cards. Periods of off-task behavior (e.g., walking around the room) were excluded. • Goal-directed play: Captured the structure, intentionality, and sophistication of the child's play, as well as their sustained attention. Ratings ranged from 1 (random approach to the activity) to 7 (consistently purposeful approach)	Children's math skill levels were moderately to strongly correlated with both time on task and goal-directed play, even after controlling for age—indicating that higher-skilled children engaged more deeply with the activity. Furthermore, early math skill (Time 1) predicted later levels of time on task and goal-directed play, even after accounting for initial levels of these behaviors. Notably, goal-directed play at Time 1 also predicted later math skill, independent of initial skill levels, whereas time on task did not significantly predict later math performance
Math attitudes	Hemmings and Kay (2010)	Secondary school students (approx. 16-year-old)	Australia	Effort was measured using the Effort Scale from the Inventory of School Motivation; however, the source did not report the total number or specific items included in the scale	A relatively strong positive correlation ($r = 0.55$) was found between students' attitudes toward mathematics and their investment of effort
Math interest and math enjoyment	Milyavskaya et al. (2021)	High school students	United States	Effort was assessed using the Academic Diligence Task (Galla et al., 2014), in which effort was operationalized as the average proportion of time participants chose to work on math problems rather than engage in leisure activities such as playing Tetris or watching videos during three activity sessions	Findings indicated that students with greater interest in mathematics were more likely to choose the cognitively demanding math tasks over the less effortful alternatives
	Song et al. (2019)	8th and 9th grade students	South Korea	Effort avoidance was assessed using a three-item survey, including statements such as: (1) "I solve only easy problems while I do exercises," (2) "When studying mathematics, I skip all the hard parts," and (3) "If I cannot understand the learning materials in mathematics, I just skip it." Students rated their agreement on a 7-point Likert scale ranging from "strongest disagreement" (1) to "strongest agreement" (7)	Results indicated that students with lower interest in mathematics were more likely to avoid challenging problems, preferring to focus on easier tasks
	Xu (2018)	8th grade students	China	Effort was measured using a three-item self-report survey, including the following statements: (1) "I have recently been doing my math homework to the best of my ability," (2) "I do my best on my math homework," and (3) "I always try to finish my math homework." Students rated their agreement on a 4-point Likert scale ranging from "completely disagree" (1) to "completely agree" (4)	Findings revealed a reciprocal relationship between interest and effort: students with greater interest in mathematics reported higher effort investment, and sustained effort over time was associated with the development of increased interest in math

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TABLE 1 (Continued)

The role of	Publication	Population	Location	Measure of effort	Main finding
	Luo et al. (2016)	8th grade students	Singapore	Homework effort was assessed using three items adapted from existing literature (Trautwein et al., 2006b). One example item was: "Even when my math homework is difficult, I try to complete it." The remaining two items were not specified in the source. Students rated their agreement on a 4-point Likert scale ranging from "completely disagree" (1) to "completely agree" (4)	Results indicated a positive association between students' enjoyment of mathematics and their self-reported effort on math homework
	Pinxten et al. (2014)	4th–7th grade students	Belgium	Perceived effort in mathematics was measured using two self-report items: (1) "I put a lot of effort into mathematics," and (2) "I work hard for mathematics." Students rated their agreement on a 5-point Likert scale, though the specific scale anchors were not reported	Findings showed that math enjoyment was concurrently associated with self-reported effort investment in mathematics. Additionally, math enjoyment in 5th grade predicted effort investment in 6th grade, suggesting a longitudinal relationship between enjoyment and effort
Math competence beliefs	Trautwein et al. (2009)	8th and 9th graders	Germany	Academic effort was measured using two parallel six-item scales—one for effort at school and one for effort at home. An example item from the school scale was: "I really work hard on classwork assignments in mathematics." The remaining five items were not reported in the source. The home scale mirrored the school items, substituting "classwork" with "homework." Students rated their agreement on a 4-point Likert scale ranging from "completely disagree" (1) to "completely agree" (4)	Findings indicated that students' beliefs about their math competence significantly predicted their investment in after-school math effort
	Chouinard et al. (2007)	High school students between the ages of 12 and 18	Canada	Effort was measured using a three-item self-report scale. Two of the items were: (1) "I work hard in mathematics," and (2) "When I do mathematics tasks, I work very hard." The third item was not reported in the source. Students rated their agreement on a 5-point Likert scale ranging from "strongly disagree" (1) to "strongly agree" (5)	Findings indicated that students' competence beliefs were a direct predictor of their effort investment in mathematics
	Chen (2002)	7th grade students	United States	Effort was assessed using an effort judgment scale, exemplified by the item: "How much effort did you put into solving this math problem?" The total number of items used was not specified. Students rated their perceived effort on an 8-point scale ranging from "none" (1) to "all" (8)	Results revealed a negative correlation between students' self-efficacy beliefs and their post-performance effort judgments
	Chen and Zimmerman (2007)	7th grade students (United States) and 6th grade students (Taiwan)	United States and Taiwan	Effort was measured using the Mathematics Effort Judgment Scale, which captures students' self-perceived effort immediately after attempting each math problem. For each item, students responded to the prompt: "How much effort did you put into solving this math problem?" using an 8-point scale ranging from "none" (1) to "all" (8)	Findings indicated a negative correlation between students' self-efficacy beliefs and their perceived effort in mathematics
	Pinxten et al. (2014)	4th to 7th graders	Belgium	Perceived effort in mathematics was measured using two self-report items: (1) "I put a lot of effort into mathematics," and (2) "I work hard for mathematics." Students rated their agreement on a 5-point Likert scale, though the specific scale anchors were not reported	Results revealed a consistent pattern of negative associations between prior math competence beliefs and subsequent perceptions of effort investment in mathematics
	Marsh et al. (2016)	Secondary school students (first 4 years)	Germany	Effort in mathematics was measured using a four-item self-report survey. Sample items included: (1) "In math, I invest much effort to understand everything," (2) "In math, I try my best to do everything as well as possible," (3) "I do my math homework as well as I can," and (4) "When we take a math test, I give all my effort." Students rated how diligently they attempted to learn math on a 5-point Likert scale: "not true" (1), "hardly true" (2), "a bit true" (3), "largely true" (4), and "absolutely true" (5)	Findings showed that prior effort investment in math positively influenced subsequent math self-concept, but only among students who already had higher levels of prior math self-concept

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TABLE 1 (Continued)

The role of	Publication	Population	Location	Measure of effort	Main finding
Beliefs about the usefulness of math	Trautwein et al. (2006b)	8th graders	Germany	Math homework effort was assessed using three self-report scales: • Homework compliance (5 items): o *"I often copy math homework from others"* o *"I've recently been doing my math homework to the best of my ability"* o *"I often do my math homework just before the lesson or during breaks"* o *"I do my best on my math homework"* o *"I always try to finish my math homework"* • Homework concentration (4 items): o *"I often get distracted when doing my math homework"* o *"It often takes me longer than necessary to do my math homework because my mind's not on it"* o *"I do my math homework in one go without interruptions"* o *"I concentrate hard when I do my math homework"* • Completed homework (1 item): o *"On average, what percentage of your math homework do you seriously try to do?"*Students rated their agreement with all items on a 4-point Likert scale ranging from "completely disagree" (1) to "completely agree" (4)	Findings indicated that students' perceptions of the usefulness of mathematics significantly predicted their effort investment in math homework assignments
	Trautwein and Lüdtke (2009)	8th and 9th grade students	Germany	Math homework effort was assessed using two self-report scales: • Homework compliance (5 items): o *"I often copy math homework from others"* o *"I've recently been doing my math homework to the best of my ability"* o *"I often do my math homework just before the lesson or during breaks"* o *"I do my best on my math homework"* o *"I always try to finish my math homework"* • Completed homework (1 item): o *"On average, what percentage of your math homework do you seriously try to do?"*Students rated their agreement with all items on 4-point Likert scales ranging from "completely disagree" (1) to "completely agree" (4)	Findings showed that students' perceived value of math homework—including its usefulness and perceived cost—significantly predicted their effort investment. Specifically, value perceptions were associated with both the care students took in completing assignments (homework compliance) and the percentage of homework they attempted each week

