CHILD DEVELOPMENT

Child Development, xxxx 2021, Volume 00, Number 0, Pages 1–20

More Than Growth Mindset: Individual and Interactive Links Among Socioeconomically Disadvantaged Adolescents' Ability Mindsets, Metacognitive Skills, and Math Engagement

Ming-Te Wang
University of Pittsburgh

Cristina D. Zepeda
Washington University in St. Louis

Xu Qin, Juan Del Toro and Kevin R. Binning
University of Pittsburgh

This article used self-regulated learning as a theoretical lens to examine the individual and interactive associations between a growth mindset and metacognition on math engagement for adolescent students from socioeconomically disadvantaged schools. Across three longitudinal studies with 207, 897, and 2,325 11- to 15-year-old adolescents, students' beliefs that intelligence is malleable and capable of growth over time only predicted higher math engagement among students possessing the metacognitive skills to reflect upon and be aware of their learning progress. The results suggest that metacognitive skills may be necessary for students to realize their growth mindset. Thus, growth mindsets and metacognitive skills should be promoted together to capitalize on the mutually reinforcing effects of each, especially among students in socioeconomically disadvantaged schools.

Active engagement in math learning is critical to youth's educational and career trajectories (Reschly & Christenson, 2012). Engaged students tend to exert more effort, perform better, and be more persistent in the face of setbacks than disengaged students (Wang, Degol, & Henry, 2019). Unfortunately, as students—especially students from socioeconomically disadvantaged backgrounds—progress through secondary school, their math engagement tends to decline (Li & Lerner, 2011; Wang & Degol, 2014; Wigfield, Eccles, Schiefele, Roeser, & Davis-Kean, 2006). In particular, adolescent students tend to regard math performance as rooted in aptitude and inherited ability rather than hard work, effort, and persistence (Ahn et al., 2016). The belief that performing well in math requires exceptional innate ability is de-motivating and may contribute to decreases in student engagement in math learning over time (Fredricks et al., 2016).

Given the role of engagement in maintaining students' pursuits of learning math, this study aims to understand the underlying individual and psychosocial factors that predict math engagement over time. Drawing from self-regulated learning (SRL) theories and the integrative development-in-sociocultural-context model, we posit that engaged math learners are both metacognitively and motivationally driven (Wang et al., 2019; Winne & Hadwin, 2008; Zimmerman, 2000). In other words, students need to develop their metacognitive skills (i.e., planning, monitoring, evaluating) to be aware of and regulate their math learning and understanding while also subscribing to the belief that they are capable of improving their math performance (i.e., growth mindset). Therefore, metacognition and a

Xu Qin and Juan Del Toro have equal intellectual contribution to this manuscript.

This study was supported by funding from National Science Foundation #1561382 and #1315943 to the first author (Ming-Te Wang).

Author contribution: Wang conceived of the study (e.g., study questions, study design, literature review, result interpretation, development of the writing outline), and drafted and revised the full manuscript; Zepeda conceived of the study and drafted and revised part of the introduction and discussion sections; Qin and Del Toro performed the data analysis, participated in the interpretation of the data, and drafted the method section; Binning participated in the result interpretation and provided feedback on the draft. All authors read and approved the final manuscript.

Correspondence concerning this article should be addressed to Ming-Te Wang, University of Pittsburgh, 230 South Bouquet Street, Pittsburgh, PA 15213. Electronic mail may be sent to mtwang@pitt.edu.

 0009-3920/2021/xxxx-xxxx
DOI: 10.1111/cdev.13560

growth mindset have unique contributions to student math engagement while also reinforcing each other.

Although research has indicated that metacognition and a growth mindset form the sociocognitive and motivational foundations for effective learning, few empirical studies have examined these constructs simultaneously or explored how they interact to shape math engagement longitudinally. Moreover, students from different socioeconomic backgrounds have differential access to quality instruction, opportunities, and resources (Wang et al., 2019); hence, the educational impact of metacognition and mindset may vary for students from lower and higher socioeconomic status (SES) schools. Consequently, this article leverages three longitudinal studies to examine the direct and interaction effects of students' metacognitive skills and growth mindset to predict math engagement in low-SES schools. To guide this inquiry, we rely on the theoretical lens of SRL and engagement theories and research on factors that drive student engagement in math learning.

Self-Regulated Learning

Both SRL theories and the integrative development-in-sociocultural-context model postulate that metacognition and motivation work together to shape academic engagement and performance (Efklides, 2011; Wang et al., 2019; Zimmerman & Moylan, 2009). Metacognition and motivation share a cyclical relation in which they simultaneously impact learning as it unfolds, which in turn affects subsequent learning experiences (Wang, Binning, Del Toro, Qin, & Zepeda, 2021). For example, Zimmerman and Moylan's (2009) SRL model posits that three dynamically interrelated phases constitute the learning process: forethought (before learning), performance (during learning), and reflection (after learning). During the forethought phase, students access their self-motivational beliefs (e.g., theories of intelligence) and create a plan; during the performance phase, students engage with a learning task while monitoring and controlling their motivations and cognitions; and during the reflection phase, students review their learning process and make attributions to their success or failure. The completion of all three phases represents one "cycle" of learning and results in students adjusting their future motivations and metacognition.

Given that self-motivational beliefs are confined to the forethought and reflection phases while metacognition exists within all three phases of the model, students' mindset beliefs may either activate or enhance current and subsequent metacognitive behaviors (Wang et al., 2019). For instance, students might apply a baseline level of metacognition to help acquire new knowledge and increase their performance; but when this baseline of metacognition is combined with productive self-motivational beliefs (i.e., growth mindsets), students' overall metacognitive skills may be enhanced. Moreover, students are likely to experience failure or frustration when they employ their metacognitive skills to identify gaps in their knowledge or mistakes in their work. In these cases, the addition of growth-mindset beliefs might help students mitigate the maladaptive attributions of these setbacks and continue to persist with their learning. Without a growth mindset, students may be less willing to try new or different metacognitive approaches in the face of academic struggles and setbacks.

In addition, students who believe in their ability to grow and learn must have the metacognitive skills to recognize when this growth has been realized. By metacognitively processing learning tasks, students are also more likely to have mastery experiences and witness their progress, thus affirming the validity of the growth mindset message. Without metacognitive skills, students with growth mindsets may not have a means by which to gauge progress and growth. Based on the nature of the SRL and integrative development-in-sociocultural-context models, we expect that growth mindset and the use of metacognitive skills will interact to facilitate deeper engagement in math learning.

Math Engagement

Scholars have defined engagement as the quality of students' interactions or involvement with learning activities (Wang & Degol, 2014; Wang et al., 2019), and researchers have established that engagement is a multidimensional construct consisting of at least three components: behavioral, cognitive, and emotional engagement (Fredricks et al., 2016; Wang, Henry, & Degol, 2020). Behavioral engagement refers to participation, persistence, and effort; cognitive engagement encompasses processes related to attention and mental investment in learning; and emotional engagement encapsulates affective reactions to learning activities. These dimensions of engagement are highly correlated with one another and have been identified as critical components of math learning (Wang et al., 2019). In fact, researchers have asserted that students' active participation in and effort toward the learning process work together to bolster the likelihood of succeeding in math (Boaler, 2013). It has also been well-documented, though, that fostering student engagement in math learning poses distinct challenges to educators: Many students find math to be overly difficult, frustrating, and boring (Leslie, Cimpian, Meyer, & Freeland, 2015), and as students move into secondary school, their engagement declines significantly (Wang, Fredricks, Ye, Hofkens, & Linn, 2016). To better understand these motivational processes, we focus on the role of engagement and what promotes students' engagement in math learning.

Math Metacognitive Skills

Students' familiarity with and use of metacognition may relate to how engaged they are in math learning. Metacognition is the awareness and regulation of one's thoughts (Flavell, 1987). Metacognitive regulation typically takes the form of three skills, each of which can be taught and improved upon with practice: planning, monitoring, and evaluating (Zimmerman & Moylan, 2009). Planning refers to identifying the goal and how to reach a goal; monitoring entails assessing one's understanding and progress toward that goal; and evaluating involves assessing the process of goal attainment. Given that math learning is an incremental process that involves increasingly intricate operations, abstract concepts, and multiple solutions, students need the skills to plan, monitor, and evaluate their understanding so that they can adjust their learning strategies, remain engaged, and accomplish their learning goals.

Studies have shown that students who use metacognitive skills to a higher degree experience a wide range of positive math outcomes (Carr, 2010; Schneider & Artelt, 2010). For example, students with higher levels of metacognitive skills tend to engage more productively with math than those with lower metacognitive skills, as they are more likely to create a plan before diving into problem solving (Schoenfeld, 1992). If students have an adequate metacognitive skillset, they should be more likely to direct their learning and engagement in math. Some studies have supported this link, as metacognitive skills have been positively associated with performance in an undergraduate psychology course through behavioral engagement (Umemoto, Ito, & Tanaka, 2016). Whether this pattern exists in math for adolescent students (i.e., students whose metacognitive skills are still developing, Veenman, Van Hout-Wolters, & Afflerbach, 2006) remains an unanswered question.

Math Growth Mindsets

Believing that one can improve their math abilities might aid students to engage with math. A *growth mindset* is an underlying belief that intelligence is malleable and can improve with effort and adequate strategies (Dweck, 2000). Those who have growth mindsets view setbacks as an opportunity to learn from mistakes, use constructive coping strategies, and persist in school as compared to those who have fixed mindsets (i.e., the belief that intelligence is inherited and unchangeable; Blackwell, Trzesniewski, & Dweck, 2007; Romero, Master, Paunesku, Dweck, & Gross, 2014). This prior work suggests that students who have growth mindsets would be more likely than those with fixed mindsets to engage in math learning, particularly during challenging learning tasks.

