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Achievement in Mathematics: Effects of Academic Motivation, Mathematics Motivation, and Mathematics Engagement

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Abstract

For the current study, a quantitative research design was used to examine the relationships among motivational and engagement factors associated with academic achievement in mathematics among Grade 8 students. The purpose was to determine how students' academic motivation, mathematics motivation, and mathematics engagement relate to each other and to their mathematical achievement. A sample of 30 mathematics teachers was selected from private schools in Karachi to provide data about their students. These teachers provided data about the motivations, engagement, and mathematical performance of 120 students (60 boys and 60 girls) using a structured questionnaire. The study evaluated the direct and indirect relationships between motivational and engagement factors and mathematics achievement using partial least squares structural equation modeling (PLS-SEM). The findings indicate a strong correlation between academic motivation and mathematical performance through the chain mediation effects of math motivation and math engagement. The study also looked at how students' ages influenced the relationship between mathematical achievement and motivational factors, highlighting the need for teachers to pay closer attention to Grade 8 students in order to help them transform from general motivation to mathematics motivation. The results have implications for curriculum interventions that may improve mathematics education in teacher-training institutions as well as for the development of supportive learning environments that promote motivation and engagement in mathematics.

Keywords: Academic motivation, mathematics motivation, mathematics engagement

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Introduction

Elementary school education is a vital stage in the academic life of children, as it provides the foundation for all complex educational tasks of the future. Elementary school contributes to a child's future academic success by laying the necessary groundwork. Research has consistently demonstrated that students are more likely to learn and succeed academically in later years when they are actively engaged in their studies at the elementary level (Chase et al., 2014; Lei et al., 2018; Mendoza & King, 2020). In elementary school, young children learn the fundamentals that they will need for the rest of their lives. Basic academic capabilities like math, reading, and writing pave the way for future learning that is more specialized. According to research, children who perform well in elementary school have a higher chance of doing well in high school and are also less likely to commit crimes (Rabiner et al., 2016). Additionally, they are more likely to succeed professionally and maintain stable relationships (Choi & Jun, 2023). This makes it essential that young elementary school children receive high-quality education that will enable them to succeed in both school and life. A high-quality elementary education will, primarily, foster a lifelong love of learning. Studies have shown that fluency in reading and mathematical skills before fourth grade can enhance a student’s lifelong learning capacity (Leahy & Fitzpatrick, 2017; McClelland et al., 2006; Watts, 2020). Therefore, a child's entire life can be impacted by the quality of education they receive at the elementary level.

Many children between the ages of 12 and 14 begin to exhibit increased capacity for cognitive development as they start to use symbolic reasoning and think abstractly. They start thinking beyond visible, tangible objects and concepts, as well as more complex and abstract ideas (Piaget, 1964). They start developing theories and hypotheses regarding various events occurring in their environment. They add new activities to their academic roles and develop new perspectives on their academic motivation regarding academic activities (Kumari & Sangwan, 2021). They develop different motivations for studying in general and for specific subjects in particular. Their level of engagement in the learning tasks of different subjects varies depending on their motivation level in that subject. Motivation (Pintrich, 2003) and engagement (Fredricks et al., 2004) are the key factors that contribute to academic achievement. Therefore, academic motivation and engagement of elementary students are of great importance and need to be investigated.

Academic motivation, described as "the process whereby goal-directed academic activity is instigated and sustained" (Koenka, 2020, p. 3; Schunk et al., 2014), is one significant type of motivation. According to this conceptualization, goal-directed actions are the overt manifestation of internal (personal) processes that drive academic motivation. Academic motivation is the force that drives students to act in a particular way for academic success. Beyond this general type of motivation, researchers also distinguish motivation toward specific academic subjects.