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TABLE 1 (Continued)

The role of	Publication	Population	Location	Measure of effort	Main finding
Beliefs about effort	Blackwell et al. (2007)	7th grade students	United States	Effort beliefs were measured using a nine-item subscale developed by Blackwell (2002), consisting of four positively worded and five negatively worded items. Positive items assessed students' belief that effort leads to success (e.g., "The harder you work at something, the better you will be at it"). Negative items reflected beliefs that effort is either indicative of low ability (e.g., "To tell the truth, when I work hard at my schoolwork, it makes me feel like I'm not very smart") or ineffective (e.g., "If you are not good at a subject, working hard will not make you good at it"). The complete list of items was not reported in the source. Students rated their agreement on a 6-point Likert scale ranging from 1 (agree strongly) to 6 (disagree strongly) Effort-based strategies were assessed using a five-item scale that measured students' likely responses to academic challenges. Items included both constructive, effort-focused strategies (e.g., "I would work harder in this class from now on," "I would spend more time studying for tests") and unproductive, effort-avoiding behaviors (e.g., "I would try not to take this subject ever again," "I would spend less time on this subject from now on," "I would try to cheat on the next test"). As with the effort beliefs scale, the full list of items was not provided. Students responded using the same 6-point Likert scale	Findings indicated that effort-based strategies mediated the relationship between students' effort beliefs and improvements in their math grades over time
	Jones et al. (2012)	9th grade students	United States	The nine-item effort beliefs subscale contained four positive and five negative items (Blackwell, 2002). Positive items measured students' belief that effort leads to positive outcomes (e.g., "*The harder you work at something, the better you will be at it*"). Negative items assessed students' belief that effort has an inverse, negative relation to ability ("*To tell the truth, when I work hard at my schoolwork, it makes me feel like I'm not very smart*"), and is ineffective in achieving positive outcomes ("*If you are not good at a subject, working hard will not make you good at it*"). Complete scale with all the items used not reported in the source. Students rated their agreement with all these survey items on a 6-point Likert scale, ranging from "agree strongly" (1) to "disagree strongly" (6) Effort-based strategies were measured using a five-item scale. This scale assessed how likely students were to respond to academic difficulties with different types of strategies. It included both constructive, effort-focused actions (e.g., "*I would work harder in this class from now on*," "*I would spend more time studying for tests*") and unproductive, effort-avoiding behaviors (e.g., "*I would try not to take this subject ever again*," "*I would spend less time on this subject from now on*," "*I would try to cheat on the next test*"). All the items used are not reported in the source. Students rated their agreement with all these survey items on a 6-point Likert scale, ranging from "agree strongly" (1) to "disagree strongly" (6)	Students who hold incremental beliefs about intelligence were more likely to use effort-based learning strategies and, as a result, they were more likely to get high math grades
Individuals' mastery goal	Chouinard et al. (2007)	High school students	Canada	Effort in mathematics was measured using a three-item self-report scale. Two of the items were: (1) "*I work hard in mathematics*" and (2) "*When I do mathematics tasks, I work very hard*." The third item was not reported in the source. Students rated their agreement on a 5-point Likert scale ranging from "*strongly disagree*" (1) to "*strongly agree*" (5)	Findings revealed that mastery goal orientation positively predicted students' investment of effort in mathematics. In contrast, performance-approach goal orientation was negatively associated with math effort investment.
	Lau and Nie (2008)	5th grade students	Singapore	Effort investment in mathematics—referred to as *engagement* in the study—was measured through students' self-reports of how focused, involved, and hardworking they were during math classes, based on established scales (Steinberg et al., 1992; Wellborn and Connell, 1987). The specific items used were not reported in the source Additional dimensions of effort were captured through two motivational constructs: • Avoidance coping (3 items): This scale measured students' tendency to give up when faced with difficult or boring math tasks (adapted from Pintrich et al., 1993). A sample item included: "*When the work in math is difficult, I give up*" • Effort withdrawal (4 items): This construct assessed students' inclination to hold back or exert minimal effort on math tasks (based on Meece et al., 1988; Nicholls et al., 1985). A sample item included: "*I do not work hard on my math homework*" The full list of items was not provided in the source	Findings indicated that students who adopted personal mastery goals—focused on learning and self-improvement—were less likely to give up or avoid challenging or uninteresting math tasks. In contrast, students motivated by performance-avoidance goals (i.e., avoiding failure or appearing incompetent) were more likely to withdraw effort and avoid difficult math tasks.

(Continued)

TABLE 1 (Continued)

