FALL 2025 | VOLUME 16, ISSUE 2

JOURNAL OF MATHEMATICS EDUCATION AT TEACHERS COLLEGE

A Century of Leadership in Mathematics and Its Teaching

Reimagining Mathematics Teaching and Learning Beyond Standardized Measures

Published Semiannually by the Program in Mathematics Education
TEACHERS COLLEGE | COLUMBIA UNIVERSITY

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The *Journal of Mathematics Education at Teachers College (JMETC)* is a recreation of an earlier publication by the Program in Mathematics Education at Teachers College, Columbia University. As a peer-reviewed, semiannual journal, it is intended to provide dissemination opportunities for writers of practice-based or research contributions to the general field of mathematics education. Although many of the past issues of *JMETC* focused on a theme, the journal accepts articles related to any current topic in mathematics education, from which pertinent themes for future issues may be developed.

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JOURNAL SUBSCRIPTION

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LIBRARY OF CONGRESS CATALOGING-IN-PUBLICATION DATA

Journal of Mathematics Education at Teachers College
p. cm.
Includes bibliographical references.
ISSN 2156-1397
EISSN 2156-1400
1. Mathematics—Study and Teaching—United States—Periodicals
QA11.A1 J963

AVAILABLE ONLINE

jmetc.columbia.edu

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TABLE OF CONTENTS

PREFACE

While mathematics in school is widely perceived as an objective subject, standardized measures of academic performance have been recognized as insufficient methods for mathematical teaching and learning. The field of mathematics education has increasingly acknowledged factors, such as emotions, that play a role in measuring educational outcomes.

Recent studies in the field of mathematics education have increasingly placed more weight on the emotions in learning mathematics. The role of affective domains in mathematics education have been studied extensively, through the topics of problem-solving (e.g., Polya, 2014; Hannula, 2012; McLeod, 1992), enacted lessons (e.g., Pekrun & Stephens, 2010; Vogel-Walcutt et al, 2012), achievement (e.g., Hoffman, 2010; Goldin et al, 2011), and others. With such growing attention to emotions, the Fall 2025 issue of the Journal of Mathematics Education at Teachers College brings together a set of contributions in that regard, with three research-based articles and one note from the field that offers insights for practice.

In the first research-based article, Dragone and her team establish a methodology with non-cognitive indicators for academic effectiveness in mathematics beyond traditional performance measures. By analyzing the six dimensions including interest, perceived usefulness, perceived difficulty, expectations of success, self-efficacy, and mathematical anxiety, their study highlights the importance of non-cognitive factors and their relation to cognitive dimension of learning.

The second research-based article by Uddin deeper investigates one of the non-cognitive aspects of learning, math anxiety. Using a phenomenological study design framed by critical pedagogy, the article looks into 9 teachers' perspectives on what triggers students' math anxiety based on semi-structured interviews. The study suggests the need for targeted professional learning for teachers to foster student agency while challenging the systemic barriers.

Adding onto the discussion on aiding teachers, the third research-based article examines preservice mathematics teachers' conceptions and beliefs about teaching mathematics through multiple sessions of mathematics confidence workshops. Audio-recorded conversations and written reflections were analyzed to suggest the importance of such purposeful dialogues to help preservice teachers to build confidence as future teachers.

Lastly, Duru and his team's note from the field showcases specific ways to promote mathematics education that transcends standardized lessons that may rely on rote memorization. Through examples of deriving geometric formulas for volume of a cone and distance on a sphere, the article argues for the importance of deeper conceptual understanding, calling for more reasoning-focused practice.

Kihoon Lee
Daria Chudnovsky

Guest Editors

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JOURNAL OF MATHEMATICS EDUCATION AT TEACHERS COLLEGE | FALL 2025 | VOLUME 16, ISSUE 2

Beyond academic results: motivational and emotional factors as indicators of educational effectiveness in mathematics

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ABSTRACT Evaluating educational effectiveness based solely on academic results obscures essential aspects of student development. This study examines the relevance of motivational and affective indicators as complementary criteria for academic effectiveness in mathematics. Six dimensions were analyzed: interest in mathematics, perceived usefulness, perceived difficulty, expectations of success, self-efficacy, and mathematical anxiety. The methodology is based on two validated instruments, supplemented by teacher evaluations. The results confirm the importance of non-cognitive factors: self-efficacy correlates positively with performance and negatively with anxiety and perceived difficulty. Significant gender differences emerge, with boys showing higher self-efficacy than girls. Mathematics anxiety is a major obstacle to learning, particularly for struggling students. This research calls for a broader conceptualization of educational effectiveness that integrates cognitive, motivational, and emotional dimensions to better support all students.

KEYWORDS: *Educational effectiveness; Self-efficacy; Mathematics anxiety; Non-cognitive factors; Academic motivation*

Introduction

Educational effectiveness is traditionally measured through academic performance, such as standardized test scores. However, this exclusive approach remains restrictive and questionable (Grützmacher et al., 2021), as it obscures the diversity of the school system's objectives, which also include the development of social and emotional skills, essential to the overall development of students (Fend, 2009) . Furthermore, the assessment of skills, particularly in complex subjects such as mathematics, cannot be reduced to purely cognitive measures (Fagnant et al., 2014). Motivational and affective factors play a central role in learning and academic success. Indeed, self-confidence, interest in the subject, perception of self-control, and motivation influence participation, perseverance, and performance in mathematics (Antunes & Fontaine, 2007; Fernández-Villaverde et al., 2015; Ma & Xu, 2004; Marsh & O'Mara, 2010; Schiefele et al., 2012; Xiao & Sun, 2021). Students with high expectations of success or who value schoolwork are more likely to engage in learning, even when faced with difficulties (Murayama et al., 2013). Conversely, mathematics anxiety, characterized by negative emotions such as fear and tension when faced with mathematics (Ahmed et al., 2013; Ashcraft & Krause, 2007), can hinder learning and performance and lead to avoidance of mathematical tasks (Barron & Hulleman, 2015; Chinn, 2009; Namkung et al., 2019; Ramirez et al., 2016; Trezise & Reeve, 2014). Difficulties in mathematics can thus generate a vicious circle of anxiety, disengagement, and loss of self-confidence, and even lead to dropping out of school (Adihou, 2011; Astolfi & Develay, 2020). These theoretical considerations highlight the need to adopt a holistic approach to educational effectiveness, integrating not only cognitive dimensions but also motivational and affective dimensions. The present study takes this perspective, examining the relevance of six complementary indicators: attraction to mathematics, perceived usefulness of the discipline, perceived difficulty, expectations of success, self-efficacy, and mathematical anxiety. These elements are not only perceived as important outcomes in themselves (Seidel, 2008) but also constitute conditions conducive to learning (Fong et al., 2018; Govaerts & Grégoire, 2006; Gupta & Zheng, 2020; Holm et al., 2017; Krapp & Prenzel, 2011; Meyer & Turner, 2006). In this context, the central question of this research is: how can motivational and affective factors be relevant indicators of educational effectiveness in mathematics? More specifically,

1. Is there a relationship between student motivation, as reported by teachers, and their results, also identified by teachers?
2. What is the relationship between the motivation and the level of anxiety?
   2.1. Is there a statistically significant relationship between the motivational dimensions measured by the Math Profile scale and the level of anxiety in mathematics (ANXMAT)?
   2.2. What distinct motivational profiles can be identified among students based on the dimensions of the Math Profile scale?
   2.3. Does the level of mathematics anxiety differ according to the motivational profiles identified in the previous question?
3. Do the dimensions of motivation (Math Profile) and anxiety in mathematics (ANXMAT) vary according to the gender of the students ?

Theoretical Framework

The influence of motivational and emotional factors

The increased interest in this topic is partly due to the accumulation of evidence demonstrating the significant impact of emotions on learning processes and student performance in mathematics (Ahmed et al., 2013; Hanin & Van Nieuwenhoven, 2016). These factors influence, in particular, the choice of knowledge mobilized, the level of effort expended, and perseverance in the face of the task (Marcoux, 2014). Failure to complete a task can profoundly affect an individual's self-esteem and self-image, often leading to abandonment of that task (Peterson & Seligman, 2004). As Adihou (2011) points out, mathematics is particularly likely to elicit a variety of negative reactions in students, such as anxiety, lack of self-confidence and early dropout, among others. Furthermore, studies have shown that encountering difficulties, obstacles or dead ends contributes to eroding learners' beliefs in their personal effectiveness (Artino Jr., 2012; Hanin & Van Nieuwenhoven, 2018). This phenomenon highlights the crucial importance of an appropriate pedagogical approach aimed at strengthening students' resilience in the face of academic challenges. Furthermore, it diminishes their positive emotions (Tornare et al., 2015) and triggers negative emotions (Hanin & Van Nieuwenhoven, 2019; Holm et al., 2017). It should be noted that studies have shown that self-efficacy in mathematics is a significant predictor of performance, both among elementary school students (Frenzel et al., 2007; Govaerts & Grégoire, 2006; A. J. Martin, 2004) and secondary school students (Seaton et al., 2014; Usher & Pajares, 2009). The cognitive challenges faced by many learners often give rise to negative feelings toward mathematics, thereby hindering their learning process and success in this field (Artino Jr., 2012). Furthermore, Usher & Pajares (2009) have shown that a student's past performance is the most decisive factor in their perception of their mathematical abilities, and that students' mathematical performance is affected by their negative emotions (Mikolajczak et al., 2014). Studies suggest that positive emotional states promote academic performance in mathematics, while negative emotions such as anxiety, shame, or despair tend to hinder it (Frenzel et al., 2007; Pekrun, 2006).