Subject-specific motivation is the motivation towards specific academic areas and focuses primarily on disciplines such as writing, reading, and math (Guay et al., 2010). When analyzing the function of student motivation, we can think of it as a general concept (student motivation for education in general) or as a subject-specific concept (e.g., student motivation for math). Understanding both general and specific academic achievements requires taking into account both motivations (Bandura, 1997; Elliot, 2005; Green et al., 2007; Pintrich, 2003). This has made room for intervention programs that aim to boost students' motivation in the classroom (Wigfield & Wentzel, 2007).

Academic engagement is active participation, dedication, and focus as opposed to indifference and lack of interest in studies (Newmann, Wehlage, & Lamborn, 1992). Students' motivation and engagement are demonstrated by their completion of homework, readiness for class, consistent attendance, and non-sick absences. There might be a reciprocal relationship between motivation and academic engagement. Engagement with academic tasks is influenced by motivation, and engagement in turn raises motivation and interest. Learning is facilitated by both academic engagement and motivation. Students may commit to or withdraw from learning based solely on how interested they are in the subject (Singh et al., 2002). Learning a subject is also correlated with one's interest in it. It appears from the body of research that motivation, attitudes, interest, and academic engagement are important factors in learning.

Mathematics has unique qualities compared to other school subjects. In many other subjects, students can learn and practice topics mostly independent of prior knowledge. Mathematics has a hierarchical and cumulative nature, where learners need to have an adequate understanding of earlier topics before they are able to successfully navigate new material. In addition, anxiety and avoidance are associated with mathematics more than other school subjects, so subject-specific motivation and engagement may play a greater role in mathematics achievement than in other subjects.

Mathematical engagement is a multifaceted concept, which includes how much students participate and invest in learning mathematics as well as the behavioral, emotional, and cognitive dimensions of this behavior (e.g., self-regulation, challenge preference, elaboration preference, effort, interest, and willingness to work and reflect on what they will do to learn and master challenging tasks) (Fredricks et al., 2004).

Asking questions to clarify concepts, perseverance through challenging tasks, adaptability in problem solving, application of learning strategies (e.g., connecting new information to previously learned material), and use of self-regulation to enhance learning are all signs of math engagement (Finn & Zimmer, 2012; Fredricks et al., 2004).

The purpose of this study is to explore the relationships among elementary students' academic motivation (motivation for education in general), math motivation (motivation for math), math engagement, and achievement in mathematics using partial least squares structural equation modeling (PLS-SEM). The study examines how math motivation and academic motivation affect math engagement and, in turn, math achievement in both direct and indirect ways. The goal is to provide important insights on individual motivational and engagement constructs rather than the broader socio-cultural resources examined in the STEM-capital literature (Moote et al., 2020).

Research Objectives

The study has the following specific objectives:

1. To examine and estimate the hypothesized relationships among academic motivation, mathematics motivation, mathematics engagement, and mathematics achievement.
2. To identify the relative importance of each motivational factor in predicting mathematics achievement.
3. To evaluate the chain mediation effect of math motivation and math engagement between academic motivation and math achievement.
4. To test the moderation and mediation effects in the model, take students' age as a moderator.

Research Hypotheses

H_1: M2 (mathematics motivation) mediates the positive relationship between M1 (academic motivation) and MAch (mathematics achievement).

H_2: M2 (mathematics motivation) mediates the positive relationship between M1 (academic motivation) and MEng (mathematics engagement).

H_3: MEng (mathematics engagement) mediates the positive relationship between M2 (mathematics motivation) and MAch (mathematics achievement).

H_4: M2 (mathematics motivation) and MEng (math engagement) act as chain mediators between the positive relationship of M1 (academic motivation) and MAch (mathematics achievement).

H_5: The positive effects of M1 $\rightarrow$ M2 and M2 $\rightarrow$ MEng are positively moderated by the age of the students.

Research Methodology

A cross-sectional design and a quantitative methodology were used in the study.