The role of	Publication	Population	Location	Measure of effort	Main finding
Contextual variables					
Classroom	Lau and Nie (2008)	5th grade students	Singapore	Effort investment in mathematics—referred to as *engagement* in the study—was assessed through students' self-reports of how focused, involved, and hardworking they were during math classes, using established scales (Steinberg et al., 1992; Wellborn and Connell, 1987). The specific items used to measure this construct were not reported in the source Two additional dimensions of effort were captured through motivational constructs: • Avoidance coping (3 items): Adapted from Pintrich et al. (1993), this scale measured students' tendency to disengage when faced with challenging or uninteresting math tasks. A sample item included: "*When the work in math is difficult, I give up*" • Effort withdrawal (4 items): Based on items from Meece et al. (1988) and Nicholls et al. (1985), this scale assessed students' inclination to withhold effort on math-related tasks. A sample item included: "*I do not work hard on my math homework*" The full list of items for both constructs was not provided in the source	Findings indicated that classroom goal structures significantly influenced students' effort investment. Specifically, mastery-oriented classroom goals negatively predicted effort withdrawal, while performance-oriented classroom goals positively predicted it. In other words, students were more likely to invest effort in classrooms that emphasized learning and self-improvement (mastery goals) than in those that emphasized outperforming others (performance goals)
	Skaalvik et al. (2017)	8th to 10th grade students	Norway	Effort investment in mathematics was measured using a three-item self-report survey. The items included: (1) "*I always do my best when I am working with mathematics*," (2) "*I always do my homework in mathematics*," and (3) "*I often rush through my work in mathematics*" (reverse-coded). Students rated their agreement on a 6-point Likert scale ranging from "*absolutely disagree*" (1) to "*absolutely agree*" (6)	Findings indicated that students who perceived their classroom as mastery-focused were more likely to enjoy mathematics, and this enjoyment, in turn, motivated greater effort investment. Conversely, students in performance-focused classrooms were less likely to find math enjoyable, which subsequently reduced their effort investment
Teachers	Xu et al. (2022)	9th grade students	China	Homework effort was assessed using a three-item scale designed to measure students' initiative in completing mathematics assignments. A sample item included: "*I always try to finish my mathematics assignments*." The remaining two items were not reported in the source. Students rated their agreement on a 4-point Likert scale ranging from "*strongly disagree*" (1) to "*strongly agree*" (4). In addition, homework completion was measured with a single item: "*How much of your assigned mathematics homework do you usually complete?*" Students responded using a 5-point Likert scale: "*none*" (1), "*some*" (2), "*about half*" (3), "*most*" (4), and "*all*" (5)	Findings indicated that instructors' involvement during homework was positively associated with students' homework effort, the number of completed assignments, and their performance on a standardized mathematics test
	Xu et al. (2021)	8th grade students	China	Effort investment in mathematics was measured using a three-item self-report scale. The items included: (1) "*I always try to finish my math homework*," (2) "*I have recently been doing my math homework to the best of my ability*," and (3) "*I do my best on my math homework*." Participants rated their agreement on a 4-point Likert scale ranging from "*strongly disagree*" (1) to "*strongly agree*" (4)	Findings revealed that the impact of instructors' autonomy support in mathematics varied depending on students' level of effort investment. In other words, students who were already investing high effort responded differently to autonomy-supportive teaching compared to those investing less effort
Parents	Silinskas and Kikas (2019)	3rd and 6th grade students	Estonia	A five-item mother-report survey was used to assess children's task persistence during homework. The items included: (1) "If difficulty arises in doing assignments, does the child easily start doing something else?"; (2) "Does the child actively try to manage even the difficult assignments?"; (3) "Does the child easily give up trying?"; (4) "Does the child show activeness or endurance when doing the assignments?"; and (5) "If the assignment does not go well, does the child begin to busy her/himself with this and that?" Mothers rated their child's behavior on a 5-point Likert scale ranging from 1 ("not at all") to 5 ("to a great extent")	Although supportive parental involvement was not directly associated with children's mathematics performance, it was positively related to mother-rated persistence in completing homework
	Xu et al., 2018	9th grade students	China	A three-item self-report survey was used to assess students' effort on math homework. The items included: (1) "I have recently been doing my math homework to the best of my ability"; (2) "I do my best on my math homework"; and (3) "I always try to finish my math homework." Students rated their agreement with each statement on a 4-point Likert scale ranging from 1 ("strongly disagree") to 4 ("strongly agree").	Higher initial levels of autonomy-supportive parental involvement and self-reported homework effort were associated with subsequent academic achievement.

(Continued)

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TABLE 1 (Continued)

The role of	Publication	Population	Location	Measure of effort	Main finding
Socioeconomic status (SES)	Hentges et al. (2019)	5th, 7th and 9th grade students	United States	Effort investment was assessed using a four-item survey measuring perceived cost, or the amount of mental and personal energy students felt was required to succeed in mathematics. The items included: (1) "I'd have to sacrifice a lot of free time to be good at math"; (2) "I'd have to invest a lot of time to get good grades in math"; (3) "Math requires me to give up too many other activities I like"; and (4) "Math demands too much of my energy." Students rated their agreement with each statement on a 5-point Likert scale ranging from 1 ("strongly disagree") to 5 ("strongly agree")	While low socioeconomic status (SES) was not a direct predictor of students' attitudes toward math, students from low-income backgrounds tended to perceive higher costs associated with learning math. These perceived costs, in turn, predicted a decline in their math achievement over time
	Balfanz and Byrnes (2006)	5th to 8th grade students	United States	Effort in math class was measured using a single-item indicator: "How hard are you working in math class?" Students responded on a 7-point Likert scale ranging from 1 ("not hard at all") to 7 ("as hard as I can")	Effort investment emerged as a key factor in explaining the reduction of the math achievement gap in high-poverty middle schools
Culture	Fwu et al. (2014)	Junior high school students	Taiwan	A scenario stimulation method was used to examine students' moral evaluations and credit assignment in academic contexts. Participants read a short story about an imaginary eighth-grade student named Minghua, who was depicted in two contrasting scenarios—one demonstrating high effort and the other low effort—both resulting in academic success. After reading each scenario, students rated their agreement with statements reflecting moral image (e.g., "Minghua fulfills his duty," "Minghua is a good student") and credit assignment (e.g., "Minghua should be praised by his parents," "Minghua should be praised by his teachers"). Responses were recorded on a 6-point Likert scale ranging from 1 ("strongly disagree") to 6 ("strongly agree")	The findings highlight that effort is viewed as morally significant and plays a central role in how credit and blame are assigned in math learning, particularly within Confucian-influenced cultural contexts
Effort as a mechanism explaining the association between affective factors and math achievement					
Math attitudes	Singh et al. (2002)	8th grade students	United States	Effort—referred to as *academic engagement* in the study—was measured by combining the amount of time students spent on math or science homework with the amount of time spent watching television on weekdays. Television viewing time was reverse-coded so that lower screen time indicated higher academic effort. Thus, greater effort was reflected by more time devoted to academic tasks and less time spent on non-academic activities	The study found that students' attitudes toward math influenced their academic achievement by shaping their investment of effort: students with more positive attitudes tended to spend more time on math, which in turn led to higher grades and test scores
	Cole et al. (2008)	College students	United States	Effort was assessed using four subject-specific items in which students reported the percentage of effort they invested in preparing for tests in English, Math, Science, and Social Studies. Responses were recorded on an 11-point scale ranging from 0 to 100%	The study found that the effort students invested in preparing for a math test fully mediated the relationship between their attitudes toward math and their performance, highlighting the central role of effort in translating positive attitudes into academic success
	Trautwein et al. (2009)	8th and 9th grade students	Germany	Academic effort was measured using two parallel six-item scales assessing students' effort in mathematics at school and at home. An example item from the school scale is: "I really work hard on classwork assignments in mathematics." The home scale used identical wording, with "classwork" replaced by "homework." Students rated their agreement with each item on a 4-point Likert scale ranging from 1 ("completely disagree") to 4 ("completely agree"). Although the remaining five items were not reported in the source, both scales aimed to capture students' self-perceived effort in different learning environments	The study found that math competence beliefs—a component of math attitudes measured at Time 1—predicted math achievement at Time 2 through increased effort investment
	Demir-Lira et al. (2020)	9- to 12-year-old children	United States	Effort was not directly measured through self-report or behavioral observation in this study. Instead, researchers inferred effort based on patterns of brain activation. Specifically, greater activation was observed in the inferior frontal cortex—a region associated with the cognitive effort required to retrieve arithmetic facts from long-term memory	Greater inferior frontal cortex activation in children with lower math skills but positive attitudes toward math, suggesting that such students may compensate for lower proficiency by exerting greater mental effort during mathematical tasks

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TABLE 1 (Continued)