Unfortunately, math is one domain in which students are less likely to endorse a growth mindset, as many students tend to associate the ability to learn math with an innate aptitude rather than hard work, practice, and effort (Ahn et al., 2016). Therefore, students with a fixed math mindset may attribute their struggles in math to their lack of ability, while those with a growth math mindset often recognize their struggles as part of the learning process or the need to use alternative strategies. Some recent work has found that adolescents' growth mindsets are related to their intention to persist in school (Renaud-Dubé, Guay, Talbot, Taylor, & Koestner, 2015) and math engagement (Bostwick, Martin, Collie, & Durksen, 2019). Considering that growth mindsets are domain-specific and students often perceive math as requiring an exceptional amount of innate ability as compared to other academic subjects (Degol, Wang, Zhang, & Allerton, 2018), the question of whether a math growth mindset is related to student engagement has strong implications for math learning.

Interaction Between Growth Mindset and Metacognition on Math Engagement

While growth mindsets and metacognition may be individually related to math engagement, these factors may also reinforce each other such that the influence of one dimension depends upon or is modified by the influence of another. As suggested by SRL theories and the integrative development-in-sociocultural-context model, students must have both the metacognitive skills and motivation to regulate their learning and achieve academically. While prior work has not directly examined the interaction between metacognition and growth mindsets on math engagement, there has been some work suggesting that they are related. For instance, high school students' use of math-specific metacognition on a math task has been positively related to a learning motivation composite score that contained indicators of growth mindsets and behavioral engagement (Gómez-Chacón, García-Madruga, Vila, Elosúa, & Rodríguez, 2014).

However, SRL theories indicate that motivational variables only help students up to a certain point. Beyond that point, students need to employ their metacognitive skills to help them fully engage in math material (Wang et al., 2021). To elaborate, both metacognition and growth mindsets are important for engagement; yet, they may work together such that the use of metacognitive skills navigates students toward learning while a growth mindset shapes the meaning that students ascribe to their progress (or lack thereof). Simply put, students with growth mindsets and adequate use of metacognitive skills might think, "I'm making progress, which means I'm getting better; so, I should keep trying."

Furthermore, recent research has disputed the impact of a growth mindset, arguing that the adoption and maintenance of a given mindset is contingent upon contextual affordances or meaning-making experiences (Walton & Wilson, 2018; Walton & Yeager, 2019). Per Walton and Yeager (2019), a growth mindset might plant the seed that learning is an incremental process; however, if the student and their environment (e.g., the student's metacognitive skills in combination with the learning opportunities provided) do not nourish that adaptive mindset, then the mindset might lose its benefit. In this case, a growth mindset gives students a perspective on how to interpret their learning progress and outcomes, but in order for this perspective to be maintained or put into action, students also need to metacognitively regulate their progress toward learning and growing. Should their metacognitive skills be underdeveloped, students' progress may stall, which would then weaken the meaning behind a growth mindset. Thus, if students do not have an adequate metacognitive skillset or if their environments do not support the development of metacognition, we should expect that a growth mindset itself would not contribute to their engagement in learning.

Current Study

Drawing from SRL theories and the integrative development-in-sociocultural-context model, this work examined the individual contributions of students' metacognitive skills and growth mindsets and their interactions with math engagement. In particular, we investigated these relations during adolescence, a developmental period during which students' math engagement tends to decline and metacognitive skills are still being developed (Veenman, Van Hout-Wolters, & Afflerbach, 2006; Wang & Eccles, 2012). Alongside the observable devaluation of math achievement among socioeconomically disadvantaged students (Hentges, Galla, & Wang, 2019), these shifts suggest that metacognition and mindset play a pivotal role in keeping these students engaged in learning. Complicating the matter further, as students progress through secondary schools, the level of math abstraction deepens while the diversity of mathematical concepts broadens (Boaler, 2013). With the increasingly complex curriculum and demands in math, students need to have adequate metacognitive skills and adaptive mindsets to learn and persist in the face of challenges.

Additionally, scholars have called for understanding not only the average impact of educational interventions across populations, but also for nuanced analyses of which contexts and for whom these interventions are most efficacious (Olsen, 2017; Weiss et al., 2017). Socioeconomic contexts influence student school experiences and perceptions of themselves and educational opportunities available to them such that students in high-SES contexts are more likely than those in low-SES contexts to interact with high-performing peers and adults with higher educational attainment, paving clearer pathways for their own college prospects (Oyserman & Lewis, 2017). Studies have also suggested that socioeconomic contexts influence adolescents' mindsets (Wang et al., 2019). For example, socioeconomically disadvantaged students are more likely than higher SES students to hold fixed mindsets about academic ability (Destin, Hanselman, Buontempo, Tipton, & Yeager, 2019). Yet, low-SES youth are also more likely to academically benefit from having growth mindsets than their higher SES peers (Hwang, Reyes, & Eccles, 2019). As such, we focus on examining the extent to which metacognitive and motivational factors contributed to students' math engagement in low-SES school contexts.

When focusing on school SES contexts, low-SES schools, unlike high-SES schools, tend to serve students from historically marginalized populations that often encounter stereotypes of academic incompetence, low-quality instruction, and limited resources, and as a result, low-SES schools are frequently low-performing schools (Nasir, 2019; Osborne & Walker, 2006). In fact, the socioeconomic opportunity gap has widened in the past several decades with socioeconomically disadvantaged students experiencing declining academic skill, proficiency, and interest, especially in math (Reardon, 2011). With these added environmental challenges and societal barriers, students in low-SES schools might especially benefit from having both a growth mindset and metacognitive skills to facilitate their engagement in math learning.

Recent studies have also indicated that metacognition and mindset interventions help academically vulnerable students more than others (Rosenzweig & Wigfield, 2016; Schneider & Artelt, 2010). For instance, intervention studies have found that students do not universally benefit from mindset messages (see Binning & Browman, 2020). In one study, the benefits of a mindset intervention were only seen among African Americans with high educational expectations (Binning, Wang, & Amemiya, 2019). In another study, academic engagement and performance increased only for African American students who experienced heightened levels of stereotype threat in academic domains (Good, Aronson, & Inzlicht, 2003). Echoing this relation, metacognitive interventions have been particularly helpful for lower achieving students (Carr, 2010; Schneider & Artelt, 2010). Together, this work suggests that the development of students' metacognition and growth mindset often needs adequate support to be effective for all students, especially in low-SES school environments.

As highlighted by learning and instruction literature, the needed support for metacognition and growth mindsets might be driven by the teacher–student relationship (Wang, Degol, Amemiya, Parr, & Guo, 2020). Some work has shown that classrooms with high growth on a conceptual math test were positively related to the amount of teacher talk that focused on metacognition (Zepeda, Hlutkowsky, Partika, & Nokes-Malach, 2019) and emphasized mastery (Boden, Zepeda, & Nokes-Malach, 2020); however, in both of these studies, not much teacher talk was actually dedicated to those areas. The teacher–student relationship also has implications for student engagement. For example, one meta-analysis revealed that a positive teacher–student relationship was associated with student engagement and achievement, whereas a negative teacher–student relationship was associated with disengagement and poor performance (Roorda, Koomen, Spilt, & Oort, 2011). With the teacher–student relationship contributing to many student learning outcomes, we account for it in our analyses.

Given SRL theories and the integrative development-in-sociocultural-context model, we hypothesized that growth mindset and metacognitive skills would individually contribute to math engagement while also interacting with each other. Specifically, metacognitive skills may be necessary for students to realize their growth mindset. Without these skills, students may have no way of knowing whether they are making progress or growing despite their belief that they are capable of said progress and growth. Although some learners have been observed to dive into solving math problems without thinking through different approaches or creating a plan (Schoenfeld, 1987), we argue that metacognitive skills (i.e., the ability to track and understand learning growth) are conducive to helping students maintain engagement over time.

To rigorously test these hypotheses, we used three longitudinal studies with large sample sizes to examine the relation between growth mindset, metacognitive skills, and math engagement. The first study examined these relations with students from low-SES schools across two semesters (one wave of survey and school record data per semester); the second study examined these relations in students from low-SES schools using daily-diary data collected over the course of 16 school days; and the third study explored the uniqueness of these relations in low-SES and high-SES schools across 4 years (one wave of survey and school record data per year). The measurement approach linking these three study designs was to evaluate the degree to which students could regulate their metacognition and motivation to remain engaged in learning over different time scales.

Our analyses represent a combination of exploratory and confirmatory approaches: Our tests of main and interaction effects were theory-driven and confirmatory, whereas our deeper investigation into the direction and pattern of interaction effect was exploratory. Once an interaction pattern was identified in Study 1, we confirmed said patterns in Studies 2 and 3.

Study 1

Study 1 served as an initial test of the individual and interactive associations between metacognitive skills and growth mindsets with math engagement over the two semesters of a single school year. The aim was to test the empirical support at the between-student level.

Method

Participants and Procedure

The sample consisted of 897 sixth- and eighth-grade students from four urban public schools in the United States (49% male; 66% African American, 31% White, and 3% other race; 78% qualified for free/reduced-price lunch). Two waves of data were analyzed in this study, with Wave 1 commencing in the fall of 2018 and Wave 2 being completed in the spring of 2019. Over half (70%) of the students in the participating schools lived at 185% or below the federal poverty level, and these schools have ranked consistently in the bottom 25th percentile on the statewide standardized math test over the past 5 years.

With teachers' assistance, the research team distributed letters with the study description and active consent/assent forms for students and their parents. Students who agreed to participate in the study completed a web-based survey in a classroom with technology during their school hours. Research staff members were available during survey administration to answer any questions that students had about the purpose or content of the survey. To ensure that students with varying literacy skills could effectively complete the survey, all survey questions were audio-recorded. All materials and procedures were approved by the first authors' university institutional review board.