Data and Sampling

A cross-sectional design and a quantitative methodology were used in the study. A three-stage sampling process was employed whereby ten private schools in Karachi, Pakistan, that demonstrated an interest in taking part in this study were selected via convenience sampling and included in the study. After that, the researcher included all Grade 8 math teachers from the participating schools in the research (N = 30). Finally, two boys and two girls were randomly selected by the teachers from their classes to serve as the targets of the teachers' responses. Teachers were not informed in advance which students would be drawn in order to reduce the risk of selective nomination. In this way, each teacher provided data about four students' motivations, engagement, and achievement.

Instrumentation

A questionnaire was designed to collect data from mathematics teachers of Grade 8 about their students' motivation, engagement, and achievement. The questionnaire consisted of three scales: Academic Motivation (M1), Math Motivation (M2), and Math Engagement (MEng); and a formative scale: Math Achievement (MAch). Academic Motivation (M1) and Mathematics Motivation (M2) were operationalized here through teacher-rated behavioral indicators (e.g., attendance, punctuality, materials preparedness) following Singh et al. (2002). Students' Math Engagement (MEng) was measured using a scale comprising seven items. Math Achievement (MAch) was measured as a formative scale through the results of the students' final examinations from the previous two years (i.e., Grade 6 and Grade 7).

Table 1
Questionnaire items and latent variables

Indicators	**Motivation 1 (M1)** [Scale: 5 = none to 1 = more than 4 days.]	**1**	**2**	**3**	**4**	**5**
M11	Number of days missed class in the last month.					
M12	Number of times joined class late in the last month.					
M13	How often did you go out for the washroom/drinking water, etc., during class in the last month?					
M14	How often were you found distracted during class in the last month?					
	Motivation 2 (M2) [Scale: 5 = none to 1 = more than 4 days.]	**1**	**2**	**3**	**4**	**5**

M21	How often did you come to class without a copy/pen/calculator/geometry box, etc., in the last month?					
M22	How often did you come to class without a book in the last month?					
M23	How often did you come to class without homework in the last month?					
M24	*Neatness of the homework. [*Scale: 5 = excellent to poor = 1]					
	Mathematics Engagement (MEng) [Scale: 5 = Always to 1 = Never.]	**1**	**2**	**3**	**4**	**5**
MEng1	The student actively participates in math class discussions and activities.					
MEng2	The student works enthusiastically during class assignments.					
MEng3	The student exhibits curiosity and a desire to learn more even beyond the curriculum.					
MEng4	The student collaborates with peers during group math activities or projects.					
MEng5	The student puts forth effort and diligence when completing math assignments.					
MEng6	The student sets and works towards specific math-related goals, such as improving grades or mastering certain concepts.					
MEng7	The student actively participates in math enrichment programs, competitions, or extracurricular math-related activities.					
	Mathematics Achievement (MAch) [Scale: 5 = A^{+}; 4 = A; 3 = B; 2 = C; 1 = D or less.]	**1**	**2**	**3**	**4**	**5**
MAch1	Grades earned in mathematics (class 6 final exam).					
MAch2	Grades earned in mathematics (class 7 final exam).					

Model and Analysis

The latent variable structural equation model was estimated employing SmartPLS 4 software. The first step was to specify and estimate the measurement part of the model (constructs and their indicators); the second step was to specify and estimate structural relationships in the model. Structural equation modeling is an especially useful method to analyze non-experimental data. In reasonable terms beyond fitting parameters, the software outputs fit indices to evaluate how well the model fits the data. Fit indices encompass analysis of variance explanations, associated hypothetical models, and modification indices, making it possible to evaluate how well a theoretical model represents the data. Following the selection of items that were logically grouped into the four constructs, the measurement model was estimated to assess whether the selected items had marked loading with hypothesized constructs.