Anxiety and its impact on academic performance

Anxiety associated with mathematics has a significant impact on academic performance, leading to lower test scores (Barroso et al., 2021; Caviola et al., 2022) and reduced learning ability (Vukovic et al., 2013). In addition, math anxiety is correlated with affective and motivational aspects such as lack of motivation (Wang et al., 2015), low self-esteem (Ahmed et al., 2013; Jameson & Fusco, 2014), and a diminished perception of competence (Goetz et al., 2013). The relationship between mathematics anxiety and performance is likely bidirectional, with anxiety causing a decline in academic performance, which in turn reinforces anxiety and disengagement (Carey et al., 2015). Furthermore, math anxiety disrupts cognitive functioning by diverting the learner's attention from the task at hand to negative thoughts and concerns, which can impact their performance in the subject (Ashcraft & Krause, 2007). Experiences of success and failure are essential to the formation of mathematical self-concept (Parker et al., 2018). Perceived competence is one of the most effective indicators for predicting success in mathematics (Seaton et al., 2014). Furthermore, it is more closely linked to emotions in mathematics classes than to the perceived value of the subject (Ahmed et al., 2013; Frenzel et al., 2007).

The influence of gender on emotional experience and motivation in mathematics

Significant differences between boys and girls have been identified in terms of their behavioral profiles (Hanin & Van Nieuwenhoven, 2019). Empirical studies reveal that emotional disparities between girls and boys in mathematics can be observed as early as primary school. Girls seem to be more prone to negative emotions such as anxiety, shame, or discouragement, while boys more often display positive emotions such as pride or pleasure (Frenzel et al., 2007; Pekrun, 2006). The study conducted by Hanin & Van Nieuwenhoven (2019) points in the same direction and indicates that young girls seem to adopt a more resigned or anxious attitude, while boys display a more positive mindset. In addition, a considerable proportion of boys expressed feelings of boredom, significantly higher than those observed in girls. These findings are consistent with previous research conducted on primary school students, indicating that girls experience more negative emotions and fewer positive emotions in relation to mathematics, and that they tend to underestimate their mathematical abilities compared to boys (Ahmed et al., 2013; Else-Quest et al., 2012; Frenzel et al., 2007; Wigfield et al., 2006). Girls also tend to place less value on mathematical activities (Frenzel et al., 2007; Wigfield et al., 2006). These differences may be related to distinct motivational beliefs: girls tend to underestimate their mathematical abilities and place less intrinsic value on this subject compared to boys (Pekrun, 2006). Furthermore, Hanin & Van Nieuwenhoven (2019) add that these gender differences can be attributed to two harmful stereotypes: girls are less gifted in mathematics than boys, and mathematics is an exclusively male field of study (Ambady et al., 2001; Frenzel et al., 2007). Additional studies have revealed that, regardless of their academic performance, good or bad, girls tend to be more affected by internal emotional distress than boys (A. J. Martin, 2004; Pomerantz et al., 2002). A significant increase in emotional differences between girls and boys is observed during adolescence (Else-Quest et al., 2012; Wigfield et al., 2006). This pivotal period seems to coincide with the emergence of more marked differences in the emotional experiences of the two sexes with regard to mathematics. Despite efforts to reduce gender inequalities, girls in secondary school often continue to experience a greater sense of discomfort than boys when it comes to mathematics (Morge, 2005).

Methodology

Self-administered questionnaires are a commonly used tool for measuring non-cognitive concepts (Grützmacher et al., 2021). To access beliefs, attitudes, conceptions, representations, and opinions, participant verbalization is essential because these elements are not directly observable (Giroux & Tremblay, 2009). Self-assessment has undeniable advantages for measuring latent variables, including ease of interpretation and rapid and economical administration (Raccanello et al., 2022).

The Math Profile: a tool for measuring motivation in mathematics

This tool, derived from previous work demonstrating satisfactory reliability and validity (Beal et al., 2006, 2008, 2010; Beal & Stevens, 2007; Boekaerts, 2002; Cohen et al., 2008; Eccles et al., 1993), has been integrated into a Moodle environment. The Math Profile is an online self-assessment tool that explores various aspects of mathematical motivation, including self-efficacy, perceived usefulness of mathematics, appeal of the subject, expectations of success, and perception of the relative difficulty of mathematics. Two items are associated with each dimension, and an average score is then calculated for each dimension. Students are asked to rate each item on a 5-point Likert scale. The reliability of the scale was assessed using McDonald's omega coefficient, which revealed acceptable internal consistency ($\omega = .727$).

The instrument for measuring anxiety in mathematics: the ANXMAT scale

Inspired by the work of Özcan & Eren Gümüş (2019), we also used the ANXMAT scale, a validated instrument consisting of five items from the 2012 and 2003 PISA surveys (OECD, 2014). Lee's (2009) study showed that these items constituted a single construct representing anxiety in mathematics. The ANXMAT scale uses a 4-point Likert scale (1 = strongly agree; 4 = strongly disagree) to measure students' anxiety about mathematics. The reliability of the ANXMAT scale was assessed using McDonald's omega, obtaining a value of 0.749, which suggests satisfactory internal consistency of the items measured in this study.

Data collection tools: from the teachers' perspective

Mathematics teachers assessed their students' motivation and performance using an online questionnaire (Google Forms). The assessment of motivation was based on a three-level scale inspired by the work of Beal and colleagues (2008): (a) high motivation, characterized by active participation in class, completion of all homework assignments, a keen interest in mathematics, and academic success; (b) average motivation; and (c) low motivation, identified by frequent failure to complete homework assignments, lack of participation and attendance in class, and disinterest in mathematics and academic performance. The results were classified into three categories: (a) high achievement, determined by performance above grade-level expectations; (b) average achievement, characterized by performance in line with expectations; and (c) low achievement, defined by performance below expectations, with the latter category indicating a risk of failure in mathematics. It should be noted, however, that this categorisation is based on expectations regarding academic achievement, which may vary depending on institutional contexts and the assessment practices of individual teachers. Because this approach reflects standard educational norms, it should therefore be interpreted as a contextualised estimate of performance rather than an absolute measure of mathematical ability.

Sample

The study was conducted among 1,228 first-year secondary school students (aged 12) from 21 secondary schools in French-speaking Belgium. The sample was constituted using a non-probabilistic sampling technique characterized by non-random selection of participants (Gumuchian & Marois, 2000), of the voluntary type (Hascoët et al., 2024). Participants were included in the study based on their motivation to contribute to the research and their willingness to participate in the protocol, resulting in a sample of committed students and teachers.

Analysis of Results

Relationship between student performance and motivation

An examination of the contingency table (see Table 1) reveals several significant trends. Firstly, 66% of pupils with low motivation in mathematics also achieve results that are considered poor by their teachers, while only 2% of them achieve performance levels above expectations for their school level. Secondly, pupils whose motivation is assessed as average are mainly distinguished by their average results (66%). Thirdly, among highly motivated pupils, one in two achieves results above expectations. Finally, pupils identified as motivated account for 88% of all high results, compared with only 0.6% for pupils with low motivation. These findings suggest a positive association between motivation in mathematics and academic performance as perceived by teachers, although they do not establish a causal relationship.

A chi-square test ($X^2 = 444.198$; df = 4; $p < .001$) confirms the existence of a statistically significant association between teacher-reported student motivation and student performance as perceived by teachers.

Analysis of the links between motivation, anxiety, and student performance

Spearman's correlation analyses revealed several highly significant relationships between the variables studied ($p < .001$), confirming the trends reported in the literature. Mathematical self-efficacy shows a strong positive correlation with expected success in mathematics ($\rho = .734$), indicating that students who feel competent

Table 1

Student motivation and student achievement as reported by teachers

Motivation		Result: Poor results	Average results	High results	Total
Low motivation	Number	85	42	2	129
	% lines	65.891 %	32.558 %	1.550 %	100.000 %
	% columns	41.463 %	7.850 %	0.625 %	12.170 %
Average motivation	Number	102	263	35	400
	% lines	25.500 %	65.750 %	8.750 %	100.000 %
	% columns	49.756 %	49.159 %	10.938 %	37.736 %
High motivation	Number	18	230	283	531
	% lines	3.390 %	43.315 %	53.296 %	100.000 %
	% columns	8.780 %	42.991 %	88.438 %	50.094 %
Total	Number	205	535	320	1060
	% lines	19.340 %	50.472 %	30.189 %	100.000 %
	% columns	100.000 %	100.000 %	100.000 %	100.000 %

in mathematics also anticipate positive results in this subject. In addition, self-efficacy is negatively correlated with perceived difficulty (p = –.630) and with anxiety in mathematics (p = –.556). A moderate positive correlation is also observed between students' self-efficacy in mathematics and their enjoyment of mathematics (p = .531). Although this relationship is weaker than the previous ones, self-efficacy is positively correlated with the perception of the usefulness of mathematics (p = .326). A negative correlation is observed between expectations of success and perceived difficulty (p = –.54), as well as between expectations of success and mathematics anxiety (p = –.55). These results indicate that students who expect to succeed in mathematics tend to perceive the subject as less difficult and experience less anxiety. Expected success is also positively correlated with enjoying mathematics (p = .452). Perceived difficulty in mathematics is positively correlated with anxiety in mathematics (p = .500), suggesting that students who find mathematics difficult tend to experience more anxiety. Furthermore, a negative correlation was observed with interest in mathematics (p = –.508), showing that students who experience more difficulty in mathematics enjoy the subject less. The perceived usefulness of mathematics by students is positively correlated with interest in mathematics (p = .478), indicating that students who perceive mathematics as useful enjoy it more. However, it should be noted that perceived usefulness is weakly correlated with anxiety in mathematics (p = –.174). We also find that the more students enjoy mathematics, the less anxiety they experience (p = –.330).