Measures

Math engagement. Math engagement was assessed in the fall and spring semesters using the *Math Engagement Scale*, a well-validated engagement scale with strong reliability and construct and predictive validity (Fredricks et al., 2016; Wang et al., 2016). This nine-item scale assessed students' engagement, including attention, effort, affect, and task persistence in math class (e.g., "I stay focused in math"; "I put effort into learning math"; "I enjoyed learning math"). Item responses fell along a 5-point Likert scale ranging from 1 (*not at all like me*) to 5 (*very much like me*) (αs = .84 and .86).

Math metacognitive skills. Using six items adapted from the Metacognitive Self-Regulation Scale of the *Motivated Strategies for Learning Questionnaire* (Pintrich, Smith, Garcia, & McKeachie, 1991), students reported on their use of planning, monitoring, and evaluating math learning in the fall semester (e.g., "I ask myself questions to make sure I understand the material I have been studying in math class"; "I used what I learned today to make sense of our earlier math classes"; "I tried to understand my mistakes when I got something wrong in math"). Students responded on a five-point Likert scale ranging from 1 (*not at all like me*) to 5 (*very much like me*) (α = .89).

Math growth mindset. Students' beliefs about the malleability of math ability were measured in the fall semester by using the well-validated *Math Ability Mindset Scale* (four items; e.g., "To be honest, you can't really change how smart you are in math"; "How smart you are in math is something about you that you can't change very much"; Degol et al., 2018). Students responded on a 5-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*) (α = .91). Responses were averaged to form a growth mindset composite and reverse-coded such that higher scores reflected stronger growth-oriented math mindsets. As suggested by extant research (Degol et al., 2018; Yeager et al., 2019), our scale used fixed-mindset items in order to avoid potential acquiescence or social desirability biases whereby participants respond more favorably to positively worded growth-mindset items.

Student-level covariates. We included several student-level covariates collected from the school record: (a) students' relationship with the math teacher (three survey items; α = .84; e.g., "My math teacher understands how I feel about things in class", "I feel comfortable in math class"); (b) prior mathematics performance; (c) grade level; (d) gender; (e) race; (f) school membership; and (g) free/reduced-price lunch status.

Missing Data

Two waves of data were collected during 2018–2019 school year. Wave 2 (spring) retained 94% of the initial sample from Wave 1 (fall). An examination of missing data patterns indicated that 90% of students either had complete data or were missing on only one study variable, which was due to students not finishing the survey. Participants with missing data did not differ on any study variables in comparison to participants with complete data.

Analytic Plan

We used regression models to examine the individual and interaction effects of metacognitive skills and growth mindset at Wave 1 on math engagement at Wave 2 while accounting for classroom random effect and prior engagement. We handled missing data using full-information maximum likelihood estimation (FIML), which included all available data by identifying the parameter values with the highest probability of producing the sample data.

Results

Individual and Interaction Effects of Metacognitive Skills and Growth Mindset

Table 1 presents the means, standard deviations, and correlations for each of the key predictor and outcome variables. As shown in Model 1 and Table 2, students' metacognitive skills were positively associated with math engagement, but growth mindset was not.

The interaction effect results indicated that the association between students' growth mindset and math engagement varied based on metacognitive skills (Model 2, Table 2). In Figure 1, we plotted these interactions at high (Mean +1 *SD*) and low (Mean −1 *SD*) levels of each variable. The plot showed that among students with low metacognitive skills, the effect of growth mindset was negative ($B = -.09$, $t = -1.99$). But among students with high metacognitive skills, the effect of growth mindset was positive ($B = .06$, $t = 1.56$). In other words, the growth mindset only became beneficial for student engagement when students had the metacognitive skills to understand and regulate their learning.

Table 2
*Regression Model Predicting Mathematics Engagement Over Two Semesters in Study 1 (*n *= 897)*

Variables	Model 1: Main effect	Model 2: Interaction effect
Key predictors		
Math growth mindset	.00 (.03)	.00 (.03)
Math metacognitive skills	.17 (.03)***	.17 (.03)***
Metacognitive skills × Growth mindset	—	.04 (.02)**
Covariates		
Teacher–student relationship	.11 (.03)***	.114 (.03)***
Prior math achievement	.02 (.00)***	.02 (.00)***
Grade level	.03 (.04)	.03 (.04)
Male (vs. female)	.02 (.06)	.01 (.06)
White (vs. racial minority)	−.04 (.06)	.04 (.06)
Free/reduced-price lunch (vs. paid)	−.05 (.09)	−.04 (.09)

Note. The values in the parentheses indicate standard errors.
$^{**}p \le .01$. $^{***}p \le .001$.

Study 2

In Study 2, we aimed to replicate the findings from Study 1 using 16 days of daily-diary data. The duration of our daily-diary assessments has been recommended as an ideal observation window to capture meaningful within-person variability and reduce participant burden for daily diary research (Bolger, Davis, & Rafaeli, 2003). Using a multilevel design, we examined the individual and interaction effects between metacognitive skills and growth mindset at both the between-student level and the within-student level.

Method

Participants and Procedures

Participants were 207 eighth-grade students (55% male; 57% African American, 33% White, 10% other race; 68% qualified for free/reduced-price lunch)

Table 1
*Means, Standard Deviation, and Zero-Order Bivariate Correlations Among Key Study Variables in Study 1 (*n *= 897)*

Variable	1	2	3	4	5	6	7	8
1. Math engagement	**1**							
2. Math growth mindset	.07	**1**						
3. Math metacognitive skills	**.43**	.07	**1**					
4. Teacher–student relationship	**.36**	**.10**	**.29**	**1**				
5. Prior math achievement	**.32**	**.18**	**.12**	**.11**	**1**			
6. Male (vs. female)	.00	−.04	−.06	−.02	−.11	**1**		
7. White (vs. racial minority)	.05	.11	.02	.12	**.23**	−.03	**1**	
8. Free/reduced-price lunch (vs. paid)	−.05	−.04	−.03	.07	**−.18**	−.02	−.04	**1**
M (*SD*)	3.65 (0.92)	3.67 (1.10)	3.27 (1.01)	3.66 (1.05)	81.89 (11.88)	—	—	—

Note. Bolded values indicate significance at $p < .05$.

from one urban public school in the United States. Over half (61%) of the students in the participating school lived at 185% or below the federal poverty level, and the school has ranked consistently in the bottom 25th percentile on the statewide standardized math test over the past 5 years.

With assistance from the students' teachers, the research team distributed letters with the study description and active consent/assent forms for students and their parents. More than 99% of the eighth-grade cohort agreed to partake in the study. All study procedures occurred in students' math classrooms on computerized tablets. The current study collected two types of data across the 2017–2018 school year: a pre-daily diary survey (fall 2017) and a 16-day daily diary (spring 2018). Data were collected during the final 5 min of each day's math class for 16 days. To address potential literacy difficulties, students were provided with headphones to listen to the audio-recorded questions. All materials and procedures were approved by the first authors' university institutional review board.

Measures

Math engagement. During each day of the daily-diary study, students responded to three math engagement items that were adapted from the *Math Engagement Scale*: "I stayed focused in math class today"; "I put effort into learning in math class today"; and "I enjoyed math class today" (Fredricks et al., 2016; Wang et al., 2016). For these items, students responded on a 5-point Likert scale from 1 (*not at all*) to 5 (*very much*). The three items were averaged to create daily composite scores of students' engagement (α_{Total} = .91, M_{Total} = 3.11, SD_{Total} = 0.69). Supporting the validity of the daily diary measure, students' daily report of math engagement was moderately correlated with their scores in the teacher grade book (i.e., classwork, homework, and tests/quizzes) during the daily diary period, r = .47, p < .001.

Math metacognitive skills. To assess daily math metacognitive skills, students responded to three items adapted from Metacognitive Self-Regulation Scale from the *Motivated Strategies for Learning Questionnaire* (Pintrich et al., 1991): "I ask myself questions to make sure I understand the material I have been studying in today's math class"; "I used what I learned today to make sense of earlier math classes"; "I tried to understand my mistakes when I got something wrong in math class today." Students responded on a 5-point Likert scale ranging from 1 (*not at all*) to 5 (*very much*). The three items were averaged to create daily composite scores of students' math metacognitive skills (α_{Total} = .83, M_{Total} = 2.79, SD_{Total} = 0.75).

Time-level covariates. We included time-level covariates that were related to student engagement: the *level of distraction* (i.e., "There were distractions in math class today; for example, other students talking during the lesson") and the *day of the study* to account for potential time and fatigue effects of study participation.

Student-level predictors. The same *Math Ability Mindset Scale* that was used in Study 1 was used for this study (α = .77).

Student-level covariates. We included the following student-level covariates collected from the pre-daily-diary survey or school records: (a) students' relationship with the math teacher (eight items; e.g., "I like my math teacher" "My math

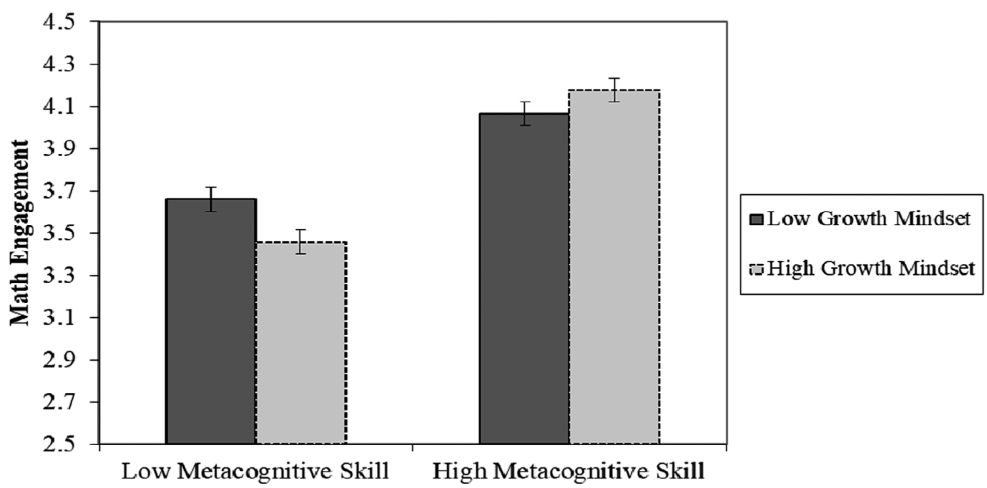

Figure 1. The interaction effect between metacognitive skills and growth mindset (Study 1).

teacher is patient and understanding"; α = .85); (b) prior year's math performance; (c) gender; (d) race; and (e) free/reduced-price lunch status.