Measurement Model

To test the measurement model (N=120), Confirmatory Factor Analysis (CFA) was carried out with SmartPLS (version 4). The factor loadings for every item were evaluated as part of the confirmatory factor analysis process. Since all factor loadings were found to be greater than 0.50, no item was eliminated from any construct. A good fit was found between the four constructs (M1, M2, MEng, and MAch) and the data (CMIN/df = 2.660, GFI = .901, CFI = 0.932, TLI = 0.924, SRMR = 0.075, and RMSEA = 0.059).

Construct reliability for each construct in the study was assessed using Cronbach's Alpha and Composite Reliability (Table 2) and was found to be within the acceptable range (Hair et al., 2010; Nunnally & Bernstein, 1994). The convergent validity (Table 2) of each construct was also established as each value of AVE was greater than 0.50 (Fornell & Larcker, 1981). For discriminant validity, both Fornell and Larcker (Table 3) and HTMT ratio (Table 4) criteria were used. The square root of AVE was greater than its correlation with the other constructs in the study (Fornell & Larcker, 1981), and all HTMT ratios were less than the threshold of .85 (Henseler et al., 2015).

Table 2

Loadings, Reliability, and Convergent Validity (N=120)

		Loadings	Cronbach's Alpha	Composite Reliability	Average Variance Extracted (AVE)
M1			0.820	0.856	0.651
	M11	0.706			
	M12	0.794			
	M13	0.930			
	M14	0.779			
M2			0.843	0.881	0.670
	M21	0.728			
	M22	0.802			
	M23	0.851			
	M24	0.882			
MEng			0.968	0.969	0.838

MEng1	0.867
MEng2	0.947
MEng3	0.897
MEng4	0.931
MEng5	0.916
MEng6	0.929
MEng7	0.921

Table 3
Fornell & Larcker Criterion

	Age	M1	M2	MEng
Age	**1.000**			
M1	0.193	**0.807**		
M2	0.239	0.670	**0.819**	
MEng	0.260	0.636	0.764	**0.916**

Note. Bold values are the square root of AVE

Table 4
HTMT Ratio

	Age	M1	M2	Age × M1	Age × M2	MEng
Age						
M1	0.213					
M2	0.267	0.765				
MEng	0.263	0.699	0.783			
Age × M1	0.200	0.193	0.096	0.121		
Age × M2	0.143	0.088	0.075	0.167	0.683	

Note. HTMT = heterotrait-monotrait ratio of correlations.

Table 5
Path Coefficients

Path	β	t-value	p-value	Result
Age → M2	0.069	0.916	0.180	Not Supported
Age → MEng	0.066	0.941	0.173	Not Supported
M1 → M2	0.686	9.912	0.000	Supported***
M1 → MAch	0.197	1.601	0.063	Not Supported
M1 → MEng	0.218	1.644	0.050	Not Supported
M2 → MAch	0.014	0.149	0.441	Not Supported
M2 → MEng	0.742	14.782	0.000	Supported***
MEng → MAch	0.705	10.833	0.000	Supported***
Age × M1 → M2	0.208	2.429	0.008	Supported**
Age × M2 → MEng	0.121	1.838	0.033	Supported*

*Note. M1 = Academic Motivation, M2 = Motivation towards Mathematics, MEng = Mathematics Engagement, MAch = Mathematics Achievement, *p < .05, **p < .01, ***p < .001.*

The direct effects within the structural model are shown in Table 5. Of the nine paths, five were significant. The direct effects of age on MEng ($\beta = 0.066$, $t = 0.941$, $p = .173$) and M2 ($\beta = 0.069$, $t = 0.916$, $p = .180$) were not significant, which demonstrates that students' age is not significantly associated with either their motivation to learn mathematics or their engagement in mathematics. Additionally, the direct effect of M1 on both MEng ($\beta = 0.218$, $t = 1.644$, $p = .050$) and MAch ($\beta = 0.197$, $t = 1.601$, $p = .063$) was not significant, and M2 has no direct impact on MAch ($\beta = 0.014$, $t = 0.149$, $p = .441$), demonstrating that academic motivation is not directly associated with mathematics engagement or achievement. In addition, motivation for mathematics is not directly associated with performance. It indicates that there may be a mediating variable between these relationships.