The role of	Publication	Population	Location	Measure of effort	Main finding
	Suárez-Pellicioni et al. (2021)	8–14 years old at Time 1 and 10–16 years old at Time 2	United States	Effort was not directly measured through self-report or behavioral observation in this study. Instead, researchers inferred effort based on patterns of brain activation. Specifically, greater activation was observed in the inferior frontal cortex—a region associated with the cognitive effort required to retrieve arithmetic facts from long-term memory	Activation in a cluster within the inferior frontal gyrus—overlapping with the region identified by Demir-Lira et al. (2020)—significantly predicted improvements in math achievement over a two-year period among children with positive attitudes toward math
Math anxiety	Jenifer et al. (2022)	High school students	United States	Math exam preparation effort was assessed using three self-reported indicators that captured students' intended study behaviors for an upcoming Calculus exam: • Perceived effort of study strategies: Students ranked six common study techniques (e.g., reading textbook material for the first time, re-reading, reviewing homework) from most to least effortful. A rank of 1 indicated the most demanding strategy, while 6 indicated the least • Study time distribution: Students allocated 100% of their planned study time across the six strategies using a percentage-based format, indicating how much time they intended to devote to more versus less effortful activities • Preference for problem difficulty: Students rated their intended focus on easy versus challenging practice problems using a 7-point scale, where 1 represented a focus on easier problems and 7 indicated a focus on more difficult ones	Students with high levels of math anxiety tend to adopt less effortful test-taking and learning strategies—such as reading textbooks and reviewing homework—rather than more cognitively demanding approaches like actively solving math practice problems
	Choe et al. (2019)	19–57 years old participants	United States	Effort in mathematics was assessed using two behavioral indicators during the *Choose-and-Solve Task*. First, participants' frequency of selecting harder, high-reward problems over easier, low-reward ones served as a measure of their willingness to exert mental effort. Since the harder problems required greater cognitive engagement, choosing them more often indicated a higher investment of effort. Second, the difficulty level of the hard problems was dynamically adjusted based on each participant's performance to maintain an accuracy rate of approximately 70%. The average difficulty level of the problems each participant completed was used as an additional indicator of their effort in tackling challenging material	The findings revealed that individuals with higher math anxiety tended to avoid difficult math problems—even when those problems offered greater rewards—preferring instead to solve easier, low-reward problems. This pattern suggests a tendency toward effort avoidance in the context of math-related tasks
	Yu et al. (2021)	10th grade students	China	In this study, effort was conceptualized as *math-specific grit* and assessed using an adapted version of the persistence of effort subscale from the Grit-S (Schmidt et al., 2017). The scale included four items, such as "When learning math, I finish whatever I begin." The remaining three items were not reported in the source. Participants rated each item on a 5-point Likert scale ranging from 1 ("not at all like me") to 5 ("very much like me")	The findings indicated that when math-specific effort and persistence were accounted for, the previously significant negative correlation between math anxiety and math achievement was no longer statistically significant. This suggests that reduced effort may be a key mechanism through which math anxiety negatively impacts performance
Effort as the foundation for cultivating positive attitudes and emotions in mathematics					
Math enjoyment	Chue (2020)	Students enrolled in a mathematics module as a prerequisite for undergraduate education	Singapore	Effort in mathematics was assessed using a five-item self-report instrument adapted from the Work Effort Scale (De Cooman et al., 2009), with items modified to reflect effort specifically in the math domain. The scale captured two key dimensions of effort: intensity, referring to the level of exertion students applied to their work, and persistence, reflecting their tendency to sustain effort over time. Students responded to each item on a 7-point Likert scale ranging from 1 ("strongly disagree") to 7 ("strongly agree"). Example items included "I do not give up quickly when solving math problems" and "I do my best in my math assignments." The full list of items was not reported in the source	The study found that students' enjoyment of math mediated the relationship between effort investment and math performance, suggesting that positive emotional engagement may enhance the effectiveness of effort
Math interest	Xu (2018)	8th graders	China	Effort on math homework was assessed using a three-item self-report survey. The items included: (1) "I have recently been doing my math homework to the best of my ability"; (2) "I do my best on my math homework"; and (3) "I always try to finish my math homework." Students rated their agreement with each statement on a 4-point Likert scale ranging from 1 ("strongly disagree") to 4 ("strongly agree")	The study identified a reciprocal relationship between math interest and effort: math interest at Time 1 predicted effort at Time 2, and effort at Time 1 also predicted math interest at Time 2, suggesting a dynamic interplay between motivation and engagement over time

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that effort may be a precursor to the development of positive attitudes and emotions toward math (see Sections 7 and 8).

5 What individual variables explain differences in effort investment?

5.1 The role of sex

Some studies suggest that women are more likely than men to use effortful learning strategies such as planning, goal-setting, and self-monitoring (Zimmerman and Martinez-Pons, 1990). Male students, on the other hand, tend to rely on less effortful strategies (Cooper et al., 1991), such as skipping difficult math questions (Song et al., 2019). These differences also appear in effort perceptions as well: women in STEM fields report feeling that they must invest more mental effort to succeed in math tasks compared to their male peers (Smith et al., 2013; Study 1).

This perception is echoed in how educators interpret student performance. For example, secondary school math teachers are more likely to attribute girls' success in math to hard work and boy's failure to a lack of effort, rather than to ability in either case (Espinoza et al., 2014).

Stereotypical beliefs, such as the notion that math is a predominantly male domain, may impact how much effort students invest, or report. Girls who struggle with math may attribute their difficulties to a lack of innate ability, leading them to believe that effort is futile. Conversely, boys who endorse the same stereotype might feel pressure to perform effortlessly, as struggling would challenge the notion that they are inherently skilled. Consequently, while girls may disengage due to a perceived mismatch between identity and ability, boys may withhold effort to maintain the illusion of innate competence (Greene et al., 1999).

Sex differences have also been observed in the relationship between effort and math performance. Matteazzi et al. (2021) found that time spent studying math at home was positively associated with math achievement for male high school students, but not for females. The authors suggested that this may be due to boys using their study time more effectively, possibly of their greater involvement in sports, which may enhance focus and time management. In contrast, they speculated that girls might not benefit as much from study time due to lower confidence in their math abilities, or higher levels of math anxiety (Matteazzi et al., 2021).

5.2 The role of age

Trautwein et al. (2006a) conducted a cross-sectional study examining age-related differences in math homework behaviors among fifth, seventh, and ninth grade students. Math effort was measured using a survey referring to math homework effort (e.g., "*I often copy math homework from others at school*"). The results showed a decline in homework effort with age, with ninth graders reporting significantly lower effort than fifth graders. Similar findings were reported by Upadyaya and Eccles (2015), who observed a decrease in teacher-rated math effort as students grew older. This age-related decline may be attributed to the increasing difficulty of math content over time (Ma and Kishor, 1997), as well as a concurrent decline in students' self-concept and enjoyment of math (Trautwein et al., 2006a).

5.3 The role of mathematical skills

It may seem intuitive to assume that individuals with lower skill levels need to invest more effort. However, the limited evidence available suggests the opposite. Fisher et al. (2012) videotaped children while interacting with an educational math activity. Math skill levels were significantly associated with two behavioral indicators: time on task (i.e., duration of active engagement with math materials) and goal-directed play (i.e., sustained, purposeful attention). Importantly, math skill at Time 1 predicted both time on task and goal-directed play at Time 2, even after controlling for initial levels of these behaviors. Additionally, goal-directed play at Time 1 predicted later math skill, independent of initial ability. These findings suggest a bidirectional relationship: early competence fosters greater engagement, and sustained, purposeful effort supports continued skill development.

Supporting this pattern, Helwig et al. (2001) found a positive correlation between teacher-rated math skills and teacher-rated students' effort in math among third and fifth graders. Similar results have been observed in reading, where proficient readers were more likely to invest more time and focus on relevant content as task difficulty increased (Naumann, 2019). Xie et al. (2013) further explored the interaction between ability and effort by comparing math posttest scores across four groups defined by high or low levels of both variables. Students with high ability and high effort achieved the highest math scores, while those with lower ability and low effort scored the lowest. Notably, students with low ability but high effort performed worse than those with high ability but low effort, suggesting that ability had a stronger influence on performance than effort alone. However, a significant interaction was found: students who exerted high effort outperformed their low-effort peers, regardless of ability level. These findings highlight the combined, multiplicative effect of ability and effort, with the best outcomes achieved when both are high (Xie et al., 2013).