Missing Data

The amount of missing data varied at both the daily and student levels. Of the possible 3,312 daily diary assessments (16 days, 207 students), data were missing for 30.3% at the daily level (N = 1,119 missing daily assessments), which was either due to students not finishing the survey (N = 927) or being absent that day (N = 192). There were also varying levels of missing data at the student level. Given the school-based nature of the study, participation rates were generally high: pre-daily-diary survey = 100%; daily diary (at least one day of participation) = 95%.; and M = 11.25 responses of 16 total possible days.

We next examined if student factors were associated with the number of responses provided in the study across the pre-daily diary survey and daily diary assessments. Students with more available data reported higher pre-daily diary math engagement (r = .05, p = .04), received higher prior year math standardized test scores (r = .06, p = .01), and were more likely to be racial minorities (r = −.05, p = .01). To retain all 207 students in analyses, we accounted for missing data at the daily and student levels using FIML (Baraldi & Enders, 2010). As a sensitivity analysis, we also used multiple imputations with 20 imputed data sets to handle missing data and achieved the same results.

Analytic Plan

Study 2 investigated how students' metacognitive skills and growth mindset in mathematics related to their daily math engagement. Our data had a nested structure in which 16 daily-diary assessments were nested within 207 students, and these students were nested within nine classrooms. Hence, we used multilevel models to address the study questions by assigning Level 1 to time and Level 2 to students while accounting for classroom random effect.

The outcome of interest was daily math engagement at Level 1. Level 1 key predictors included metacognitive skills and day of the study (i.e., time), and the Level 2 predictor was growth mindset. We investigated the interaction between metacognitive skills and growth mindset as well as how such interactions varied over time.

Results

Individual and Interaction Effects of Metacognitive Skills and Growth Mindset

Table 3 presents the zero-order correlations among daily level and student-level variables. The results of the multilevel modeling predicting daily math engagement are shown in Table 4. As shown in Model 2, Table 4, students' math metacognitive skills were positively associated with daily math engagement. However, students' growth mindset did not predict math engagement on average.

The association between students' growth mindset and math engagement varied based on metacognitive skills and this interaction effect did not vary by time (Model 3, Table 4). The plot in Figure 2 illustrates that among students with low metacognitive skills, the effect of growth mindset was negative (B = −.13, t = −2.46). But among students with high metacognitive skills, the effect of growth mindset was positive (B = .07, t = 1.35). Consistent with the findings from Study 1, growth mindset only predicted math engagement positively when students had high metacognitive skills.

Study 3

In Study 3, we sought to replicate the results from Studies 1 and 2 by examining the longitudinal associations among metacognitive skills, growth mindset, and math engagement with a 4-year longitudinal study. The sample included students from low- and high-SES schools, allowing us to examine whether the patterns of the findings from Study 1 and Study 2 were unique to students from low-SES schools.

Method

Participants and Procedure

The sample consisted of 2,325 fifth- (32%), seventh- (35%), and ninth-grade (33%) students from 20 public schools in the United States (51% male; 65% White, 35% African American; 65% qualified for free or reduced-price lunch). Forty-two percent of the sample came from high-SES schools (51% male; 96% White, 4% African American; 28% free or reduced-price lunch), whereas 58% of the sample came from low-SES schools (50% male; 25% White, 75% African American; 93% free or reduced-price lunch). These low-SES schools have consistently ranked in the

Table 3
Zero-Order Correlations Between Daily-Level and Student-Level Variables in Study 2 (n = 207)

Variable	1	2	3	4	5	6
Daily-level variables (Level 1)						
1. Math engagement	1					
2. Math metacognitive skills	**.52**	1				
3. Level of distraction	**−.05**	−.03	1			
4. Day of study	−.04	**.07**	**−.22**	1		
Student-level variables (Level 2)						
1. Math growth mindset	1					
2. Prior year's math achievement	**.09**	1				
3. Male (vs. female)	.03	**.34**	1			
4. White (vs. minority)	**−.16**	**.10**	−.04	1		
5. Free/reduced-price lunch (vs. paid)	**−.04**	.01	**.05**	.04	1	
6. Teacher–student relationship	**.15**	**.19**	**.12**	**−.07**	**.01**	1

Note. Bolded values indicate significance at $p < .05$.

bottom 25th percentile on the statewide standardized math test over the past 5 years. Although these schools did not differ by gender, students in the high-SES schools were more likely to be White and pay full price for their lunch as relative to students in low-SES schools, who were more likely to be of a racial minority and qualify for free or reduced-price lunch (race-$\chi^2(1) = 1{,}162.77$, $p < .001$; lunch status-$\chi^2(1) = 1{,}043.17$, $p < .001$). Four waves of data were analyzed in this study once per year with Wave 1 commencing in 2015.

Students completed a web-based survey in a classroom with technology during their school hours. Research staff members were available during survey administration to answer any questions that students had about the purpose or content of the survey. To ensure that students with varying literacy skills could effectively complete the survey, all survey questions were audio-recorded, and students were provided with headphones to listen to the questions. All materials and procedures were approved by the first authors' university institutional review board.

Measures

Math engagement. The same scale used in Study 1 was utilized to measure students' math engagement in the spring semester for this study (αs ranged from .83 to .89).

Math metacognitive skills. The same scale used in Study 1 was utilized to measure students' metacognitive skills in the fall semester for this study (αs ranged from .75 to .78).

Math growth mindset. The same scale used in Study 1 was utilized to measure students' math mindset in the fall semester for this study (αs ranged from .81 to .85).

Covariates. We included three time-level covariates that were related to math engagement: (a) students' relationship with the math teacher (three

Table 4
Multilevel Model Predicting Daily Mathematics Engagement Over 16 Days in Study 2 (n = 207)

Variables	Model 1: Unconditional model	Model 2: Main effect	Model 3: Interaction effect
Level 1 (day)			
Time	−.02 (.00)***	−.02 (.00)***	−.02 (.00)***
Math metacognitive skills		.35 (.02)***	.35 (.02)***
Class distraction		−.02 (.01)	−.03 (.01)
Metacognitive skills × Growth mindset		—	.11 (.03)***
Level 2 (student)			
Math growth mindset		−.03 (.05)	−.02 (.05)
Teacher–student relationship		.06 (.06)	.06 (.06)
Math achievement (prior year)		.00 (.00)	.00 (.00)
Male (vs. female)		.13 (.08)	.14 (.08)
White (vs. minority)		.11 (.08)	.11 (.08)
Free/reduced-price lunch (vs. paid)		−.11 (.08)	−.09 (.08)
−2log likelihood	4,819.47	4,594.76	4,582.35
Akaike information criterion	4,851.47	4,644.76	4,634.35
Bayesian information criterion	4,942.05	4,786.19	4,781.43

Note. The values in the parentheses indicate standard errors.
***$p \leq .001$.

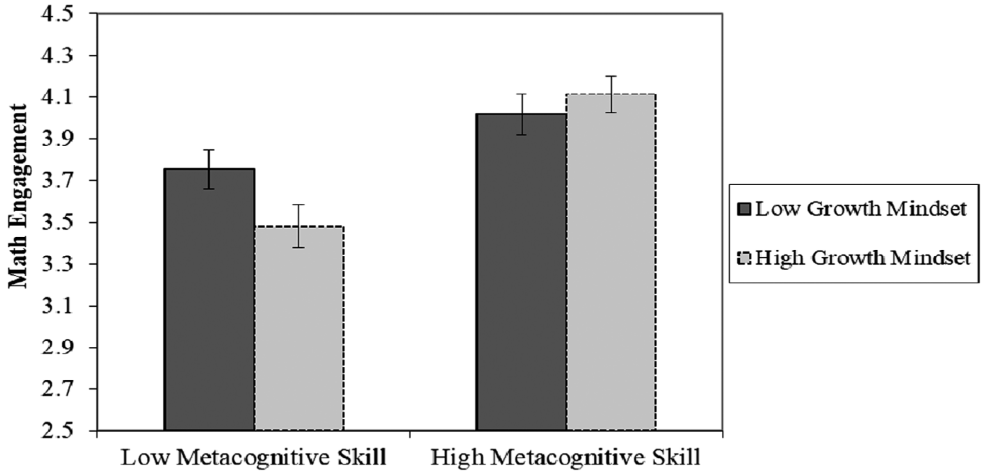

Figure 2. The interaction effect between metacognitive skills and growth mindset (Study 2).

items; e.g., “My math teacher understands how I feel about things in class”, “I feel comfortable in math class”; αs from .78 to .83); (b) students’ mathematics performance; and (c) the year of the study. We also included student-level covariates: (a) grade level; (b) gender; (c) race; (d) school membership; and (e) free/reduced-price lunch status.