Using the K-means clustering method, we grouped students according to the five variables from the Math Profile scale. The optimal number of clusters appears to be four, as adding a fifth cluster does not significantly reduce intra-class inertia. The K-Means algorithm converged after 15 iterations, with zero residual variations between cluster centers. This convergence shows that the cluster centers have stabilized and that the clusters obtained are robust and well defined. The minimum distance between the initial centers was 4.61, indicating good separation between clusters from the outset. The relatively homogeneous size of the groups ensures that the results are not dominated by a single cluster, thus increasing the robustness of the analysis (see Table 2). The centers of the final clusters highlight four distinct groups of students according to the dimensions of the "Math Profile" scale, providing a typology of student profiles in relation to mathematics.

These results show that the four clusters identified capture a variety of student profiles, ranging from students who are highly engaged and confident in mathematics to those who feel challenged and less inclined to enjoy it. Thus, cluster 1 represents the most motivated and confident students, while cluster 2 includes those who experience difficulties and are unmotivated. Clusters 3 and 4 offer intermediate profiles, with students possessing moderate confidence and perception of usefulness. However, cluster 4 stands out for its greater appreciation of mathematics. These results offer interesting avenues for tailored educational interventions, particularly to support students in cluster 2 and reinforce the motivation of students in the intermediate clusters.

An ANOVA reveals a significant effect of cluster membership on mathematics anxiety ($F(3, 1226) = 183.71$; $p < .001$). In addition, the effect size ($\omega^2 = .308$) indicates that

Table 2
Final cluster center

	1 : High-achieving and confident students N = 314	2 : Discouraged and disengaged students in difficulty N = 292	3 : Moderately confident and uninterested students N = 267	4 : Students motivated despite difficulties N = 357
Self-efficacy in mathematics	4.3	2.2	3.4	3.0
Expected success in mathematics	4.3	2.5	3.6	3.3
Difficulty in mathematics	2.0	3.6	2.8	2.9
The usefulness of mathematics	4.1	3.2	3.2	3.9
Interest in mathematics	4.3	2.2	2.5	3.8

approximately 30.8% of the variance observed in mathematics anxiety is attributable to cluster membership, reflecting a moderate to strong effect. The differences in mean values (M, here representing the mean anxiety scores for each cluster) show that cluster 1 consistently has significantly lower anxiety levels than the other clusters. The differences are particularly marked with cluster 2 ($t = -22.901$; $p_{Tukey} < .001$ and $M = -0.970$), which has the highest anxiety levels ($M_{Anxiety\_Cluster2} = 2.749$). Significant differences were also observed between cluster 1 and clusters 3 ($t = –7.080$; $p_{Tukey} < .001$ and $M = –.307$) and 4 ($t = –12.831$; $p_{Tukey} < .001$ and $M = –0.517$), confirming that cluster 1 is distinguished by particularly low anxiety levels ($M_{Anxiety\_Cluster1} = 1.779$). Cluster 2, with the highest average anxiety level, is significantly different from cluster 3 ($t = 15.027$; $p_{Tukey} < .001$ and $M = 0.663$) and cluster 4 ($t = 11.015$; $p_{Tukey} < .001$ and $M = 0.453$), suggesting significant heterogeneity in anxiety levels within the groups. In addition, a statistically significant difference was also found between cluster 3 ($M_{Anxiety\_Cluster3} = 2.086$) and cluster 4 ($t = –4.985$; $p_{Tukey} < .001$ and $M = –0.210$; $M_{Anxiety\_Cluster4} = 2.296$).

Influence of gender on motivation and anxiety

Boys (M = 3.310) display significantly higher self-efficacy than girls (M = 3.050) (W = 184,142.5; p < .001). This result suggests that boys have greater confidence in their ability to perform mathematics-related tasks. Similarly, boys (M = 3.535) have higher expectations of success than girls (M = 3.296) (W = 185,564; p < .001). This finding reflects boys' more positive perception of their potential for success in mathematics. In addition, they (M = 3.374) are also more attracted to mathematics than girls (M = 3.114) (W = 188554; p < .001). This perception is probably reinforced by the usefulness they attribute to mathematics (M = 3.697) compared to girls' perception of this subject (M = 3.519) (W = 189365.5; p < .001). Girls, on the other hand, report more difficulties in mathematics (M = 2.933) than boys (M = 2.776) (W = 243,753; p < .001). These results show that girls perceive mathematics as a more complex subject than boys. They are also significantly more anxious about mathematics (M = 2.374) than boys (M = 2.131) (W = 269,761; p < .001).

Discussion

The school's mission is not only to impart knowledge, but also to promote the development of students' social and emotional skills (Fend, 2009). With this in mind, it seems essential to carefully examine the many factors that influence students' attitudes toward mathematics in order to provide appropriate support and promote their success.

Our results confirm the existence of a significant association between teachers' perceived motivation and academic performance in mathematics. Students considered to be low in motivation are mostly found in the low-performance category, while those perceived as highly motivated stand out with results above expectations. This correspondence between motivation and performance highlights the relevance of teachers' observations in understanding student engagement and is consistent with the work of Beal et al. (2008) on the link between observable motivation and academic success.

Difficulties encountered in mathematics can lead to anxiety, loss of confidence, and avoidance strategies (Adihou, 2011; Focant, 2021). Fear of making mistakes, often the source of mathematical anxiety, creates a vicious cycle of disengagement (Astolfi & Develay, 2020). These negative emotions disrupt students' emotional balance and hinder their motivation to learn (Hanin & Van Nieuwenhoven, 2019; Holm et al., 2017; Meyer & Turner, 2006).

Correlation analyses confirm the importance of students' beliefs about their skills and emotions when it comes to mathematics (Ahmed et al., 2013; Cosnefroy, 2011). Self-efficacy appears to be a key factor: it is positively correlated with expected success, but negatively correlated with perceived difficulty and anxiety. These results corroborate the work of Frenzel et al. (2007) and Usher & Pajares (2009), according to which feelings of competence directly influence expectations of success and perseverance. Confident students perceive mathematics as more accessible and engage more in tasks, while those who doubt their abilities tend to avoid challenges, thus limiting their learning opportunities (Fong et al., 2018).

The negative correlation observed between perceived difficulty and anxiety confirms that the perception of mathematical complexity is a significant barrier to learning (Marcoux, 2014). Students in cluster 2, identified as discouraged and struggling, have the highest levels of anxiety, while those in cluster 1, who are high-performing and confident, have low levels of anxiety. These results are consistent with the findings of Xiao & Sun (2021) and reinforce the idea that emotional regulation is an essential lever for success (Depaepe et al., 2015; Hanin & Van Nieuwenhoven, 2019, 2020). Motivation, on the other hand, seems to partially mitigate the harmful effects of mathematics anxiety, particularly among students in cluster 4, who are motivated despite the difficulties and compensate for stress with increased engagement (Justicia-Galiano et al., 2017).

With regard to gender, the results confirm marked differences in perceptions and emotions associated with mathematics (Frenzel et al., 2007; Parker et al., 2018). Boys exhibit higher self-efficacy and expectations of success than girls, which is consistent with the literature on gender-differentiated self-confidence (Ahmed et al., 2013; Else-Quest et al., 2012). These differences could be explained by the persistence of stereotypes associating mathematical skills with masculinity (Ambady et al., 2001; Wigfield et al., 2006) and by certain teacher evaluation biases, which tend to underestimate high-performing girls (Lafontaine & Monseur, 2009). Although girls recognize the usefulness of mathematics, they more often perceive it as difficult (Hanin & Van Nieuwenhoven, 2019), which fuels their anxiety and can hinder their engagement.

Mathematics anxiety, which is higher among girls, is a documented risk factor for academic success (Ahmed et al., 2013; Barroso et al., 2021). This difference could result from greater internalization of emotional distress (Pomerantz et al., 2002) and increased expression of negative emotions (Frenzel et al., 2007). Adolescence amplifies these emotional differences (Morge, 2005; Wigfield et al., 2006), a period when girls express more apprehension and discomfort with the subject.