5.4 The role of math attitudes

One of the earliest and most comprehensive definitions of math attitudes describes them as "an aggregated measure of liking or disliking of math, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics (i.e., math competence beliefs), and a belief that mathematics is useful or useless (i.e., perceived usefulness of math)" (Neale, 1969, p. 632). In a study of 16-year-old students, Hemmings and Kay (2010) found a relatively strong positive correlation ($r = 0.55$) between math attitudes and effort investment, as measured by the Effort scale from the Inventory of School Motivation (e.g., Ali and McInerney, 2005). While some studies have examined math attitudes as a unified construct (Neale, 1969), others have focused on specific subcomponents such as self-competence beliefs, or perceived usefulness of math. In the following sections we explore in greater depth how these individual components of math attitudes relate to effort investment in math.

5.4.1 The role of math interest and math enjoyment

People tend to invest more effort in tasks they find interesting (Thoman et al., 2011). In the context of mathematics, Milyavskaya et al. (2021), Study 3 found that high school students who reported greater interest in math were more likely to choose cognitively demanding math problems over leisure activities such as playing Tetris or watching a movie. Similarly, Song et al. (2019) showed that math interest (e.g., "I find mathematics interesting") positively predicted effort investment, referred to in this study as "persistence" (e.g., "If a mathematics problem is really hard, I keep working on it") and negatively predicted effort avoidance (e.g., "When studying mathematics, I skip all the hard parts"). Less interested students were more likely to prioritize easy problems and avoid challenging ones.

Using a longitudinal design, Xu (2018) examined the relationship between math interest and math homework effort among Chinese eighth graders. Results showed that math interest at Time 1 predicted homework effort at Time 2 (e.g., "*I have recently been doing my math homework to the best of my ability*"), and vice versa, with effort at Time 1 also predicting later interest. This suggests a reciprocal relationship in which interest fosters effort, and effort, in turn, enhances math interest over time.

Additional studies support this pattern. Luo et al. (2016) found that math enjoyment was positively associated with self-reported math homework effort among eighth graders in Singapore. Pinxten et al. (2014), in a longitudinal study of Belgian students from grades 4 to 7, found that math enjoyment was not only concurrently associated with effort investment in math, but also predicted effort in the following academic year (6th). Together, these findings support the intuitive yet empirically grounded idea that students are more likely to invest more effort in math when they find it enjoyable or interesting.

5.4.2 The role of math competence beliefs

In the literature, competence beliefs have been described using various terms, including self-efficacy beliefs (Bandura, 2008) and self-concept (Marsh, 1990). While these constructs differ slightly in definition, they fundamentally refer to individuals' perceptions of their ability to accomplish a goal (Malmberg and Martin, 2019). Although competence beliefs are often assumed to influence effort investment, research findings on this relationship are mixed.

On one hand, several studies have found a positive association between competence beliefs and effort investment. For instance, Trautwein et al. (2009) reported that math competence beliefs (e.g., "I really work hard on classwork assignments in mathematics") predicted after-school math effort [e.g., "If I make an effort, I can do all of my math homework (classwork)"] among German eighth and ninth graders. Similarly, Chouinard et al. (2007) found that competence beliefs, measured with the confidence Scale from Fennema and Sherman's (1976) Mathematics Attitude Scales, directly predicted of effort investment in math (e.g., "I work hard in mathematics") among students in grades 7 through 11. These findings suggest that students who perceive themselves as more competent in math tend to put more effort in the subject.

On the other hand, other studies have found a negative relationship. For instance, Chen (2002) found that seventh-grade students' self-efficacy beliefs (e.g., "How confident are you about solving this math question correctly") were negatively correlated with their post-performance effort judgments. Similarly, Chen and Zimmerman (2007) observed negative correlations between self-efficacy and perceived effort in both American and Taiwanese middle school samples. In a longitudinal study, Pinxten et al. (2014) found that math competence beliefs in grade 4 negatively predicted effort investment in grade 5 and beliefs in grade 5 negatively predicted effort in grade 6. These findings suggest that students who perceive themselves as more competent in math may report exerting less effort in math, possibly because they feel less need to do so.

Further nuance is provided by Marsh et al. (2016), who analyzed longitudinal data from German secondary students and found an interaction between prior effort (e.g., "It is easy for me to learn in math") and prior math self-concept (e.g., "In math, I try hard to understand everything") in predicting later self-concept (however, see Xu, 2018). Specifically, prior effort positively influenced subsequent math self-concept only for students who already had high math self-concept. For those with low initial self-concept, prior effort actually had a negative effect on later self-concept. This finding suggests that while effort can reinforce confidence in students who already feel capable, it may undermine confidence in those who do not, perhaps because effort without success reinforces feelings of inadequacy.

5.4.3 The role of beliefs about the usefulness of math

Students' beliefs about the usefulness of math are considered another key subcomponent of math attitudes. Trautwein et al. (2006b) investigated the relationship between perceived usefulness of math (e.g., "I do not learn much from our math homework") and homework effort among German eighth graders. They found that students who perceived math as more useful invested greater effort in their math homework. This finding was later replicated by Trautwein and Lüdtke (2009), who conceptualized usefulness of math as the perceived value of math homework. Together, these studies suggest that students are more likely to invest effort in math when they believe it has practical value or relevance to their lives.

5.5 The role of beliefs about effort

Beliefs about the role of effort in shaping intelligence and achieving success can explain individual differences in students' willingness to invest effort in math. Blackwell et al. (2007) found that effort beliefs (e.g., "*The harder you work at something, the better you will be at it*") mediated the relationship between students' endorsement of the incremental theory of intelligence—the belief that intelligence is malleable and can be improved through effort (e.g., "*You can always greatly change how intelligent you are*"; Dweck, 1999)—and their use of effort-based strategies (e.g., "*I would work harder in this class from now on*"). Furthermore, effort-based strategies mediated the relationship between effort beliefs and improvement in math grades. These findings suggest two key mechanisms. First, students who believe intelligence is malleable are more likely to value effort, which increases the likelihood of adopting effort-based learning strategies that enhance performance. Second, students who believe in the value of effort are more likely to engage in these strategies, which in turn leads to better math outcomes (Blackwell et al., 2007). Supporting this, Jones et al. (2012) found that ninth-grade students who endorse incremental beliefs about intelligence were more likely to believe that effort leads to math success. These students were also more likely to use effort-based learning strategies and, as a result, achieved higher math grades. Taken together, these studies suggest that students' beliefs about the malleability of intelligence and the importance of effort play a critical role in shaping their academic behaviors and outcomes in math, primarily thorough the adoption of effort-based strategies.

5.6 The role of individuals' mastery goals

Individuals differ in their motivational orientations when approaching learning situations. Some adopt a performance goal orientation, aiming to demonstrate their competence and gain favorable evaluations from others. Others exhibit a performance-avoidance goal orientation, where the focus is on avoiding negative judgments and not appearing inferior. In contrast, those with a mastery goal orientation are primarily motivated by a desire to learn, understand, and develop new skills (Linnenbrink and Pintrich, 2002). Chouinard et al. (2007) found that mastery goal orientation positively predicted effort investment in math, whereas performance-approach goal orientation negatively predicted it among high school students. Similar findings were reported by Lau and Nie (2008) in a study of Singaporean fifth graders. Together, these results suggest that students who are motivated by a genuine desire to understand math (i.e., mastery goal) are more likely to invest effort in the subject than those driven by external evaluations or fear of failure.