Missing Data

In this study, 1,489 adolescents (64%) participated at Wave 1, 629 (27%) at Wave 2, 142 (6%) at Wave 3, and 65 (3%) at Wave 4. Since first participation, 1,140 (51%) adolescents had no missing waves of data missing, 491 (23%) had one wave of data missing, 363 (16%) had two waves of data missing, and 331 (10%) had three waves of data missing. Participants with more waves of data were more likely to be girls (than boys; $r = .06$, $p < .05$), White youth (than ethnic-racial youth; $r = .19$, $p < .001$), pay for full-price lunch (than those in a free/reduced-price lunch program; $r = .18$, $p < .001$), and have higher math achievement ($r = .24$, $p < .001$) than their peers with fewer waves of data. We dealt with the missing data through FIML estimation. We also used a multiple imputation approach with 20 imputed data sets and achieved the same results.

Analytic Plan

We used multilevel models to address the study questions by assigning Level 1 to time and Level 2 to students while accounting for classroom-level random effects. Level 1 key predictors included metacognitive skills, growth mindset, and time. At Level 2, we explained the variation in students’ average level of math engagement across the 4 years by including student-level covariates. We also investigated the interactions among metacognitive skills and growth mindset. Finally, we used multigroup analysis to test whether the individual and interaction effects of metacognitive skills and growth mindset varied by students from low-SES and high-SES schools.

Measurement equivalence was assessed to ensure that the content of each item in the measures of math engagement, metacognitive skills, and growth mindset was perceived and interpreted in the same way across different groups. We found empirical support for scalar invariance of these underlying constructs across time and SES (see Supporting Information).

Results

Individual and Interaction Effects of Metacognitive Skills and Growth Mindset

Table 5 presents the means, standard deviations, and correlations for each predictor and outcome variable. As shown in Table 6, there was a linear decline in math engagement over 4 years. In addition, students’ metacognitive skills were positively associated with changes in math engagement over time, suggesting greater metacognitive skills protected against the normative rate of decline in math engagement. Growth mindset did not predict math engagement for students from low-SES schools, though it positively predicted math engagement for students from high-SES schools. This finding suggests that the nonsignificant effect of growth mindset on math engagement found in Studies 1 and 2 was unique to students from low-SES schools.

Table 5

Means (SD) and Zero-Order Bivariate Correlations Among All Key Study Variables in Study 3 (n = *2,325)*

	1	2	3	4	5	6	7	8	9	10	11	12
1 Math engagement Wave 1	1	**.49**	**.46**	**.38**	**.49**	**.42**	**.43**	**.32**	**.19**	**.21**	**.16**	**.16**
2 Math engagement Wave 2	**.49**	1	**.60**	**.44**	**.50**	**.74**	**.53**	**.43**	.04	**.28**	**.16**	**.20**
3 Math engagement Wave 3	**.48**	**.54**	1	**.52**	**.44**	**.56**	**.45**	**.53**	**.13**	**.24**	**.30**	**.26**
4 Math engagement Wave 4	**.30**	**.44**	**.47**	1	**.37**	**.41**	**.51**	**.45**	**.09**	**.12**	**.22**	**.30**
5 Math metacognitive skills Wave 1	**.43**	**.49**	**.43**	**.34**	1	**.53**	**.49**	**.41**	**.17**	**.21**	**.18**	**.20**
6 Math metacognitive skills Wave 2	**.45**	**.49**	**.46**	**.41**	**.52**	1	**.60**	**.49**	.07	**.30**	**.22**	**.24**
7 Math metacognitive skills Wave 3	**.44**	**.48**	**.49**	**.52**	**.49**	**.55**	1	**.62**	**.09**	**.24**	**.32**	**.28**
8 Math metacognitive skills Wave 4	**.32**	**.36**	**.41**	**.52**	**.45**	**.51**	**.59**	1	.07	**.14**	**.24**	**.36**
9 Math growth mindset Wave 1	**.10**	**.15**	**.10**	.02	**.22**	**.21**	**.12**	**.13**	1	**.44**	**.28**	**.19**
10 Math growth mindset Wave 2	**.17**	**.21**	**.13**	.04	**.24**	**.23**	**.20**	**.14**	**.36**	1	**.43**	**.30**
11 Math growth mindset Wave 3	**.29**	**.22**	**.25**	**.21**	**.29**	**.24**	**.37**	**.31**	**.32**	**.34**	1	**.47**
12 Math growth mindset Wave 4	**.19**	**.09**	**.19**	**.17**	**.26**	**.14**	**.27**	**.28**	**.18**	**.31**	**.42**	1
Low-SES schools, *M* (*SD*)	3.84 (0.75)	3.92 (0.76)	3.78 (0.77)	3.67 (0.81)	3.62 (0.76)	3.65 (0.76)	3.55 (0.76)	3.46 (0.73)	3.39 (1.16)	3.67 (1.16)	3.85 (1.08)	3.78 (1.04)
High-SES schools, *M* (*SD*)	4.31 (0.59)	4.23 (0.68)	4.15 (0.75)	4.07 (0.79)	4.00 (0.65)	3.86 (0.71)	3.78 (0.76)	3.71 (0.76)	3.64 (1.06)	3.86 (1.08)	3.88 (1.07)	3.71 (1.05)
Independent samples *t*-tests' *p*-value	< .01	< .01	< .01	< .01	< .01	< .01	< .01	< .01	< .01	*ns*	*ns*	*ns*

Note. Below the diagonal includes correlations among study variables for students in low-SES schools; above the diagonal includes correlations among study variables for students in high-SES schools Bolded-values indicate significance at $p < .05$. SES = socioeconomic status.

Table 6
Multilevel Model Predicting Mathematics Engagement Over Four Years in Study 3 (n = 2,325)

Variables	Model 1: Unconditional model		Model 2: Main effects		Model 3: Interaction effects	
	Low-SES schools	High-SES schools	Low-SES schools	High-SES schools	Low-SES schools	High-SES schools
Level 1 (time)						
Time	−.09 (.01)***	−.09 (.01)***	−.07 (.02)***	−.03 (.01)**	−.08 (.02)***	−.03 (.01)**
Math metacognitive skills			.48 (.02)***	.47 (.02)***	.49 (.02)***	.47 (.02)***
Math growth mindset			.02 (.02)	.04 (.01)**	.02 (.02)	.03 (.01)**
Metacognitive skills × Growth mindset			—	—	.09 (.04)*	−.06 (.02)**
Teacher–student relationship			.14 (.02)***	.10 (.01)***	.14 (.02)***	.10 (.02)***
Math achievement			−.01 (.01)	.01 (.01)	.00 (.01)	.00 (.01)
Level 2 (student)						
Grade level			−.04 (.02)**	−.06 (.01)**	−.04 (.02)**	−.06 (.01)***
Male (vs. female)			−.01 (.06)	−.14 (.03)***	−.01 (.06)	−.14 (.03)***
White (vs. African American)			.03 (.04)	.08 (.08)	.03 (.04)	.08 (.08)
Free/reduced-price lunch (vs. paid)			−.14 (.06)*	−.21 (.03)***	−.14 (.06)*	−.21 (.03)***
−2log likelihood	−6,430.71		−4,499.85		−4,494.87	
Akaike information criterion	12,877.43		9,047.69		9,041.73	
Bayesian information criterion	12,931.50		9,129.19		9,212.64	

Note. The values in the parentheses indicate standard errors. SES = socioeconomic status.
$^*p \le .05$. $^{**}p \le .01$. $^{***}p \le .001$.

The interaction effect (see Model 3, Table 6) revealed that the association between students' growth mindset and engagement varied by metacognitive skills and the interaction effect did not differ by time. This finding was consistent, although in opposite directions for students from both low- and high-SES schools (ES = .06 for low-SES schools; ES = −.04 for high-SES schools). The plot in Figure 3 shows that among students from low-SES schools, the effect of the growth mindset was nonsignificant for those with low metacognitive skills (B = .39, t = 1.10); however, the effect of the growth mindset was positive for those with high metacognitive skills (B = .59, t = 2.09). Similar to the findings of Studies 1 and 2, growth mindset only predicted math engagement positively for students from low-SES schools when those students had high metacognitive skills. For the high-SES schools (see Figure 4), growth mindsets compensated for the relation to engagement when students had low metacognitive skills (B = .52, t = 1.07), but when students had high metacognitive skills, the growth mindset effect was less salient (B = .43, t = 0.97).

Discussion

Mathematics engagement serves as a pipeline to educational success and attainment; yet, math engagement declines during the developmental period of adolescence. These three studies examined the underlying metacognitive and motivational factors that can attenuate this decline.

Guided by SRL theories (Zimmerman, 2000) and the integrative development-in-sociocultural-context model (Wang et al., 2019), we investigated the individual and interactive effects of growth mindsets and metacognitive skills on adolescent math engagement, particularly in low-SES schools. Critically, we addressed the call to evaluate in which contexts and for whom growth mindsets and metacognitive skills contribute to math engagement. Across the three longitudinal studies, results revealed consistent patterns across contexts and time span in terms of school socioeconomic background: In sum, it takes both a growth mindset and metacognitive skills to deeply engage in math, thereby supporting our guiding theories.

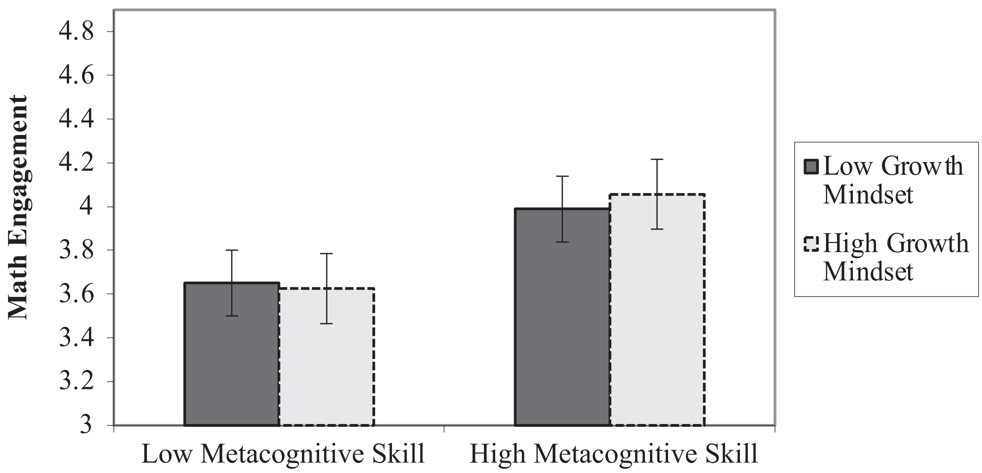

Figure 3. The interaction effect between metacognitive skills and growth mindset from the low-socioeconomic status school sample (Study 3).