The results of this study invite further exploration of the concept of self in mathematics, whose fragility makes it particularly sensitive to experiences of failure and cognitive obstacles encountered during learning. These difficulties, by generating negative emotions, can alter students' motivation, perseverance, and ultimately their success (Kramarski et al., 2010; Tzohar-Rozen & Kramarski, 2014). It therefore seems essential to better understand the role of experiences of success and failure in the construction of mathematical self-efficacy, i.e., a student's belief in their ability to succeed in this discipline (Parker et al., 2018).

With this in mind, future research could explore the educational and emotional conditions that promote the development of a strong sense of competence, particularly in difficult situations. Particular attention should be paid to psychological support interventions aimed at boosting self-confidence and regulating mathematics anxiety, especially among girls, who are more vulnerable to these negative emotions (Barroso et al., 2021). Several studies have demonstrated the effectiveness of emotional regulation techniques such as relaxation (Brunyé et al., 2013; Segool et al., 2013) and mindfulness, whose benefits in reducing school anxiety are increasingly well documented (Bautista, 2023; Burke, 2010).

It would also be appropriate to engage in in-depth reflection on how mathematics teaching practices can incorporate explicit strategies to combat gender stereotypes (Lafontaine & Monseur, 2009). In this context, Morin-Messabel (2014) emphasizes the need for a proactive approach by teachers, consisting of clearly stating that mathematical skills do not depend on gender, but on the development of cognitive strategies and individual effort. This stance could help to change the social representations associated with mathematical success and encourage a more equitable engagement between girls and boys.

In addition, self-efficacy can be undermined by repeated learning experiences that are perceived as solitary or unrewarding, such as solving complex problems individually. Adihou (2011) shows that this type of approach, by causing apprehension and cognitive isolation, tends to increase anxiety and weaken perceptions of competence. In this regard, the results of the PISA program (2017), which focuses on collaborative problem solving, offer promising prospects: girls outperform boys in all participating countries, which could be explained by their more developed interpersonal skills and a stronger orientation toward cooperation and collective success.

However, the gender composition of learning groups influences participation and anxiety dynamics. Dasgupta et al. (2015) show that girls who are in the minority in a male-dominated group participate less actively and show greater anxiety. These findings highlight the importance of designing inclusive learning environments that are attentive to diversity and gender balance in order to foster a safe and stimulating emotional climate for all.

Promoting an equitable educational culture, where girls and boys feel equally legitimate and encouraged to engage in scientific disciplines, is a key challenge in reducing gender disparities in academic performance and strengthening all students' engagement with mathematics. Future research could therefore examine: the effects of mixed collaborative arrangements on reducing anxiety and strengthening motivation, the role of teacher training in recognizing and deconstructing gender stereotypes, and the long-term impact of emotional regulation programs (mindfulness, relaxation, psycho-educational support) on self-concept and success in mathematics.

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JOURNAL OF MATHEMATICS EDUCATION AT TEACHERS COLLEGE | FALL 2025 | VOLUME 16, ISSUE 2

Math Teachers' Perceptions of Student Math Anxiety in Underserved Schools: Systemic Barriers and Transformative Practices

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ABSTRACT This qualitative phenomenological study utilized critical pedagogy as a framework to explore K-12 students' math anxiety from teachers' perspectives, the systemic barriers contributing to this anxiety, and the transformative practices that educators implement to promote students' math learning. Semi-structured interviews were conducted with nine math teachers with an average of 17 years of teaching experience in diverse, urban, or Title I schools. A reflexive thematic analysis was applied, revealing that teachers clearly understood their students' math anxiety and the systemic challenges contributing to it. This study found that students' math avoidance behavior, their lack of cumulative math learning, shortage of qualified math teachers, families with low-socioeconomic status, high-stakes testing, and lack of transformative practices were perceived as the reasons for math anxiety by the teachers. This finding suggests targeted professional development for math teachers to enhance their skills in developing students' agency and sense of belonging to challenge systemic barriers.

KEYWORDS: *Math anxiety, STEM education, systemic challenges, transformative practices*

Introduction

In today's technology-driven world, STEM (Science, Technology, Mathematics, and Engineering) disciplines are critical, and experts are needed in those fields to cope with global progress and development. Since mathematics is the core subject of STEM, understanding the barriers to learning, such as math anxiety, is critical to developing future STEM experts (Cuder et al., 2024). Research also shows that math anxiety is a persistent barrier to mathematics learning (Lau et al., 2024; Szczygiet et al., 2024). Improving instructional strategies might not be the solution to math anxiety, as systemic challenges in the school systems, such as deficit thinking based on student backgrounds and a lack of effective mathematics teachers, persist. So, when we talk about math anxiety, we need to consider the systemic challenges related to it. Also, incorporating transformative teaching practices alongside mathematics instruction is essential to empowering and motivating students in learning mathematics.

Math Anxiety

Dreger and Aiken's (1957) "number anxiety" is considered the beginning of math anxiety studies; the authors explained "number anxiety" as an emotional tension that creates anxiety or stress when solving any numerical, mathematical, or arithmetical problems. Khasawneh et al. (2021) extended the concept of math anxiety to a broader context arguing for a more comprehensive approach, saying that math anxiety is a psychological response to tension that arises when students face mathematical tasks and cannot solve them. This reduces their confidence and increases their fear of mathematics.

Math is a complex subject for many students because it requires more attention and thoughtful approaches to solve mathematical problems. (Finell et al., 2022; Langoban, 2020; Radiamoda, 2024). Students need more attention in mathematics than in other subjects because math demands high-level cognitive functions, like logical reasoning and abstract thinking (Finell et al., 2022). Motivation is also an important factor for students to be engaged in learning mathematics. So, to get motivated, they need equitable learning environments, effective mathematics instruction, and resources (e.g., manipulatives, technology) in learning mathematics (Furner & Duffy, 2022; O'Hara et al., 2022; Pizzie & Kraemer, 2023). Szucs and Toffalini (2023) found that students' perceived control and low expectations of mathematics learning are the reasons behind their math anxiety. When students feel a lack of control over their mathematics learning and believe that no matter how hard they work, they fail in mathematics, it negatively influences their mathematics learning.

Many studies on students' math anxiety solely focus on students' cognitive, emotional, and psychological factors (Luttenberger et al., 2018; Ramirez et al., 2023) that causes their math anxiety. However, there are some institutional and policy factors that might have an impact on students' math anxiety, over which students have no control. These factors, including teachers' deficit thinking, curriculum design, and the lack of certified mathematics teachers in the school, shape the learning environment where math anxiety may develop.

Systemic Challenges

Systemic challenges are deep-rooted, invisible obstacles in school systems for students, particularly those from low socioeconomic backgrounds. Bertrand and Marsh (2021) found that teachers' deficit thinking about their bilingual, disabled, and struggling students negatively impacted their academic success. The authors concluded that teachers in those schools promoted inequality and deprived students of opportunities to learn. Similarly, Battey et al. (2021) found that teachers hold biases against students based on race; the authors also noted that those teachers showed less care and support to students from low-income families regardless of their color. Funding disparities exacerbate the inequalities. Powell (2018) found that while schools in affluent communities and schools in low-income communities received similar amounts of federal and state funding, the former received more money through property taxes and private donations compared to the latter. This funding gap creates challenges for the low-income community schools to hire effective mathematics teachers, even licensed teachers, and cannot provide the necessary resources (e.g., licensed teachers and manipulatives) to students.

Carroll et al. (2023) described how schools implement below-standard mathematics curricula for low-income students, as they cannot offer many mathematics classes due to teacher shortages, where funding is essential to hire teachers. Moldavan et al. (2022) found that in this technology-driven era, schools in urban areas often lack technology, such as a smartboard for the classroom and individual laptops for students. This lack of technology in the classroom limits teachers' ability to visualize mathematical concepts, and students do not have access to some online mathematics resources (e.g., Khan Academy). As a result, the students in those schools were behind in mathematics learning and felt math anxiety. The authors concluded that neither parents nor schools can provide students with updated technological devices to support them in learning mathematics due to a lack of funding. London et al. (2021) used the "glass ceiling" metaphor to describe the invisible but real obstacles faced by students in low-socioeconomic communities due to systemic challenges. Despite the students' inherent potential, these systemic barriers hinder their mathematics progress in school and, subsequently, negatively impact their ability to study STEM in college.

Teachers are in a unique position as they work with students regularly. Their position allows them to observe how the systemic factors and students' backgrounds are interconnected in mathematics learning and overall reduce their math anxiety. However, very few studies examined students' math anxiety through the lens of teachers' perspectives and how they try to reduce it (Horne, 2022).