6 What contextual variables explain differences in effort investment?

6.1 The role of the classroom

The distinction between mastery and performance goals at the individual level (Section 5.6) can also be applied to the classroom environment. In a mastery goal-oriented classroom, the emphasis is on learning, understanding and skill development. In contrast, a performance goal-oriented classroom focuses on demonstrating competence, receiving favorable evaluations, and competing for high grades (Lau and Nie, 2008; Patrick et al., 2011). Research indicates that the classroom's goal structure significantly influences students' effort investment. For instance, Lau and Nie (2008) found that a mastery-oriented classroom climate negatively predicted students' effort withdrawal, while a performance-oriented climate positively predicted it. In other words, students were more likely to invest effort in classrooms that emphasize mastery rather than performance. Further supporting this, Skaalvik et al. (2017) studied Norwegian middle school students and found that perceived classroom mastery goals were indirectly and positively related to effort investment through enjoyment. Students who perceive their classroom as mastery-focused were more likely to enjoy math and this enjoyment, in turn, motivated greater effort. Conversely, performance-oriented classroom structures were negatively associated with enjoyment, which subsequently reduced effort investment. Overall, these findings align with individual-level evidence (see Section 5.6) and suggest that when the classroom environment emphasizes learning and mastery over competition and grades, students are more likely to enjoy math and invest greater effort in it.

6.2 The role of teachers

Xu et al. (2022) demonstrated that instructors' involvement during homework was significantly associated with Chinese secondary school students' homework effort, number of completed assignments, and performance on a standardized math test. Instructors involvement was assessed across three dimensions: autonomy support (e.g., "My mathematics teacher encourages me to ask questions about homework assignments"), homework quality (e.g., "Our mathematics teacher knows what homework to give us so that we understand the material covered in the lesson"), and feedback quality (e.g., "The feedback I receive from my mathematics teacher helps me do my work"). Students who rated their mathematics instructor highly on all three dimensions were more likely to invest effort in their math homework, complete more math assignments, and perform better on standardized math assessments.

A related study by the same group (Xu et al., 2021) found that the impact of instructor autonomy support (e.g., "My math teacher encourages me to ask questions about homework assignments") varied depending on students' initial effort levels. For students who were already investing substantial effort in math, autonomy support predicted improved performance on standardized math tests. In contrast, for students with lower initial effort, autonomy support did not directly enhance math performance but instead predicted increased subsequent effort (e.g., "I do my best on my math homework"). These findings suggest a differentiated effect: autonomy support boosts performance for already-engaged students and encourages greater effort among those less engaged. Taken together, these studies underscore the importance of instructor behaviors, particularly autonomy support, homework quality and feedback, in fostering student effort and enhancing math achievement.

6.3 The role of parents

Parental involvement plays a critical role in shaping students' effort investment. When parents support their children education, by encouraging study habits or assisting with homework, students are more likely to invest effort, which can positively influence academic achievement (Opdenakker and Van Damme, 2005). According to Moorman and Pomerantz (2008), parents who promote autonomy by allowing children to solve problems independently and offering assistance only when needed, foster persistence and self-regulation. In contrast, when parental involvement is perceived by children as intrusive, controlling, and disruptive, it can undermine children's confidence and sense of competence, ultimately reducing their persistence and academic performance. In contrast, when parental involvement is perceived as intrusive, controlling, or disruptive, it can undermine children's confidence and sense of competence, ultimately reducing their persistence and academic performance.

Silinskas and Kikas (2019) found that parental control (e.g., "My parents often interfere when I'm doing math homework") was associated with lower levels of mother-rated persistence in doing math homework and poorer math performance among sixth graders. In contrast, more supportive parental involvement (e.g., "When I'm doing math homework, I can ask my parents for help at any time") was positively associated with persistence, though not directly with performance.

A longitudinal study by Xu et al. (2018) with ninth-grade students further highlighted the importance of autonomy-supportive parenting. Higher initial levels of autonomy-based support ("When my parents help me with my homework, they always encourage me first to find the correct answers for myself") and homework effort predicted subsequent academic achievement. Conversely, overly directive help (e.g., "My parents always help me if I get stuck with math homework") was linked to lower later achievement, suggesting that excessive assistance may prevent students from developing the persistence needed for success. Interestingly, the study also found that students who initially demonstrated higher effort later received more autonomy-oriented support from their parents—indicating that parents may adjust their involvement based on their child's demonstrated motivation and effort.

Together, these findings underscore the importance of balanced, autonomy-supportive parental involvement in fostering students' effort and academic success in mathematics.

6.4 The role of socio-economic status

Research has consistently shown that socioeconomic status (SES) has a negative effect on math achievement (Hernandez, 2014; Valero et al., 2015). The evidence of the association between SES and effort in math is very scarce. Hentges et al. (2019) conducted a longitudinal study with fifth-, seventh-, and ninth-grade students in the US. They examined the relationship between socioeconomic (SES) status (as indicated by eligibility for free or reduced-price lunch), student's evaluation of the level of effort required to excel in math (i.e., perceived cost), and math achievement. The researchers found that compared to other students, students from low-income families tended to perceive higher costs of learning math, which in turn predicted their decline in math grades over time. They also found that low SES was not a significant predictor of math attitudinal beliefs such as interest, perceived ability, and usefulness of math suggesting that SES may more strongly influence how students weigh the immediate costs of learning math a rather than their general attitudes toward it. Specifically, some evidence suggests that children in socioeconomically disadvantaged conditions recognize the long-term benefits of math for academic success, but they may view the immediate effort and resources needed to excel in math as too costly (Hentges et al., 2019).

Balfanz and Byrnes (2006) found that effort investment was an important factor in explaining the reduction in the math achievement gap in high-poverty middle schools, with students who indicated investing more effort in math ("*I'm working as hard as I can in math class*") having up to 19% greater probabilities of catching up than those who indicated low effort ("*I'm not working hard at all*"). This finding aligns with broader research on academic effort. For instance, Jin (2024) investigated the relationship between family SES, academic effort investment, and Chinese student's achievement. The author found that Chinese students from low-SES backgrounds who reported having invested greater effort (subjective effort) or dedicated more time to studying (objective effort) show significant improvements in academic achievement. In contrast, students from high-SES families often reported putting in less subjective effort or spending less time studying, yet their academic performance remained largely unaffected. These findings highlight the critical role of effort for individuals from disadvantaged socioeconomic conditions. They suggest that despite adversity, students from low-SES families can still achieve academic success through persistent and determined effort (Jin, 2024). However, while these studies suggest that effort investment may help mitigate the negative effects of poverty on math achievement, they do not imply that underperformance is simply due to a lack of effort. More research is needed to address this imperative and complex question.