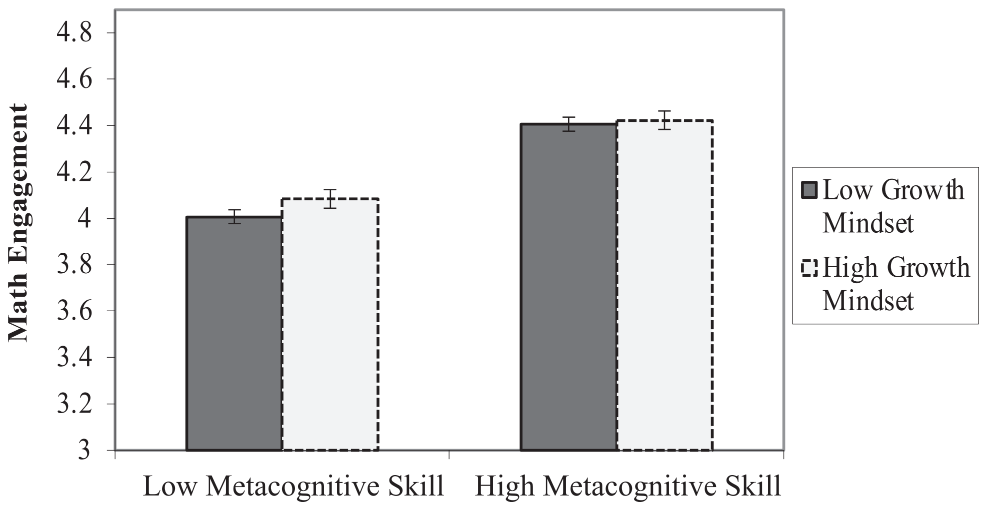

Figure 4. The interaction effect between metacognitive skills and growth mindset from the high-socioeconomic status school sample (Study 3).

Individual and Interaction Effects of Metacognitive Skills and Growth Mindset

All three studies showed that metacognitive skills positively predicted math engagement. These individual contributions existed regardless of the school's SES and the time scale of the study design, illuminating that metacognitive skills have a robust link with engaging in math: If students had high metacognitive skills, then they were more likely to engage in math. Unlike metacognitive skills, the adoption of a growth mindset revealed a different pattern. Growth mindset did not predict math engagement for students from low-SES schools irrespective of the timeframe of the study, but it did for students from high-SES schools. In other words, the nonsignificant individual effect of growth mindsets on engagement was unique to students from low-SES schools.

Despite its promise of promoting student learning, there has been debate regarding whether growth mindsets benefit all students across different school contexts (Miller, 2019). Although growth mindsets send a positive message about the nature of learning, researchers have indicated that this mindset needs particular contextual support to align before it is effective (see Yeager et al., 2019). These contextual factors could create an environment that supports students' use of learning strategies and allows them to see improvement in their learning. Unfortunately, low-SES schools tend to have limited resources and supports to help students with growth mindsets associate their efforts with positive learning outcomes (Wang et al., 2019). In fact, research has shown that students from urban school districts frequently encounter underqualified math teachers, limited learning resources, and stereotype threat (Nasir, 2019; Osborne & Walker, 2006), all of which undermine students' access to math learning opportunities. Therefore, it is imperative to identify the necessary instructional supports and learning skillsets for nurturing adaptive mindset beliefs so that students from socioeconomically disadvantaged backgrounds can benefit from growth mindsets alongside their higher SES peers.

In these three studies, we sought to take the first steps in understanding the variation of student engagement by socioeconomic context. These studies all revealed an interaction between growth mindset and metacognitive skills on math engagement. For low-SES schools, the interaction suggested that growth mindsets work to engage students only when students have appropriate metacognitive skills. In other words, believing that you can improve your math ability through effort is only useful when you have the tools to help you realize this growth (e.g., knowing how to regulate one's learning process to make progress). If students have adequate metacognitive skills, then they can monitor their understanding and evaluate when progress is being made, thus creating opportunities for students to implement and experience growth mindset messages. For example, having adequately using metacognition provides students the ability to monitor their learning, recognize areas of improvement or progress, and identify ways to be more productive learners in subsequent learning experiences. This interpretation is consistent with prior work showing that students who received a metacognitive intervention had higher growth mindsets and better learning outcomes than students in a control condition (Zepeda, Richey, Ronevich, & Nokes-Malach, 2015). Hence, metacognition organically creates support for a growth mindset by conveying the message "you can improve, and you have control over improving." That is, for the seed of the mindset to grow, students need adequate soil; and from this work, we find that metacognition is one nutritional aspect of the soil that allows for growth mindsets to blossom. Further, having adequate use of metacognition in conjunction with a growth mindset allows for students to be more engaged with math, as they have the means to both progress in their learning and interpret their learning experiences in a positive and meaningful manner.

It is noteworthy that socioeconomically disadvantaged students with a high growth mindset but low metacognitive skills had lower engagement. In other words, solely holding a growth mindset without the adequate metacognitive skills to regulate learning could be detrimental to engagement in learning. After multiple attempts of trying to learn and putting forth effort to do so (e.g., growth mindset), a student may feel helpless if they cannot experience mastery, especially if they do not know how to reflect upon or change their means of understanding. Hence, it might be risky to solely focus on promoting growth mindsets without adequate support for maintaining it. For instance, educators may attribute socioeconomically disadvantaged students' low engagement to fixed mindsets rather than focusing on how to change their teaching to better support these students' development of metacognition.

Additionally, students from low-SES schools had lower metacognitive skills on average than their peers in high-SES schools, but there were fewer differences in students' growth mindsets between low- and high-SES schools. This finding suggests that low-SES schools might be deficient in supporting students' use of metacognition. One reason for this deficit might be that teachers tend to believe that only high-performing students can benefit from higher-order skills such as metacognition (Warburton & Torff, 2005; Zohar, Degani, & Vaaknin, 2001); yet, studies have refuted this viewpoint (e.g., Cardelle-Elawar, 1995). Teaching metacognition not only helps students with distinct achievement reap the benefits of a growth mindset, but it also provides students with equitable access to learning activities.

In Study 3, we found that the direction of the interactions between growth mindsets and metacognitive skills differed between low- and high-SES schools. These findings echo the importance of situating the study results within context (Wang et al., 2019). For students from high-SES schools, growth mindsets may compensate for the lack of metacognition and work to engage students only when students have low metacognitive skills. Indeed, students with low metacognitive skills in high-SES schools were likely lower achieving students who were stigmatized or who have received less recognition and lower expectations from teachers (Wang et al., 2020). Thus, these academically struggling students may first need to believe they can do math and become better with effort so that they can be motivated to initiate and continue their learning. In contrast, many students from the low-SES schools in our study appeared to be struggling with learning math, as evident by the low math performance from those schools. Hence, solely promoting a growth mindset (e.g., telling them they can do math and improve at it) is probably not as effective as promoting a growth mindset while simultaneously providing them with adequate skills and learning support to process and make sense of math materials (e.g., telling and showing them they can do math and improve at it). Consistent with other studies, these results provide evidence that having a growth mindset can be beneficial for students; however, mindsets and other related psychological beliefs are not the major explanation of the opportunity gap between low- and high-SES school settings (Destin et al., 2019).

It is also plausible that a learner cannot reap the benefits of a growth mindset without some basic levels of metacognitive skills. For instance, students in low-SES schools had very low levels of metacognitive skills; therefore, solely having a growth mindset may not have been sufficient enough to engage them in math learning. Indeed, only those with higher metacognitive skills benefitted from a growth mindset. In contrast, students in the high-SES schools (even students with lower metacognitive skills) had relatively higher levels of metacognitive skills than their peers in low-SES schools, perhaps explaining why students from high-SES schools benefitted from growth mindsets (i.e., because they have the basic metacognitive skills). Future work should identify the level to which these metacognitive skills may help facilitate growth mindsets and how to provide psychological and cognitive support to best increase student engagement and learning in mathematics.

Furthermore, teachers clearly play a critical role in the quality of math instruction, the promotion of growth mindsets and metacognitive skills, and student engagement. Studies have suggested that teaching quality varies by teacher–student relationship and that the teacher–student relationship is an important indicator of teaching quality (e.g., Roorda et al., 2011). Our findings show that the teacher–student relationship is positively related to math engagement; thus, we should not rule out the importance of the teacher–student relationship in promoting engagement in academic learning. In particular, teachers from low-SES schools have less resources and often contend with higher student behavioral problems that may impede instructional quality and their ability to spend time on developing supportive teacher–student relationships (Wang et al., 2020). Future studies should investigate how students' growth mindsets and metacognitive skills may interact with the teacher–student relationship in shaping math engagement.

Limitations

This work is a first step into examining the interactive relations between metacognition and mindsets on math engagement within low-SES schools. More work can examine the extent to which these patterns are robust across different contexts (e.g., content domain, classroom climate). For example, considering that math often comes with negative attributions and prompts maladaptive emotions from students, these patterns might look different in elective courses (e.g., foreign language) in which there might be fewer motivational challenges and consequences. Examining whether these patterns exist for schools in other areas or countries where there are different curricula and standards is also important, as those standards may have implications for what and how the material is taught and emphasized. Moreover, there may be teacher effects such that teachers in low-SES schools who seek to create an inclusive, equitable environment in which they teach students metacognitive skills and emphasize adaptive beliefs have patterns similar to that of students from high-SES schools.