A significant direct effect of M1 on M2 was observed ($\beta = 0.686$, $t = 9.912$, $p < .001$), which indicates that students' motivation towards mathematics is positively associated with academic motivation, or their overall motivation to study. Furthermore, M2 showed a direct impact on MEng ($\beta = 0.742$, $t = 14.782$, $p < .001$). These results reveal that engagement in mathematics is positively associated with motivation towards the subject. Moreover, mathematical engagement is strongly positively associated with mathematics achievement ($\beta = 0.705$, $t = 10.833$, $p < .001$).

Age was found to have a significant moderating effect on the positive relationship between M1 and M2 ($\beta = 0.208$, $t = 2.429$, $p < .01$). According to the basic slope analysis, there is a positive correlation between M1 and M2 that increases with age. It demonstrates that teachers may need to make greater efforts in this area because it is relatively challenging to convert younger children's academic motivation into mathematics motivation.

It was also found that age had a significant moderating effect on the positive relationship between M2 and MEng ($\beta = 0.121$, $t = 1.838$, $p < .05$.) The results of the simple slope analysis showed that there is a positive correlation between M2 and MEng that increases with age. It demonstrates that it is relatively challenging to convert young children's motivation for mathematics into engagement with the subject, so educators must make an extra effort in this area.

Table 6
Chain Mediation Effects

Path	β	t-value	p-value	Result
M2 → MEng → MAch	0.523	8.193	0.000	Supported***
M1→ M2→ MEng	0.509	7.155	0.000	Supported***
M1→ M2→ MAch	0.009	0.141	0.444	Not Supported
Age → M2 → MEng → MAch	0.036	0.905	0.183	Not Supported
Age → MEng → MAch	0.047	0.942	0.173	Not Supported
M1 → M2 → MEng → MAch	0.359	5.678	0.000	Supported***

*Note. M1 = Academic Motivation, M2 = Motivation towards Mathematics, MEng = Mathematics Engagement, MAch = Mathematics Achievement, *p < .05, **p < .01, ***p < .001.*

As shown in Table 5, the direct effect of M2 on MAch is not significant, demonstrating that motivation for mathematics is not directly associated with achievement. Table 6 reveals that the indirect effect of M2 on MAch through MEng is significant ($\beta = 0.523$, $t = 8.193$, $p < .001$). This shows that there is a full mediation effect of MEng between M2 and MAch. The results indicate that motivation for mathematics is associated with mathematics achievement through mathematics engagement (active involvement in solving math problems and other related activities) only.

No direct effect of M1 on MEng was found (Table 5), but the indirect effect of M1 on MEng through M2 was found significant ($\beta = 0.509$, $t = 7.155$, $p < .001$) as shown in Table 6. This shows that M2 fully mediates between M1 and MEng. These results reveal that academic motivation (general motivation towards studies) is not directly associated with mathematics engagement; rather, it relates to engagement indirectly, through students' motivation towards mathematics.

M1 showed no significant effect on MAch directly (Table 5) or indirectly (Table 6) through M2 ($\beta = 0.009$, $t = 0.141$, $p = .444$). This demonstrates that M1 does not affect MAch, which implies that there should be some chain mediation effect in this model.

The chain mediation effect (Table 6) was assessed in the model, and it was found that M1 is associated with MAch through the chain mediation of M2 and MEng ($\beta = 0.359$, $t = 5.678$, $p < .001$). The findings show that students' academic motivation is associated with their mathematical achievement through motivation and engagement in mathematics.