Transformative Practices in Math Teaching

Transformative practices in mathematics teaching refer to instructional methods that prioritize student-centered teaching and learning over traditional, lecture-based approaches. Darder et al. (2023) defined critical pedagogy as a transformative practice that empowers students to develop personal interests and a sense of control in education. Such an approach is crucial for students from marginalized and underserved communities to gain empowerment and develop agency in their education, especially in mathematics, to enter the STEM fields in the future. Practically, students from low socioeconomic status are systemically marginalized as the system suppresses their voices and limits their agency, and constrains their potential. The established systems constantly oppress and exclude them from learning mathematics in an attempt to divert them away from STEM disciplines, regardless of color. For example, Carr and Kefalas (2011) conducted an ethnography in a 100% White community school in rural Iowa. They found that school officials showed biases and helped students with special coaching and scholarship applications based on their social status. Such differences in support systems show how schools uphold the inequality, providing access only to the privileged students and depriving students from low-income families who deserve more support.

As a transformative practice in mathematics classrooms, the dialogical approach engages students in meaningful mathematical dialogue to foster critical thinking and shared understanding. Song et al. (2023) found that dialogical interaction enables students to articulate and refine their mathematical reasoning. This practice leads students to a deeper understanding and increases confidence in learning mathematics. Uddin (2019) also recognized the dialogical approach as a transformative practice that promotes collaborative inquiry and peer-to-peer communication. This approach positions students as active participants in knowledge constructions rather than passive recipients of information. By encouraging students to justify their reasoning, analyze their own learning, and learn from mistakes, the dialogical approach reframes errors as an essential part of the learning process. Thus, the dialogical approach is exemplified as a transformative practice in teaching mathematics, as it establishes a classroom culture grounded in two-way communication, mutual respect, and empowerment.

All the above studies discussed transformative teaching practices as a theoretical framework, but none discussed the practical implications of these practices for reducing students' math anxiety. But reducing students' math anxiety is nationally essential, as mathematics is the core of STEM subjects. Thus, understanding teachers' perspectives is critical as they are primarily responsible for students' mathematics learning. They are in a unique position because they teach mathematics regularly and see systemic challenges students face.

Purpose of this Study

Understanding student math anxiety is crucial for providing the necessary support to the students to succeed in mathematics. This study aimed to understand K-12 students' math anxiety from their teachers' perspectives. It focused on how mathematics teachers perceived math anxiety in their students and explored their understanding of the reasons behind this anxiety. Additionally, the study examined how teachers viewed systemic barriers contributing to their students' math anxiety and the transformative practices they employ to alleviate it.

Theoretical Framework

This study employed critical pedagogy as its theoretical framework. Critical pedagogy is grounded in Freire's (1968, 1970) seminal work, *Pedagogy of the Oppressed*. Freire identified unequal education systems and systemic oppression within classrooms and school environments based on students' backgrounds. According to Freire, students from low-income families lack a voice in the classroom, and school systems oppress them systematically. While Freire did not originate the term "critical pedagogy," later pioneers such as Henry Giroux referred to this empowering educational approach as critical pedagogy. Darder et al. (2023) described critical pedagogy as a transformative education system that promotes democratic schooling and fosters students' motivation and interest in meaningful learning activities. Thus, the students take control of their own learning. Similarly, Kincheloe (2008) explained that critical pedagogy promotes reflective practices for teachers to examine the effectiveness of their teaching methods and their own biases in order to promote equitable practices for all students.

This study used critical pedagogy as a lens to explore teachers' understanding of systemic challenges that negatively impact marginalized student populations when learning mathematics and help create their math anxiety. This study's critical pedagogy lens helped determine whether teachers were aware of the inequalities in school systems and educational policies. This lens helped to examine whether teachers were engaged in reflective practices and considered students' sociocultural backgrounds in order to provide equitable support. By addressing this issue, the critical pedagogy lens guided this study to explore the intersection of math anxiety, systemic inequality, and transformative teaching practices.

Research Questions

1. What do mathematics teachers recognize as signs of their students' math anxiety?
2. What do teachers see as systemic challenges that contribute to students' math anxiety?
3. What transformative practices do they employ to promote their students' mathematics learning and remove anxiety?

Methods

Methodology

This study employed a phenomenological approach to investigate student math anxiety based on their teachers' experiences in teaching mathematics. According to Creswell and Poth (2018), the phenomenological approach examines the lived experiences of individuals with a specific phenomenon they encounter directly. The authors note that this approach centers on how individuals perceive and interpret their experiences. Similarly, Ayton et al. (2023) state that phenomenology emphasizes individual experiences and how individuals articulate and make sense of those experiences. The current study explored mathematics teachers' analysis of their students' math anxiety, their understanding of the systemic barriers students faced in the classroom, and the actions they took to reduce this anxiety. All these activities were part of teachers' daily experiences of working with students with math anxiety, making a phenomenological approach suitable for this study.

Participants

The nine participants in this study were K-12 mathematics teachers from a Midwest state in the United States. The recruitment criteria required that participants have at least three years of experience teaching mathematics and work in diverse, urban, or Title 1 schools. Diverse schools are those that have students from different races or ethnicities, such as Asian, Black, Hispanic, and White. Urban schools are located in cities with low-income neighborhoods, and the student population may be homogeneous. Title 1 schools located in low-income communities, either in cities or counties, and receive extra federal funding due to their high percentages of students from low-income families. The following participants were recruited and interviewed. Their identities were hidden using self-naming pseudonyms. They are listed in Table 1 in order of the interview schedule.

Table 1

List of Participants

Name	Years of Experience	School-Level	Type of School
Eric	15	High	Diverse
Neolle	15	Elementary	Title 1
Ani	30	Middle	Urban and Title 1
Kimberly	20	High	Diverse
Lisa	30	High	Diverse
Ashley	3	Middle	Urban and Title 1
Derek	25	Elementary	Title 1
Lacey	7	Middle	Urban and Title 1
TC	7	High	Urban

Data Collection

Data was collected through individual interviews using Zoom, which were recorded with the participants' permission. Each interview lasted about 30 minutes. The interview questions were developed through the literature review for the introductory part of this study. The questions were:

1. How would you describe your students' math anxiety?
2. How do you recognize it in your students?
3. What do you think are your students' primary causes of math anxiety?
4. Do you notice math anxiety affecting certain groups of students more than others (e.g., based on gender, race, or socioeconomic background)?
   a) If so, why do you think this happens?
5. How do you think systemic factors, such as school policies or resource availability, contribute to math anxiety in your students?
6. How do you see your role as a teacher in addressing inequities that might promote student math anxiety?
7. In your opinion, how does cultural or socioeconomic background influence a student's experience with math anxiety?
8. What strategies or practices do you use to help students manage or overcome math anxiety?
9. Have you received training or professional development on addressing student math anxiety?
   a) If so, what did you find helpful, and what do you feel was missing?
10. What additional resources or support would help you address math anxiety more effectively, especially for marginalized students?

Data Analysis

This study used reflexive thematic analysis to analyze qualitative data. Braun et al. (2022) defined reflexive thematic analysis as the identification, analysis, and reporting of the themes from qualitative data. The authors also explained a six-step process in which the researcher's subjectivity and positionality are utilized to identify themes within a data set. This six-step process of data analysis is:

1. Familiarization with the data
2. Coding,
3. Generating initial themes
4. Developing and reviewing themes
5. Refining, defining, and naming themes
6. Write-up.

Based on the reflexive thematic analysis, the final themes of this study are:

- Math Avoidance Tendency
- Lack of Basic Math Skills
- Shortage of Qualified Math Teachers
- Blaming Parents with Low -Socioeconomic Status
- Influence of High-Stakes Testing
- Impact of School Policies
- Limited Transformative Practices

Results

Math Avoidance Tendency

Participant mathematics teachers were acutely aware of their students' struggles with math anxiety, and they recognized it through students' avoidance behaviors. For example, TC said, "I show a problem and ask them to do another, and they ask to go to the bathroom, raising a million hands. There's also class skipping. I see them all day, but they don't attend math class." Similarly, Lacey noted, "I recognize math anxiety in my students when they seem disengaged, avoid eye contact, or become easily distracted. They appear busy with something else instead of attempting to solve the problem." TC and Lacey's experiences clearly illustrated how students avoided mathematics classes and participation in mathematics learning. Another participant, Lisa, described a similar experience. She said, "They don't give me any responses to show what they know, and they don't want me to understand what they don't know."

Other participants also demonstrated a clear understanding of their students' avoidance of math-related tasks and practices. For instance, Eric remarked, "You give them a question, and they don't want to answer or get involved, like not staying on task." Similarly, Ani mentioned, "I see avoidance behavior when they encounter mathematics problems. There are many signs, such as not participating." One participant, Kimberly, elaborated on why students exhibit this avoidance behavior. She noted, "[Math anxiety] comes naturally. Many students come to me openly and share their anxiety even before they give themselves a chance. They do not participate." The participants described their students disengaging from mathematics learning due to their fear of failing to solve mathematics problems. As Ashley stated, "Sometimes they express emotions like worry. They feel overwhelmed by certain problems. They said, 'I am overwhelmed.' They fear they won't solve the mathematics problem correctly. It's like an unknown worry." So, the students have a fear of mathematics, and it influences them to avoid mathematics tasks in class.