6.5 The role of cultural differences

Several studies have documented clear cultural differences in beliefs about effort and its value, particularly between "Western" (e.g., USA, Canada, England) and "Eastern" (e.g., India, Japan, China) societies. In many Eastern cultures, continuous self-improvement is viewed as a moral virtue (Li, 2012), which significantly shapes students' learning attitudes and behaviors. For instance, in a cross-cultural study, children from Japan, Canada, and the United States were asked to open a jar that contained a toy. The results showed that American children were more likely to seek adult assistance, whereas Japanese children were more likely to persist independently in solving the task (Broesch et al., 2017). In some Eastern societies such as Taiwan, effort in math learning is not only associated with academic success but is also seen as a moral obligation. Students are encouraged to work hard because it is considered the right thing to do, regardless of the outcome. As a result, even when students do not achieve high grades, their effort is still recognized and praised by teachers (Fwu et al., 2014). Cultural differences in effort beliefs have also been observed within countries. For instance, East German students were more likely than their West German peers to attribute academic success to hard work and effort, reflecting a stronger meritocratic belief system (Trautwein et al., 2006c). Overall, these findings highlight the powerful role of cultural values in shaping students' beliefs about effort and their willingness to invest in learning—particularly in mathematics.

7 Effort as the mechanism explaining the association between affective factors and math achievement

Student performance in mathematics is shaped not only by cognitive abilities but also by affective factors. While cognitive abilities determine the resources students possess, affective factors influence their willingness to invest those resources in a given task (Hepler and Albarracin, 2014; Demir-Lira et al., 2020; Suárez-Pellicioni et al., 2021). In the following sections, we review literature suggesting that effort and lack of effort may serve as key mechanisms through which math attitudes and math anxiety, respectively, impact math performance.

7.1 Effort as the potential mechanism explaining the positive effects of math attitudes on math performance

Singh et al. (2002) found that math attitudes significantly influenced math achievement both directly and indirectly. Directly, students with positive math attitudes were more likely to earn higher grades and score better on math achievement tests. Indirectly, math attitudes affected math achievement through effort investment, measured as the number of hours that students spent completing math homework versus watching television. In other words, students with more positive math attitudes were more likely to dedicate time to learning, and this increased effort translated into better academic outcomes. Similar findings were reported by Cole et al. (2008), who measured math attitudes as perceived usefulness and importance of math among college students. They found that effort invested in preparing for a math test fully mediated the relationship between math attitudes and performance. Likewise, Trautwein et al. (2009), in a study of German eighth graders found that math competence beliefs at Time 1 predicted math achievement at Time 2 through increased effort investment, operationalized as homework compliance (e.g., "I always try to complete my mathematics homework"). Together, these studies support the intuitive notion that effort investment is a key mechanism through which positive math attitudes enhance performance.

Neuroscientific evidence further supports this relationship. Using functional magnetic resonance imaging (fMRI), Demir-Lira et al. (2020) investigated the neural basis of the interaction between math attitudes and math skills in children. They found greater activation in the inferior frontal cortex, a brain region associated with cognitive effort during arithmetic retrieval (Prado et al., 2011, 2014), in children with lower math skills but positive math attitudes. Although effort was not measured directly, the authors interpreted this activation as evidence that low-skill, high-attitude children were exerting more cognitive effort than their low-attitude peers. In a follow-up study, Suárez-Pellicioni et al. (2021) found that activation in a similar region of the inferior frontal gyrus predicted improvements in math achievement over 2 years, but only for children with positive math attitudes. This suggests that cognitive effort may be a key mechanism explaining why students with positive math attitudes tend to improve more over time. These findings align with earlier behavioral research evidence (Singh et al., 2002; Cole et al., 2008; Trautwein et al., 2009), reinforcing the idea that positive math attitudes promote greater cognitive effort, which in turn enhances math performance.

7.2 Lack of effort as the potential mechanism explaining the effects of math anxiety on math performance

Math anxiety is commonly defined as a feeling of tension, apprehension, or even dread, that interferes with the manipulation of numbers and the solving of mathematical problems (Ashcraft and Faust, 1994, p. 98). A substantial body of research has documented the detrimental effects of math anxiety on math performance (e.g., Suárez-Pellicioni et al., 2016). Individuals with high levels of math anxiety tend to adopt less effortful learning and test-taking strategies, such as passively reading textbooks or reviewing homework, rather than engaging in more cognitively demanding activities like solving math practice problems (Jenifer et al., 2022). This pattern aligns with the broader tendency of math anxious individuals to avoid math-related tasks (Ashcraft and Faust, 1994; Hembree, 1990) and with findings that they are less likely to enjoy thinking about complex or abstract problems (Maloney and Retanal, 2020). Supporting this, Choe et al. (2019) found that individuals with higher math anxiety were more likely to avoid difficult math problems, even when those problems offered greater rewards. Instead, they preferred easier, lower-reward math problems, suggesting a clear pattern of effort avoidance.

Further evidence comes from Yu et al. (2021), who found that students with higher math anxiety performed worse in math. However, when effort and persistence in math were included in the analysis, the previously significant negative correlation between math anxiety and math achievement became non-significant. This suggests that reduced effort may be a key mechanism through which math anxiety impairs performance: students with high math anxiety may underperform not because of lack of ability, but because they are less willing to invest the effort required to succeed.

8 Effort as the foundation for cultivating positive attitudes and emotions in mathematics

Beyond its association with math achievement and its mediating role between affective factors and performance, another important reason to study effort in math is its connection to the development of positive attitudes and emotions toward the subject.

In a cross-sectional study, Chue (2020) examined the relationship among math enjoyment, effort investment, and math performance among students enrolled in a mathematics module required as a prerequisite for undergraduate education. The study found that enjoyment mediated the relationship between effort and performance, suggesting that students must first invest effort in understanding math before they can begin to enjoy it. This initial effort may help students appreciate the subject and experience satisfaction from recognizing correct answers, which aligns with their desire for immediate feedback and gratification (Bembenutty and Karabenick, 1998). Once enjoyment is established, it further motivates them to engage with math, leading to improved academic outcomes. This finding is consistent with other research showing that enjoyment can predict better math performance (Pinxten et al., 2014). Similarly, Xu (2018) found a reciprocal relationship between math interest and effort in a longitudinal study. Not only did math interest at Time 1 predict effort at Time 2, but effort at Time 1 also predicted increased math interest at Time 2. Together, these findings suggest that effort investment may not only mediate the relationship between affective factors and performance but may also *precede* and foster the development of positive math attitudes (interest) and emotions (enjoyment).

9 Motivating students to invest effort in math

One effective way to increase students' efforts in mathematics is by helping them understand the value and real-world applicability of math across various life domains. When students perceive math as relevant to their daily lives and future goals, they a more likely to invest effort in learning the subject. In an intervention study, Brisson et al. (2017) assigned ninth-grade students to one of two conditions: a quotations condition, in which students read testimonials from older peers about the relevance of mathematics, and a text condition, in which students wrote about the importance of math themselves. Students in the quotations condition were rated by their teachers as exerting more effort than those in the text condition. Hearing relatable testimonials from older students may have helped participants internalize the value of math, thereby increasing their motivation and effort.

Another strategy to boost effort investment is fostering a growth mindset, the belief that intelligence and abilities can be developed through dedication and hard work (Dweck, 2006; Yeager and Dweck, 2012; Macnamara and Burgoyne, 2023). Bettinger et al. (2018) experimentally manipulated students' beliefs about their ability to learn and measured the effects 3 weeks later on algebra performance. This study was among the first to demonstrate a direct link between changes in mindset and performance on an effortful math task. These findings suggest that emphasizing the connection between effort and success can motivate students to work harder.