Additionally, the ability mindset (also referred to as theories of intelligence) has been often assessed with items addressing fixed mindset beliefs to ensure measurement consistency across literature and avoid social desirability of respondents. The two ends of the scale (i.e., fixed and growth mindsets) are treated as equivalent, with the fixed items typically being reverse scored to indicate the degree to which people have a growth mindset. However, some researchers have argued that most people may hold both growth and fixed mindsets simultaneously, with each mindset having its own unique process and associated learning outcomes (Hwang et al., 2019; Wang et al., 2019). Thus, future studies should include and differentiate entity and incremental theory items to investigate whether the endorsement of a growth versus a fixed mindset leads to different learning outcomes.

Another limitation is the use of self-report to measure students' metacognitive skills and growth mindsets. Although self-reports are often critiqued for whether students are accurately reporting their internal beliefs and skillsets, studies have shown that adolescents' self-reports are strongly predictive of their academic and behavioral outcomes (Wang et al., 2021; Wang & Degol, 2014). To further unpack this work, future studies need to assess these variables with behavioral or observational assessments to determine whether different assessment methods reveal similar outcomes. Although students have been identified as reliable reporters of certain dimensions of engagement (e.g., cognitive engagement; Reschly & Christenson, 2012), it is imperative for future research to include other approaches to provide a more comprehensive picture of engagement over multiple assessments. For example, researchers have suggested that teachers and school record data can provide useful and complementary information on behavioral engagement (Wang et al., 2019). Future studies should also include additional outcomes (e.g., test scores) and investigate whether different mechanisms may be involved in the learning process (e.g., the indirect effect of metacognition and mindset on academic performance through engagement). Finally, given the nature of the data from these studies, we were only able to examine correlational links between underlying factors. Future experimental designs are needed to examine whether these relations are causal.

Implications for Research and Practice

This work has several implications for practice and research. Our findings present an important caveat to recent grand-scale educational movements promoting growth mindsets: It is imperative that educators recognize that growth mindsets alone may not be effective, especially without consideration of school contexts. In fact, such practices may even be detrimental for students at low-SES schools. Therefore, teachers should focus on creating learning environments that both support metacognitive skills (see Schneider & Artelt, 2010; Zepeda et al., 2019) and promote growth mindsets (see Yeager et al., 2019), with more emphasis being placed on the former in low-SES contexts. Supporting the development of metacognitive skills alongside a growth mindset creates a complementary support system in which students have the ability to monitor, control, and direct their learning (i.e., metacognitive skills) as well as the means to interpret their learning progress adaptively (i.e., a growth mindset).

Regarding implications for research, the interactions between metacognition and growth mindsets for different school contexts provide new insights into learning theories. In particular, much extant work emphasizes that metacognition and motivation build upon each other: The more of one construct, the more of another. In the case of math learning, we find that it is not enough to just have a growth mindset—students also need the metacognitive skills to act upon this mindset. Understanding the constraints and thresholds of how much or the specific type of metacognitive skill that is enough to boost growth mindset (and vice versa) and the parameters of these factors will further advance learning theories and inform practice in education.

When designing math interventions to support growth mindsets and metacognitive skills, a necessary first step is to understand the learning environments that their student populations experience (e.g., classroom norms, teaching styles, curricular focus). Researchers can then use this information to better develop context-specific interventions. For instance, if students have low levels of metacognitive skills, then the intervention should focus on developing and providing continued support for those skills. When considering how to best integrate an intervention addressing both the use of metacognitive skills and growth mindset, educators need to dig deeper so as to facilitate these elements through authentic practice, positive reinforcement, and constructive feedback. Critically, interventionists should collaborate with math teachers and iteratively solicit students' feedback on the materials to understand if they are relevant and informative from the student perspective.

Implicit in these implications is a resounding underlying message: *Context matters*. It is imperative that future work accounts for differential environmental stressors and challenges as well as societal and historical barriers experienced by adolescents. At a minimum, future research should contextualize not only who the participants are and the time frame between measures, but it should also consider the learning environments in which participants are situated. This contextualization will allow researchers to better understand how different relations or intervention effects emerge based on the interactions in a given environment. By taking a development-in-context perspective, we have revealed novel insights into the nature of learning (Turner & Nolen, 2015; Wang et al., 2019), but many questions remain. Further work examining the environmental conditions of differing learning contexts will help answer questions around for whom, when, and in which contexts SRL and engagement theories are most effective for facilitating student engagement and achievement.

References

Ahn, J. N., Luna-Lucero, M., Lamnina, M., Nightingale, M., Novak, D., & Lin-Siegler, X. (2016). Motivating students' STEM learning using biographical information. *International Journal of Designs for Learning*, *7*, 71–85. https://doi.org/10.14434/ijdl.v7i1.19409

Baraldi, A. N., & Enders, C. K. (2010). An introduction to modern missing data analyses. *Journal of School Psychology*, *48*, 5–37. https://doi.org/10.1016/j.jsp.2009.10.001

Binning, K. R., & Browman, A. S. (2020). Theoretical, ethical, and policy considerations for conducting social–psychological interventions to close educational achievement gaps. *Social Issues and Policy Review*, *14*, 182–216. https://doi.org/10.1111/sipr.12066

Binning, K. R., Wang, M. T., & Amemiya, J. (2019). Persistence mindset among adolescents: Who benefits from the message that academic struggles are normal and temporary? *Journal of Youth and Adolescence*, *48*, 269–286. https://doi.org/10.1007/s10964-018-0933-3

Blackwell, L. S., Trzesniewski, K. H., & Dweck, C. S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development*, *78*, 246–263. https://doi.org/10.1111/j.1467-8624.2007.00995.x

Boaler, J. (2013). Ability and mathematics: The mindset revolution that is reshaping education. *Forum*, *55*, 143–152. https://doi.org/10.2304/forum.2013.55.1.143

Boden, K. K., Zepeda, C. D., & Nokes-Malach, T. J. (2020). Achievement goals and conceptual learning: An examination of teacher talk. *Journal of Educational Psychology*, *112*, 1221–1242. https://doi.org/10.1037/edu0000421

Bolger, N., Davis, A., & Rafaeli, E. (2003). Diary methods: Capturing life as it is lived. *Annual Review of Psychology*, *54*, 579–616. https://doi.org/10.1146/annurev.psych.54.101601.145030

Bostwick, K. C. P., Martin, A. J., Collie, R. J., & Durksen, T. L. (2019). Growth orientation predicts gains in middle and high school students' mathematics outcomes over time. *Contemporary Educational Psychology*, *58*, 213–227. https://doi.org/10.1016/j.cedpsych.2019.03.010

Cardelle-Elawar, M. (1995). Effects of metacognitive instruction on low achievers in mathematics problems. *Teaching & Teacher Education*, *11*, 81–95. https://doi.org/10.1016/0742-051X(94)00019-3

Carr, M. (2010). The importance of metacognition for conceptual change and strategy use in mathematics. In H. S. Waters & W. Schneider (Eds.), *Metacognition, strategy use, and instruction* (pp. 176–197). New York, NY: Guilford.

Degol, J. L., Wang, M. T., Zhang, Y., & Allerton, J. (2018). Do growth mindsets in math benefit females? Identifying pathways between gender, mindset, and motivation. *Journal of Youth and Adolescence*, *47*, 976–990. https://doi.org/10.1007/s10964-017-0739-8

Destin, M., Hanselman, P., Buontempo, J., Tipton, E., & Yeager, D. S. (2019). Do student mindsets differ by socioeconomic status and explain disparities in academic achievement in the United States? *AERA Open*, *5*, 1–12. https://doi.org/10.1177/2332858419857706

Dweck, C. S. (2000). *Self-theories: Their role in motivation, personality, and development*. East Sussex, UK: Psychology Press.

Efklides, A. (2011). Interactions of metacognition with motivation and affect in self-regulated learning: The MASRL model. *Educational Psychologist*, *46*, 6–25. https://doi.org/10.1080/00461520.2011.538645

Flavell, J. H. (1987). Speculation about the nature and development of metacognition. In F. Weinert & R. Kluwe (Eds.), *Metacognition, motivation, and understanding* (pp. 21–29). Hillsdale, NJ: Erlbaum.