Table 7

Moderated Mediation Effects

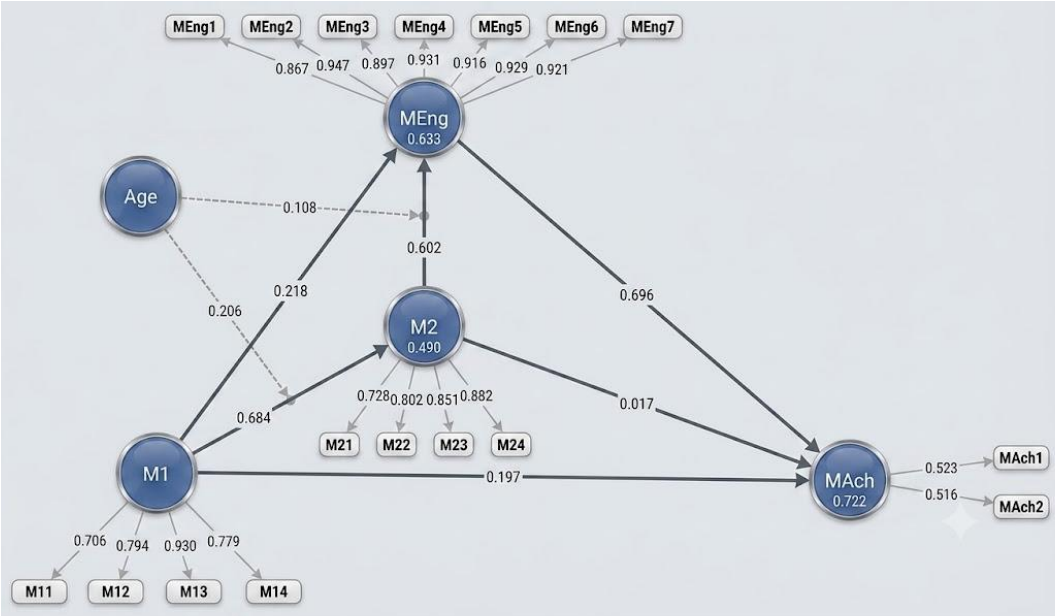
Path	β	t-value	p-value	Result
Age × M2 → MEng → MAch	0.085	1.777	0.038	Supported*
Age × M1 → M2 → MEng	0.154	2.433	0.008	Supported**
Age × M1 → M2 → MAch	0.003	0.146	0.442	Not Supported
Age × M1 → M2 → MEng → MAch	0.109	2.339	0.010	Supported*

*Note. M1 = Academic Motivation, M2 = Motivation towards Mathematics, MEng = Mathematics Engagement, MAch = Mathematics Achievement, *p < .05, **p < .01, ***p < .001.*

The path M2 → MEng → MAch was evaluated to determine the moderated mediation effect of age. The R^2 value of MAch was 0.658, and the R^2 value of MEng was 0.595 in the absence of the moderating effect (Age*M²). When the interaction term was included, R^2 went up to 0.722 for MAch and 0.633 for MEng. This indicates that the moderator is responsible for an increase of 6% in variance explained in MAch and 4% in MEng. Results show (Table 7) that there is a significant moderated mediation effect ($\beta = 0.085$, $t = 1.777$, $p < .05$) in the model (Figure 1). This demonstrates how the relationship between M2 and MEng gets stronger as age increases, which further benefits MAch. This suggests that age has a favorable impact on the positive correlation between M2 and MEng, which in turn has a good impact on MAch.

The moderated chain mediation was assessed for the path M1 → M2 → MEng → MAch. Before the introduction of the moderating effect (Age*M1), the R^2 values of M2, MEng, and MAch were 0.462, 0.593, and 0.687, respectively. After the introduction of the interaction effect, the R^2 values of M2, MEng, and MAch were raised to 0.490, 0.633, and 0.722, respectively. This indicates that the moderator is responsible for an increase of 3% in variance explained in M2, 4% in MEng, and 3.5% in MAch. Results show (Table 7) that there is a significant moderated mediation effect ($\beta = 0.109$, $t = 2.339$, $p < .05$) in the model (Figure 1). This demonstrates how the chain relationship among M1, M2, and MEng becomes stronger as age increases, which further aids MAch. This suggests that age has a favorable impact on the positive relationship between M1, M2, and MEng, which in turn has a good impact on MAch.