Effort-based praise is another powerful tool for increasing motivation and performance in math. Zentall and Morris (2010) found that children who received praise focused on effort (e.g., "Y*ou worked hard*") were more likely to attribute their success to diligence and consistent practice, whereas those who received ability-based praise (e.g., "*You're so smart*") attributed success to innate ability. Effort-based praise has also been linked to greater task persistence, as shown by increased time and quantity of problem-solving (Medway and Venino, 1982), as well as a preference for challenging tasks and the belief that effort leads to success (Gunderson et al., 2013). Mueller and Dweck (1998) similarly found that praising effort led to greater persistence, enjoyment, and performance compared to praising intelligence. Collectively, these findings suggest that effort-based feedback fosters a growth mindset, helping students persevere through challenges and increasing their willingness to invest effort in math learning.

10 Conclusion

Investing cognitive effort is essential for learning mathematics. Despite its importance, to the best of our knowledge, no prior study has comprehensively reviewed the literature on the role of effort in math learning. This review aimed to address that gap by mapping existing evidence, identifying key concepts, and highlighting areas in need of further research.

At the individual level, several variables help explain variability in effort investment. While some studies suggest that women report higher effort than men in math (Zimmerman and Martinez-Pons, 1990), these differences may reflect attributional patterns rather than actual differences in effort (Espinoza et al., 2014). Age and skill level also appear influential: younger students tend to invest more effort than older ones (Trautwein et al., 2006a; Upadyaya and Eccles, 2015) and higher-skilled individuals often invest more effort (Fisher et al., 2012; Helwig et al., 2001). However, these findings are limited and require replication.

The literature is more consistent regarding math attitudes. Positive attitudes, such as interest or perceived usefulness, are strongly associated with greater effort investment (Hemmings and Kay, 2010) and showing that those who are more interested in math and enjoy math invest more effort in learning it (Luo et al., 2016; Milyavskaya et al., 2021; Song et al., 2019; Xu, 2018; Pinxten et al., 2014). Beliefs in the value of effort and the malleability of intelligence also predict greater effort (Blackwell et al., 2007; Jones et al., 2012). Similarly, a mastery goal orientation, focused on learning and developing skills positively predicts effort, in contrast to performance-goal orientation (Chouinard et al., 2007; Lau and Nie, 2008).

The relationship between math self-confidence and effort is less clear. Some studies report a positive association (Chouinard et al., 2007; Trautwein et al., 2009), while others find a negative association (Chen, 2002; Chen and Zimmerman, 2007; Pinxten et al., 2014). These inconsistencies may stem from differences in age groups or sample characteristics, highlighting the need for further investigation.

Contextual factors also play a significant role. Classrooms that emphasize mastery goals foster greater effort than those focused on performance (Lau and Nie, 2008; Patrick et al., 2011). Teacher behaviors, such as autonomy support, high quality homework, and constructive feedback are positively associated with student effort (Xu et al., 2021, 2022). Parental involvement is beneficial when it is supportive and autonomy-promoting (Opdenakker and Van Damme, 2005; Silinskas and Kikas, 2019; Moorman and Pomerantz, 2008), but excessive or controlling parental help can hinder effort (Xu et al., 2018).

The literature on socioeconomic status (SES) and effort is limited and mixed. Some evidence suggests that students from low SES backgrounds can achieve strong outcomes through high effort (Jin, 2024), while other studies highlight SES-related differences in perceived costs and benefits of effort (Hentges et al., 2019). More research is needed to clarify these dynamics. Cultural beliefs also influence effort, with Eastern societies emphasizing effort and hard work, while Western cultures often prioritize innate abilities (Trautwein et al., 2006c).

Importantly, this review highlights that effort investment mediates the relationship between affective factors and math achievement. Positive math attitudes enhance performance through increased effort (Cole et al., 2008; Singh et al., 2002; Trautwein et al., 2009), while reduced effort helps explain the negative impact of math anxiety on performance (Choe et al., 2019; Yu et al., 2021; Jenifer et al., 2022). Moreover, initial effort has been shown to foster later interest and enjoyment in math (Chue, 2020; Xu, 2018).

To promote e effort in math, educators and parents can emphasize the subject's relevance to everyday life and future success (Brisson et al., 2017), cultivate a growth mindset (Dweck, 2006; Macnamara and Burgoyne, 2023; Yeager and Dweck, 2012), and provide effort-based praise rather than ability-based praise (Medway and Venino, 1982; Mueller and Dweck, 1998; Zentall and Morris, 2010). These strategies can help students persist through challenges and invest the sustained effort needed for success in mathematics.

11 Limitations and future directions

The majority of the studies reviewed in this paper assessed effort using self-report measures, where participants were asked to indicate how much effort they invested in a math task (e.g., Trautwein et al., 2006a; Trautwein, 2007; Trautwein and Lüdtke, 2007, 2009; Xu, 2018). However, several concerns have been raised regarding the validity and reliability of self-reports. Some researchers argue that asking participants to reflect on their effort may interrupt task performance (Antonenko et al., 2010), divert attention from the task itself (Zimmerman, 2008), or even alter the cognitive processes being measured (Van Gog et al., 2012). Additionally, the timing of self-report collection can influence results (Chen, 2003; Chen and Zimmerman, 2007; Schmeck et al., 2015) and individual differences in interpreting questions or using numerical scales can further compromise reliability

(Vanneste et al., 2021). Some scholars have even questioned whether individuals can accurately introspect on their own effort, suggesting that effort may be, at least in part, an unconscious process (Zijlstra, 1993). Moreover, self-reports are retrospective and cannot capture real-time fluctuations in cognitive effort (Matthews et al., 2020).

Alternative approaches include behavioral measures such as time on task, for example time spent on homework (e.g., Suárez et al., 2019; Singh et al., 2002; Schmitz and Skinner, 1993) or math practice (e.g., Benedict and Anderton, 2004; Saville et al., 2006). However, these measures may also not accurately reflect cognitive engagement, as time spent with materials does not necessarily equate to effort. Similarly, some studies have measured effort by counting the number of math problems solved or attempted within a set time (e.g., Medway and Venino, 1982; Trautwein and Lüdtke, 2009), but this too can be misleading, as individuals with different skill levels may achieve similar outcomes with varying levels of effort.

To address these limitations, some researchers have turned to physiological measures as a more objective indicator of cognitive effort (Charles and Nixon, 2019; Tao et al., 2019; Kramer, 2020; Das Chakladar and Roy, 2024). These include heart rate variability measures (Lyu et al., 2018; Singh et al., 2019), eye-tracking metrics such as pupil dilation (Beatty, 1982; Hess and Polt, 1964; Kahneman and Beatty, 1966), and skin conductance (Ghaderyan et al., 2018; Nourbakhsh et al., 2012). Physiological measures offer the advantage of capturing real-time effort without relying on introspection (Ayres et al., 2021), but this literature remains limited. Future research should continue exploring the use of physiological indicators in math learning and examine how they relate to subjective self-reports.

In addition to improving measurement, future studies should explore interventions aimed at helping students regulate their effort, particularly when facing challenges such as difficult tasks or errors (Halisch and Heckhausen, 1977). Effort regulation has been shown to be a critical predictor of math achievement (León et al., 2015). Notably, students who were not intrinsically motivated but demonstrated strong effort regulation outperformed those with weaker regulatory skills (Kim et al., 2015). This suggests that interventions should focus on enhancing students' ability to manage and sustain effort, especially in the absence of intrinsic motivation.

Finally, while this review has emphasized the importance of effort in explaining math achievement, it is important to acknowledge that effort alone may not be sufficient. As Yeager et al. (2016) argue, exerting effort using ineffective strategies is unlikely to lead to meaningful learning gains. Future research should examine the interaction between strategy use and effort investment to better understand how both contribute to math performance.

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