Fredricks, J. A., Wang, M. T., Schall Linn, J., Hofkens, T. L., Sung, H., Parr, A. K., & Allerton, J. (2016). Using qualitative methods to develop a survey measure of math and science engagement. *Learning and Instruction*, *43*, 5–15. https://doi.org/10.1016/j.learninstruc.2016.01.009

Gómez-Chacón, I. M., García-Madruga, J. A., Vila, J. Ó., Elosúa, M. R., & Rodríguez, R. (2014). The dual processes hypothesis in mathematics performance: Beliefs, cognitive reflection, working memory and reasoning. *Learning and Individual Differences*, *29*, 67–73. https://doi.org/10.1016/j.lindif.2013.10.001

Good, C., Aronson, J., & Inzlicht, M. (2003). Improving adolescents' standardized test performance: An intervention to reduce the effects of stereotype threat. *Journal of Applied Developmental Psychology*, *24*, 645–662. https://doi.org/10.1016/j.appdev.2003.09.002

Hentges, R. F., Galla, B. M., & Wang, M. T. (2019). Economic disadvantage and math achievement: The significance of perceived cost from an evolutionary perspective. *British Journal of Educational Psychology*, *89*, 343–358. https://doi.org/10.1111/bjep.12242

Hwang, N. Y., Reyes, M., & Eccles, J. S. (2019). Who holds a fixed mindset and whom does It harm in mathematics? *Youth and Society*, *51*, 247–267. https://doi.org/10.1177/0044118X16670058

Leslie, S.-J., Cimpian, A., Meyer, M., & Freeland, E. (2015). Expectations of brilliance underlie gender distributions across academic disciplines. *Science*, *347*, 262–265. https://doi.org/10.1126/science.1261375

Li, Y., & Lerner, R. M. (2011). Trajectories of school engagement during adolescence: Implications for grades, depression, delinquency, and substance use. *Developmental Psychology*, *47*, 233–247. https://doi.org/10.1037/a0021307

Miller, D. I. (2019). When do growth mindset interventions work? *Trends in Cognitive Sciences*, *23*, 910–912. https://doi.org/10.1016/j.tics.2019.08.005

Nasir, N. S. (2019). Teaching for equity: Where developmental needs meet racialized structures. *Applied Developmental Science*, *24*, 146–150. https://doi.org/10.1080/10888691.2019.1609737

Olsen, R. B. (2017). Evaluating educational interventions when impacts may vary across sites. *Journal of Research on Educational Effectiveness*, *10*, 907–911. https://doi.org/10.1080/19345747.2017.1364554

Osborne, J. W., & Walker, C. (2006). Stereotype threat, identification with academics, and withdrawal from school: Why the most successful students of colour might be most likely to withdraw. *Educational Psychology*, *26*, 563–577. https://doi.org/10.1080/01443410500342518

Oyserman, D., & Lewis, N. A. (2017). Seeing the destination AND the path: Using identity-based motivation to understand and reduce racial disparities in academic achievement. *Social Issues and Policy Review*, *11*, 159–194. https://doi.org/10.1111/sipr.12030

Pintrich, P. R., Smith, D. A. F., Garcia, T., & McKeachie, W. J. (1991). *A manual for the use of the Motivated Strategies for Learning Questionnaire (MSLQ)*. Ann Arbor, MI: National Center for Research to Improve Post-Secondary Teaching.

Reardon, S. F. (2011). The widening academic achievement gap between the rich and the poor: New evidence and possible explanations. In G. J. Duncan & R. Murnane (Eds.), *Whither opportunity?: Rising inequality, schools, and children's life chances* (pp. 91–115). New York, NY: Russell Sage Foundation.

Renaud-Dubé, A., Guay, F., Talbot, D., Taylor, G., & Koestner, R. (2015). The relations between implicit intelligence beliefs, autonomous academic motivation, and school persistence intentions: A mediation model. *Social Psychology of Education*, *18*, 255–272. https://doi.org/10.1007/s11218-014-9288-0

Reschly, A. L., & Christenson, S. L. (2012). Jingle, jangle, and conceptual Haziness: Evolution and future directions of the engagement construct. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 3–19). New York, NY: Springer.

Romero, C., Master, A., Paunesku, D., Dweck, C. S., & Gross, J. J. (2014). Academic and emotional functioning in middle school: The role of implicit theories. *Emotion*, *14*, 227–234. https://doi.org/10.1037/a0035490

Roorda, D. L., Koomen, H. M. Y., Spilt, J. L., & Oort, F. J. (2011). The influence of affective teacher–student relationships on students' school engagement and achievement: A meta-analytic approach. *Review of Educational Research*, *81*, 493–529. https://doi.org/10.3102/0034654311421793

Rosenzweig, E. Q., & Wigfield, A. (2016). STEM motivation interventions for adolescents: A promising start, but further to go. *Educational Psychologist*, *51*, 146–163. https://doi.org/10.1080/00461520.2016.1154792

Schneider, W., & Artelt, C. (2010). Metacognition and mathematics education. *Zdm—international Journal on Mathematics Education*, *42*, 149–161. https://doi.org/10.1007/s11858-010-0240-2

Schoenfeld, A. H. (1987). What's all the fuss about metacognition? In A. H. Schoenfeld (Ed.), *Cognitive science and mathematics education* (pp. 189–215). Hillsdale, NJ: Erlbaum.

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense-making in mathematics. In D. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 334–370). New York, NY: Macmillan.

Turner, J. C., & Nolen, S. B. (2015). Introduction: The relevance of the situative perspective in educational psychology. *Educational Psychologist*, *50*, 167–172. https://doi.org/10.1080/00461520.2015.1075404

Umemoto, T., Ito, T., & Tanaka, K. (2016). Relationships between regulation strategies, emotional and behavioral engagement, and academic achievement. *The Japanese Journal of Psychology*, *87*, 334–342. https://doi.org/10.4992/jjpsy.87.15020

Veenman, M. V. J., Van Hout-Wolters, B. H. A. M., & Afflerbach, P. (2006). Metacognition and learning: Conceptual and methodological considerations. *Metacognition and Learning*, *1*, 3–14. https://doi.org/10.1007/s11409-006-6893-0

Walton, G. M., & Wilson, T. D. (2018). Wise interventions: Psychological remedies for social and personal problems. *Psychological Review*, *125*, 617–655. https://doi.org/10.1037/rev0000115

Walton, G. M., & Yeager, D. S. (2019). Seed and soil: Psychological affordances in contexts help to explain where wise interventions succeed or fail. *Current Directions in Psychological Science*, *29*, 219–226. https://doi.org/10.1177/0963721420904453

Wang, M.-T., Binning, K. R., Del Toro, J., Qin, X., & Zepeda, C. D. (2021). Skill, thrill, and will: The role of metacognition, interest, and self-control in predicting student engagement in mathematics learning over time. *Child Development*, http://dx.doi.org/10.1111/cdev.13531.

Wang, M.-T., & Degol, J. (2014). Staying engaged: Knowledge and research needs in student engagement. *Child Development Perspectives*, *8*, 137–143. https://doi.org/10.1111/cdep.12073

Wang, M.-T., Degol, J. L., & Henry, D. A. (2019). An integrative development-in-sociocultural-context model for children's engagement in learning. *American Psychologist*, *74*, 1086–1102. https://doi.org/10.1037/amp0000522

Wang, M.-T., & Eccles, J. S. (2012). Adolescent behavioral, emotional, and cognitive engagement trajectories in school and their differential relations to educational success. *Journal of Research on Adolescence*, *22*, 31–39. https://doi.org/10.1111/j.1532-7795.2011.00753.x

Wang, M.-T., Fredricks, J. A., Ye, F., Hofkens, T. L., & Linn, J. S. (2016). The Math and Science Engagement Scales: Scale development, validation, and psychometric properties. *Learning and Instruction*, *43*, 16–26. https://doi.org/10.1016/j.learninstruc.2016.01.008

Wang, M.-T., Degol, J. L., Amemiya, J., Parr, A., & Guo, J. (2020). Classroom climate and children's academic and psychological wellbeing: A systematic review and meta-analysis. *Developmental Review*, *57*, 100912. https://doi.org/10.1016/j.dr.2020.100912

Wang, M.-T., Henry, D., & Degol, J. (2020). A development-in-sociocultural-context perspective on the multiple pathways to youth's engagement in learning. In A. Elliot (Ed.), *Advances in Motivation Science* (Vol. *7*, 1st ed., pp. 113–160). Elsevier.

Warburton, E. C., & Torff, B. (2005). The effect of perceived learner advantages on teachers' beliefs about critical-thinking activities. *Journal of Teacher Education*, *56*, 24–33. https://doi.org/10.1177/0022487104272056

Weiss, M. J., Bloom, H. S., Verbitsky-Savitz, N., Gupta, H., Vigil, A. E., & Cullinan, D. N. (2017). How much do the effects of education and training programs vary across sites? Evidence from past multisite randomized trials. *Journal of Research on Educational Effectiveness*, *10*, 843–876. https://doi.org/10.1080/19345747.2017.1300719

Wigfield, A., Eccles, J. S., Schiefele, U., Roeser, R. W., & Davis-Kean, P. (2006). Development of achievement motivation. In W. Damon & N. Eisenberg (Eds.), *Handbook of child psychology: Social, emotional, and personality development* (6th ed., pp. 933–1002). Hoboken, NJ: Wiley.

Winne, P. H., & Hadwin, A. F. (2008). The weave of motivation and self-regulated learning. In D. H. Schunk & B. J. Zimmerman (Eds.), *Motivation and self-regulated learning: Theory, research, and applications* (pp. 297–314). Hillsdale, NJ: Erlbaum.

Yeager, D. S., Hanselman, P., Walton, G. M., Murray, J. S., Crosnoe, R., Muller, C., . . . Dweck, C. S. (2019). A national experiment reveals where a growth mindset improves achievement. *Nature*, *573*, 364–369. https://doi.org/10.1038/s41586-019-1466-y

Zepeda, C. D., Hlutkowsky, C. O., Partika, A. C., & Nokes-Malach, T. J. (2019). Identifying teachers' supports of metacognition through classroom talk and its relation to growth in conceptual learning. *Journal of Educational Psychology*, *111*, 522–541. https://doi.org/10.1037/edu0000300

Zepeda, C. D., Richey, J. E., Ronevich, P., & Nokes-Malach, T. J. (2015). Direct instruction of metacognition benefits adolescent science learning, transfer, and motivation: An in vivo study. *Journal of Educational Psychology*, *107*, 954–970. https://doi.org/10.1037/edu0000022

Zimmerman, B. J. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. R. Pintrich, & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13–39). San Diego, CA: Academic Press.

Zimmerman, B. J., & Moylan, A. R. (2009). Self-regulation: Where metacognition and motivation intersect. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Handbook of metacognition in education* (pp. 299–316). New York, NY: Routledge.

Zohar, A., Degani, A., & Vaaknin, E. (2001). Teachers' beliefs about low-achieving students and higher order thinking. *Teaching and Teacher Education*, *17*, 469–485. https://doi.org/10.1016/S0742-051X(01)00007-5

Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's website:

Appendix S1. Measurement Invariance Test for the Key Constructs and Item Questions for Teacher-Student Relationship Construct