Lack of Basic Math Skills

When the participants were asked why their students showed mathematics avoidance and what might be the possible reason behind it, all participants said that students lacked basic mathematics skills that are essential to solving mathematics problems. As Ashley said, "When they are in high school, I expect them to know certain things, right?" Similarly, Lisa said, "If they lack knowledge in multiplication and division, it makes them very hesitant to try math since it's a subject that builds each year." Kimberly said, "I show my students and help them solve logarithmic equations, and they don't know what log is. So, I stay on basics." Ani's experience was similar: "The first thing I will say is that their lack of foundational skills leads them to frustration when tackling a math problem." Eric also echoed the same. He said, "It could be a lack of fundamental skills. They don't have basic math skills that they need to build on."

Shortage of Qualified Math Teachers

In addition to a lack of basic mathematics skills, participants reported that a shortage of skilled and effective mathematics teachers contributes to their students' math anxiety and bad experiences. Neolle said, "When I think about student math anxiety, I think about teacher math anxiety. The way they teach it causes the kids to have some anxiety." TC said, "Low staffing is a challenge. If you barely have enough qualified teachers to teach the content classes, you don't have anybody to do math intervention." Derek added, "Are our teachers prepared to teach math content? Do they have the pedagogy?" Eric shared the same concern, saying, "We have math teachers who are not certified. They might have a degree in Computer Science with many math credits, but it does not mean they have math pedagogy skills."

Blaming Parents with Low-Socioeconomic Status

Participants often blamed parents for their students' math anxiety. Despite having understanding parents with little education and low-income, the participants still placed responsibility on the parents. Ani said, "Socioeconomic status plays a role in math anxiety. Like, students who come from low-income families lack resources at home, which impacts their math ability." Similarly, Neolle said, "[Parents] need to reinforce the math skills because [teachers] cannot just teach them in one period. If [students] don't have anyone at home to help [them], that's going to cause more anxiety." Eric mentioned how parents' educational backgrounds negatively impact his students' mathematics learning when he said, "I notice that parents of students from low socioeconomic backgrounds may not have matriculated to high school or may be dropouts. They may not have the math content they need to help their child." TC noted, "I think parents have math anxiety. So, it gets passed down through the generations." Kimberly also said, "I think [math anxiety] starts at home. It is generational."

Influence of High-Stakes Testing

Along with blaming parents, the participants also shared how standardized testing increased their students' math anxiety. Ashley said, "Students get lots of pressure to get a good score but not to learn. Those types of tests are stressing [students] out." Ani said the same: "The pressure to perform well in high-stakes testing is another challenge for [students]." Similarly, Eric said, "I think standardized testing is one of the contributing factors for students' math anxiety because they have fear about it." Derek added, "I focus now on the test because we are accountable for testing data." The participants also discussed how the testing process put pressure on the students. Neolle said, "We teach kids solving math problems with all strategies, but then we have to assess them with a specific approach. So, they do not feel comfortable." Kimberly also said, "English language learners are allowed to learn math in their own language, and they face testing in English when many of the English terms are challenging for them."

Impact of School Policies

Like the impact of testing, participants also shared that some school policies negatively impacted students' learning of mathematics. For example, Derek said, "Schools are hiring brand-new math teachers who have not gone through the teacher preparation program. These teachers are unaware of what is going on in the developmental stages." Additionally, Lisa talked about how the curriculum is unfavorable for some students. She said, "Many students do not want to work in a group. They are uncomfortable working with others and letting others know what they don't know." TC shared a practical challenge she encountered due to her school policy when she said, "School allows students to retake the test as many times as they want to. By the 10th chance, they still don't do well. By this time, I will be one or more units ahead, and they will still miss some new math concepts."

Limited Transformative Practices

Although there was no direct interview question about transformative practice, participants shared their regular teaching strategies in the class in response to question number 8. When participants were asked how they generally mitigate their students' math anxiety and help them overcome systemic challenges, their answers varied. Eric said, "I use a growth mindset approach. I try to help them get out of their fixed mindset. I told them that I expect them to change their attitude towards mathematics. So, I give them lots of hands-on experience." Ani said, "I use manipulatives all the time, like visual aids." Lacey said, "I create a judgment-free environment where students feel safe to ask questions." Ashley also gave a similar response. Lacey said, "I like to create an open space and just make sure everyone is treated equally and also working together." Kimberly talked about empowering parents' mathematics skills. She said, "I invite all of my parents to my classroom. I ask them, 'Do you need a special session on manipulating your son's or daughter's math curriculum?'" TC takes a different approach. She said, "I have students come to the board. I definitely have them shout out. "Do you agree? Do you disagree? Why, why not? Just having some dialogue around math."

Intersection of Systemic Barriers and Teacher Pedagogical Confidence

Among these seven themes, mathematics avoidance tendency, lack of basic mathematics skills, shortage of licensed teachers, and blaming parents were the most frequently discussed by all participants. The participants consistently associated those factors with students' math anxiety. They also blame the school systems as systemic challenges that shaped their classroom realities. In addition to those central themes, one salient yet less frequently articulated observation disclosed a deeper dimension of teacher experience. Several participants expressed their feelings of inadequacy in teaching mathematics. They shared their hopelessness and uncertainty about how to engage students in learning mathematics, encourage reluctant students, or connect mathematical concepts with real-life scenarios. Their reflections suggest that teachers' pedagogical confidence plays a crucial role in the mathematics classroom. When teachers are unsure and unskilled in engaging students in learning mathematics, they rely on traditional lecture methods, and students are not interested in learning.

Discussion and Conclusion

The results section indicates that the participating mathematics teachers possess a strong understanding of their students' math anxiety and their mathematics avoidance tendencies. The research agrees that math anxiety is common among students, leading to avoidance behavior (Jenifer et al., 2022; Schmitz et al., 2023). Participants also found the same behavior in their students. They recognized their students' disengagement from mathematics classes and their tendencies to avoid mathematics altogether. One participant, TC, stated that students look for possible excuses to skip mathematics tasks in class. TC also mentioned that she sometimes saw some of her students in the building, but they did not attend mathematics classes.

The findings of this study have provided a foundation for exploring the perceived reasons for math anxiety from math teachers' perspectives and the urgency to address math anxiety, especially for students from low-income families. This study's exploration of how teachers perceive students' math avoidance behavior and their lack of cumulative math learning suggests potential implications for addressing math anxiety. An important finding of this study is the gaps between math teachers' accountability and pedagogical preparedness. Teachers' blaming of students' family backgrounds for their math anxiety is significant because it echoes the status quo instead of providing support. This finding suggests implications for targeted professional development for math teachers. Teachers need training in implementing transformative practices, like an approach to engage students in meaningful dialogue in math class to enhance their agency and sense of belonging, so they can challenge systemic barriers.

Students' mathematics avoidance behavior is a primary reason for their math anxiety. When they avoid mathematics practices, they miss learning content, and this gradually prevents them from developing enough basic or foundational knowledge in mathematics. Kyttälä and Björn (2022) said that when students avoid mathematics lessons, they build the trajectory of future mathematics avoidance because they lack past mathematics knowledge required for future mathematics learning. Participants of the current study found the same to be true. For example, Lisa said, "If they lack knowledge in multiplication and division, it makes them very hesitant to try math since it's a subject that builds each year." Students' gradual mathematics avoidance develops a cumulative learning gap in mathematics, causing them to ultimately build math anxiety that keeps them from mathematics learning.

Students with math anxiety commonly develop a fear of mathematics. The gradual development of fear of mathematics becomes an insurmountable hurdle, as Markovits and Forgasz (2017) said: "Mathematics is like a lion" (p. 49). When students see mathematics as a big challenge and think they cannot solve mathematical tasks, it can develop their deficit mentality towards mathematics. As Kimberly said, "I can tell you [researcher] they have a fear of embarrassment. They come in with more of a defeatist mentality. So, they prepare themselves to fail." This cycle of avoidance and fear in mathematics develops a solid mathematics anxiety and a negative mindset about mathematics. Students, therefore, lose belief in themselves and their ability to learn mathematics.

There may be several reasons why students develop math anxiety and avoid mathematics. Uddin (2022) stated that teachers' math anxiety or insufficient knowledge of mathematics content and pedagogy contribute to students lacking a strong mathematics foundation. The participants of this study corroborated this. Neolle noted, "A lot of our teachers are not prepared enough with the content." Eric also echoed the same as he said, "In my school, we have math teachers who are not certified and teachers who are not certified, they don't have the pedagogical skills." When teachers are not prepared enough to teach mathematics, they have trouble effectively engaging their students in learning mathematics. This type of mathematics teaching-learning creates math anxiety among students. Thus, it can be argued that teachers' math anxiety is one possible reason for students' math anxiety, leading to their mathematics avoidance behavior.

In addition, the participating mathematics teachers discussed other systemic factors, such as high-stakes testing, that contribute to students' math anxiety. Göloğlu-Demir and Kaplan-Keleş (2021) found that standardized tests are not motivational for both teachers and students. The participants of this study said they focus on testing rather than helping their students conceptualize mathematics content. Derek said, "I must prepare my students for the test and teach steps to solve problems, not conceptually understand the math we discuss." The participants also discussed school policies as a barrier that contributes to students' math anxiety. Ingersoll and Tran (2023) note that schools in low-income communities face significant challenges in hiring qualified teachers due to a lack of funding and place individuals in front of students without adequate content knowledge and pedagogical skills. One participant, Derek, stated, "Schools are hiring brand-new math teachers who have not completed the teacher preparation program." As a result, students who experience math anxiety do not receive the qualified teachers and equitable instruction needed to learn mathematics.