Figure 1
Full structural equation model for latent constructs



Findings

This study identified a significant path required for performance in mathematics at the eighth-grade level. The structural model identified a significant chain of relationships underlying mathematics achievement. According to this path, general academic motivation is associated with math motivation, which is in turn related to math engagement and, ultimately, math achievement. Moreover, age positively moderates these relationships, i.e., these relationships become stronger with the increase in age. This implies that the relationship between academic motivation and math motivation appears weaker among younger students than older ones. Additionally, it is also challenging to transform students' math motivation to math engagement at this level.

Discussion

The findings of this study indicate that math engagement, rather than motivation alone, is the more immediate predictor of mathematics achievement. These results point to math engagement as the more immediate factor connecting motivation to achievement. The findings are aligned with the results of other studies (Chase et al., 2014; Lei et al., 2018; Mendoza & King, 2020). These findings are also coherent with the studies that revealed that motivation (Pintrich, 2003) and engagement (Fredricks et al., 2004) are the key factors that contribute to academic achievement in mathematics. The results also reveal a full mediation effect of MEng between M2 and MAch. This indicates that math motivation is associated with math achievement through math engagement (active involvement in solving math problems and other related activities) only.

Math motivation mediates between academic motivation and math engagement. This shows that for better engagement in mathematics, students need a motivation for mathematics along with their general motivation towards studies. These findings are consistent with the findings of the studies (Bandura, 1997; Elliot, 2005; Green et al., 2007; Pintrich, 2003) that highlighted that academic achievements require taking into account both motivations.

The results further showed that mathematics motivation neither has a direct effect on mathematics achievement nor mediates between academic motivation and mathematics achievement. It means that only motivation (either general academic or subject-specific) is not enough for better performance. Performance in mathematics is associated with academic motivation, via the chain mediation of mathematics motivation and mathematics engagement. These results suggest that students' academic motivation relates to their subject-specific motivation, which in turn relates to their engagement, which relates to performance.

Age did not show any direct effect on mathematics motivation or engagement; instead, age exhibited a moderating effect on the relationships between academic motivation, mathematics motivation, and mathematics engagement such that these relationships become stronger with age. This implies that for younger children, teachers need to devote more attention and effort to transform their general motivation for studies into mathematics motivation and then to their engagement in mathematics. This is broadly consistent with the view that abstract reasoning capacity develops gradually across this age range (Piaget, 1964), rather than a fixed age cutoff.

Limitations

There are multiple limitations to this research. First, the use of non-probability sampling and drawing from private schools in one system limits the generalizability of the findings to other types of schools and regions. The second limitation is that motivation and engagement were operationalized through behavioral indicators rated by the teacher (i.e., attendance and punctuality) rather than by the student's self-reported emotional/cognitive state; therefore, the motivation construct may not be completely captured. Future studies may utilize triangulation of teacher-report and student self-report and use a more diverse selection of schools.

Conclusion

With the limitations noted above in mind, the following recommendations are offered as context-specific starting points rather than broad prescriptions. It is recommended that mathematics teachers receive professional development related to fostering mathematics motivation and mathematics engagement among students. Mathematics teacher-education programs should place a strong emphasis on mathematics motivation and engagement of students as a means for pedagogical practice. It is also recommended that individual students' general motivation, as well as their mathematics motivation and engagement levels, be explored with the goal of creating a supportive learning environment for student academic success. In addition to interventions that target teachers only, multiple factors exist outside the classroom that have the potential to influence students' motivation. Family support, previous academic performance, and curriculum and assessment design will help to shape the development of student motivation and should therefore be highlighted as a focus for intervention and support as well. Additional research is recommended to further investigate the association between motivational and engagement factors and mathematics achievement.

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