Blaming parents for students' poor performance is not a new trend. Some teachers and schools consistently evade responsibility and shift the blame to parents. Coleman et al. (1966) first reported that students from low socioeconomic backgrounds struggle regardless of the initiative schools implement. Likewise, the participants of this study assigned some blame to the parents. For example, Kimberly said, "It is generational. It is cultural because underrepresented communities lack emphasis on math." Similarly, TC stated, "I think their parents have math anxiety. So, I believe it's passed down through generations."

The participating mathematics teachers recognized several systemic challenges: a shortage of mathematics teachers, high-stakes testing, and students' low socioeconomic backgrounds, contributing to this anxiety. Schools in low-income communities struggle with funding because of insufficient property taxes, and end up recruiting underqualified, and sometimes unqualified, mathematics teachers to fill the vacancies with lower salaries. State and federal funding must be based on schools' needs. Low-income community schools must get the necessary financial support to provide quality education to their students. When schools hire skilled and licensed mathematics teachers, they can offer effective mathematics instruction to their students.

Luzano (2024) noted that transformative practices like the problem-solving approach in the mathematics classroom can activate students' prior knowledge and develop conceptual understanding. However, no participants in this current study showed problem-solving strategies. While Dresel et al. (2025) found that students learned better from their errors when they received constructive feedback, only one participant, Ashley, discussed trial and error. She said, "It's about guiding their emotion and thinking and making them feel comfortable about making mistakes because we all make mistakes." The dialogical approach in mathematics learning is a practical method that allows students to have a voice by engaging in meaningful learning activities (Uddin, 2019). Only one participant, Derek, discussed this approach, stating, "Having students talk about the answers and strategies is critical. It's not just about finding the correct answer; it's [about] the pathway you choose to get there." Derek's strategy of a dialogical approach is a transformative practice, but it lacks deeper critical engagements with students' lived experiences and systemic challenges.

The limited transformative practices observed in this study suggest the need for targeted professional development for mathematics teachers on how to apply transformative practices in the mathematics classroom. Transformative practices, such as a dialogical approach, are essential because they promote student-centered learning, reflection, and empowerment, all of which are crucial to enhancing students' motivation and agency in learning, and to reducing their math anxiety. These professional developments might target inquiry-based, socially relevant lesson planning practices to implement dialogical practices and problem-solving strategies. Schools can also organize trauma-informed pedagogy to provide students with psychological support to minimize their math anxiety. The teacher education program should introduce a course for preservice mathematics teachers to enhance their skills and knowledge on the psychological and systemic roots of students' math anxiety. The federal or state government can provide funding for Title 1 schools for some transformative projects, such as student-led math circles or peer mentoring to establish a mathematics community in schools.

This study has several limitations. First, its findings cannot be generalized due to the small sample size. While participants' insights provided robust data, they may not represent the diverse perspectives of mathematics teachers from various backgrounds. Second, this study relied on participants' self-reported data without observational validation. Finally, this study offered only a snapshot of students' math anxiety, lacking long-term data.

This study has created opportunities for future research. A qualitative case study approach might be helpful in exploring some systemic challenges, such as curriculum barriers, teachers' efficacy, and resource availability. A quasi-experimental study might be practical in justifying the effectiveness of some transformative practices, such as dialogical approaches and problem-solving strategies. A qualitative case study might help examine how engagement in transformative teaching practices impacts teachers' confidence and pedagogical beliefs about mathematics learning. Another case study could help to investigate how teachers' self-perceived inadequacy in mathematics instruction influences classroom practices, student engagement, and math anxiety.

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JOURNAL OF MATHEMATICS EDUCATION AT TEACHERS COLLEGE | FALL 2025 | VOLUME 16, ISSUE 2

Confident Conversations: Unpacking Emotions About Mathematics to Build Confidence among Preservice Teachers

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ABSTRACT Preservice teachers (PSTs) often enter mathematics methods courses with emotional histories that shape their engagement with mathematics and their learning to teach. This qualitative study explores how structured, reflective conversations can be used in mathematics teacher education to surface these emotions and support PST learning. The study reports on a mathematics confidence workshop with 25 PSTs in a post-undergraduate teacher education program in Eastern Canada. During the workshop, PSTs engaged in small-group dialogue using conversation cards designed to prompt reflection on mathematical beliefs, prior experiences, emotions, and conceptual understanding. Analysis of audio-recorded conversations and written reflections suggests that purposeful dialogue supported PSTs in articulating and re-examining their relationships with mathematics, recognizing shared experiences, and developing greater confidence as future teachers. The findings highlight reflective conversation as a pedagogical practice that attends to affect while supporting professional learning in mathematics teacher education.

KEYWORDS: *mathematics confidence, affect in mathematics education, reflective practice, classroom discourse*

Introduction

Reflecting on a conversation with peers about their emotions surrounding the teaching and learning of mathematics, preservice teacher (PST) Antonin (All names of the participants are pseudonyms) succinctly summarized a potential impact on future practice for all PSTs: "A key takeaway from the conversations was that every student must feel comfortable in math class and that each student is capable of understanding math." Many students, including PSTs like Antonin, enter their mathematics classrooms with feelings of trepidation and anxiety (Bosica, 2022). For PSTs to feel comfortable with and capable of doing and teaching mathematics, it is essential to create an environment in which they can openly discuss their emotions and experiences.

In this study, I report on efforts to unpack these emotions among PSTs through meaningful conversations, aiming to initiate a process that builds confidence among future mathematics teachers and their students. In what follows, I will explore the significance of addressing mathematics anxiety, the role of open dialogue in transforming PSTs' beliefs about mathematics, and the specific strategies employed in the workshop to facilitate these conversations.

Emotions Count

Students in elementary classrooms often exhibit a wide range of emotions when it comes to learning mathematics. While some express delight and enthusiasm for mathematical activities and problem solving, others display signs of panic and anxiety when faced with similar tasks (Trezise & Reeve, 2014). Their confidence may be impacted by previous negative experiences, which may include lower-than-expected performance on assignments and instances of verbal or written mistreatment from teachers (Lott, 2003; Rossnan, 2006). If one of the primary objectives of mathematics education is to foster engagement in mathematical thinking and discourse (Bennett, 2014), addressing the emotional barriers paralyzing students in their mathematical endeavors is fundamental. Overcoming these barriers may afford students more opportunities to participate effectively in productive mathematical engagement.

PSTs often experience similar emotions when teaching mathematics (Boyd et al., 2014). Low confidence in their understanding of mathematical concepts, coupled with the pressures of increasing curricular demands and an emphasis on achievement scores, can lead to heightened anxiety when it comes time to teach mathematics (Boaler, 2022). Research supports the notion that mathematics anxiety is a pervasive issue among PSTs, manifesting as a barrier to effective teaching and learning (Beilock & Willingham, 2014). As a mathematics teacher educator (MTE) working with PSTs, I have observed firsthand the expressions of mathematics anxiety that can spread quickly among students. Addressing this concern requires a multifaceted approach that involves MTEs, teachers, and students collectively working to create a supportive and empowering learning environment.

This study responds to the call from Boyd et al. (2014) for MTEs to actively engage with and address the anxieties surrounding mathematics and its teaching among PSTs. By implementing strategies that promote mathematical confidence, we can begin to mitigate the challenges posed by mathematics anxiety and foster a more positive attitude toward mathematics education among future educators.

Shifting Anxiety to Building Mathematical Confidence

Initially, I sought to address teachers' negative attitudes toward mathematics by implementing workshops focused on mathematics anxiety. The objective of these workshops was to confront the issue directly, identify its underlying causes, and ease the impact of anxiety on students' learning experiences. However, despite these efforts, data indicated that anxiety levels among PSTs remained unchanged (Foley et al., 2017). This observation highlighted the need for a more effective intervention in my teaching practice.

In response, I shifted my focus from merely addressing the negativity surrounding mathematics to actively fostering mathematical confidence among PSTs. This change in approach led to the development of targeted workshops designed to promote discussions about PSTs' personal experiences with mathematics, their beliefs, and their emotional connections to the subject. The primary aim of these workshops was to help PSTs explore both their positive and negative emotions related to mathematics, with the aim of influencing their future teaching practices.

Relevant Literature

Building confidence in mathematics through classroom conversations is essential for PSTs, particularly in the context of addressing mathematics anxiety and the beliefs that shape their instructional practices. The following literature highlights key themes related to mathematics anxiety among PSTs, the impact of their beliefs about mathematics, and the importance of promoting mathematical discourse in the classroom.

Mathematics Anxiety

Mathematics anxiety is characterized by feelings of tension, apprehension, and fear related to mathematical tasks (Beilock & Willingham, 2014). Researchers have identified anxieties as significant psychological barriers that adversely affect individuals' performance and achievement in mathematics (Ashcraft & Ridley, 2005). The prevalence of mathematics anxiety among PSTs is well-established, indicating that many future educators grapple with similar emotional challenges when teaching mathematics (e.g., Brown et al., 2011; Gresham, 2007, 2018). Addressing this anxiety requires a multifaceted approach that considers cognitive, affective, and contextual factors (Peker & Ertekin, 2011). For instance, incorporating mindfulness-based practices into mathematics instruction can foster present-moment awareness and equip PSTs with adaptive coping strategies to manage their emotions (Samuel & Warner, 2021). Creating a supportive learning environment that emphasizes effort, a growth mindset, and collaboration may cultivate more positive attitudes toward mathematics, reducing the perceived threat of mathematical tasks, and ultimately building confidence.

Mathematics Beliefs

Beliefs about mathematics significantly influence instructional practices and, consequently, students' learning experiences and outcomes. PSTs' experiences with mathematics throughout their education shape their beliefs about the subject, where positive experiences can foster confidence and enthusiasm, while negative experiences may lead to anxiety or feelings of inadequacy (Swars et al., 2009). Teacher education programs, along with ongoing professional development opportunities, play a vital role in positively shaping these beliefs about mathematics teaching and learning (Philipp et al., 2007; Ren & Smith, 2018). Understanding PSTs' beliefs regarding the nature and characteristics of mathematics—such as its coherence, usefulness, and certainty—can inform their instructional goals and approaches (Hughes et al., 2019). By recognizing the implications of these beliefs for teaching and learning, MTEs can promote effective mathematics education practices and support PSTs through focused professional development.

Mathematics Conversations and the Transformative Power of Open Dialogue

Mathematics teaching involves various modes of communication, with teachers' talk moves being a central component of classroom conversations. The way teachers communicate mathematical concepts, explanations, and strategies significantly influences students' understanding and engagement with the subject (Herbel-Eisenmann et al., 2015). Engaging in discussions about mathematical ideas allows PSTs to articulate their reasoning, justify solutions, and participate in mathematical argumentation (Woods, 2022). Further, PSTs' active engagement in conversation may support their development of mathematical facility and build confidence.

Research indicates that students learn effectively through sharing their ideas, listening to the perspectives of their peers, and critiquing the narratives presented by others (Gutiérrez et al., 2023). This collaborative discourse is further enhanced when PSTs engage in open dialogue that encourages emotional unpacking of their experiences with mathematics (Childs & Glenn-White, 2018). Such conversations hold transformative potential to foster a supportive learning environment and promote active participation, thereby empowering PSTs to confront and articulate their anxieties and beliefs about mathematics.

Purposeful facilitation of conversations by MTEs fosters confidence among PSTs, equipping them with the skills necessary for their future classrooms. This facilitation can take the form of structured discussions that guide PSTs in exploring their emotional connections to mathematics and help transform their anxieties into a more positive outlook. Shaughnessy et al. (2021) emphasize the importance of formatively assessing PSTs' skills in orchestrating discussions in mathematics, highlighting how effective dialogue can serve as a powerful tool for building confidence, and enhancing teaching practices.

The exploration of classroom conversations reveals several key components of mathematics education. Research identifies mathematics anxiety among PSTs as a significant barrier to effective teaching and learning (Itter & Meyers, 2017), underscoring the need for comprehensive strategies that address cognitive, affective, and contextual factors. Additionally, understanding and shaping PSTs' beliefs about mathematics is essential for promoting positive instructional practices and fostering student success. Promoting math conversations in the classroom is vital for not only enhancing engagement, reasoning, and problem-solving skills but also for addressing the emotional barriers that PSTs face. Through purposeful facilitation and support from MTEs, PSTs can develop the confidence and skills necessary to create enriching mathematical experiences for their future students. Open dialogue that encompasses emotional unpacking in classroom conversation fosters a nurturing and caring learning environment for students in mathematics education.

Purpose and Context

The purpose of this study is to introduce a communications strategy that MTEs can use to facilitate meaningful conversations about mathematics with PSTs. This strategy was selected based on its alignment with previous research, which highlights the positive impact of open dialogue on addressing mathematics anxiety and building confidence among PSTs. Specifically, this study aims to explore how these conversations influence PSTs' emotions regarding mathematics.

The precise objectives of these conversations are: (1) to articulate beliefs about mathematics; (2) to recognize the impact of previous experiences with mathematical contexts; and (3) to build confidence in understanding and applying mathematical concepts.

In the following sections, I report on a mathematics confidence workshop conducted with PSTs. Throughout the school term and prior to attending the workshop, PSTs worked in randomized groupings to complete rich mathematical tasks across various strands (i.e., numbers and operations, patterns and relations, measurement, geometry, and statistics) during each of the 17 classes they attended. The workshop occurred after the conclusion of the term and provided an opportunity for PSTs to reflect on their learning, growth, and future teaching practices.

By enhancing PSTs' confidence in mathematics through such workshops, it is my hope that they will, in turn, inspire and empower their future students, nurturing a sense of confidence in the subject. The research question guiding this study is: How do structured conversations about mathematics influence preservice teachers' emotions and beliefs regarding their mathematical abilities?

Theoretical Framework

I integrated sociocultural perspectives on learning, complexity thinking, and discourse in mathematics education to create a conceptual lens that helped me understanding how mathematics conversations might promote rich classroom discourse and PSTs' growth as future mathematics educators.

Sociocultural Theory of Learning

At the core of fostering rich classroom discourse is Vygotsky's sociocultural theory of learning, which posits that knowledge construction is fundamentally a social process (Vygotsky, 1978). According to this theory, learning occurs within a classroom community through interaction, dialogue, and engagement with others during conversations about mathematics. Powell and Kalina (2009) explored the practical applications of social constructivism in educational settings, demonstrating how problem-solving and collaborative activities enable students to co-construct knowledge and develop higher-order thinking skills.

Conversations serve as essential tools for collaborative sense-making and the co-construction of mathematical understanding (Bergem & Klette, 2016). One aspect of Vygotsky's theory is the role of the *more knowledgeable other*, who facilitates learning by guiding interactions and supporting less experienced learners in their understanding of mathematical concepts. By focusing on classroom conversations, my aim is to afford PSTs opportunities to externalize their thought processes, share diverse perspectives, and negotiate meanings with the more knowledgeable other. This collaborative endeavour with MTEs allows mathematical ideas to be socially constructed and explored more deeply within the group, fostering a supportive environment for learning and teaching mathematics.

Complexity Thinking in Mathematics Education

Mathematics classrooms can be viewed as complex learning systems where various elements—students, teachers, tasks, and tools—interact dynamically (Davis & Sumara, 2006). Evidence of complexity occurring in the natural world (e.g., a hive of bees, a colony of ants, a flock of birds, etc.) draws attention to the interconnected and adaptive interactions among classroom learners which create rich discourse through mathematical conversations (Johnson, 2009). Rather than functioning as a linear or predictable environment, a mathematics classroom operates as a dynamic ecosystem where the exchange of ideas, feedback loops, and social interactions all contribute to learning outcomes (Davis & Simmt, 2003). A complexity thinking perspective encourages MTEs to facilitate open-ended discussions, problem-solving tasks, and inquiry-based learning with PSTs to bring about collectively what might not be possible as individuals. In such contexts, unpredictable yet productive discourse emerges as PSTs engage with mathematical ideas, allowing them to explore, negotiate, and refine their understanding of mathematics in a collaborative environment.

Discourse in Mathematics Education

Classroom discourse means more than communication; it serves as a complex means for learners to engage in higher-order thinking, critique reasoning, and build connections among mathematical concepts (Cazden, 2001). Classroom discourse in mathematics highlights the roles of language, argumentation, and reasoning in developing mathematical understanding (Sfard, 2007). A focus on classroom discourse also emphasizes the importance of conversations as a vehicle for engaging students in the language of mathematics, thereby fostering deeper conceptual understanding through dialogue (Herbel-Eisenmann & Cirillo, 2009). Effective discourse in mathematics education requires balancing open exploration with structured guidance, where MTEs orchestrate conversations, pose probing questions, and encourage PSTs to articulate, justify, and refine their mathematical ideas.

This theoretical framework provides a multifaceted lens for viewing how mathematics conversations can serve as a vital tool to promote meaningful classroom discourse and build PSTs' confidence in their mathematical abilities within a complex learning system. By fostering open, dynamic, and purposeful discourse, MTEs can create an environment that enhances PSTs' mathematical understandings while preparing them to teach in ways that give their future students opportunities to develop a positive relationship with mathematics.

Methods

Research Design

This study employs a qualitative research design to explore the impact of conversations on PSTs' emotional responses and beliefs about mathematics. The focus is on understanding more fully how open dialogue can foster confidence and engagement in mathematics education.

Setting

The research was conducted at a small university in Eastern Canada, where the Faculty of Education offers a two-year post-undergraduate degree teacher education program. The study took place during a mathematics confidence workshop designed for PSTs nearing the completion of their professional certification program.

Participants

The participants in this study consisted of 25 PSTs enrolled in the second year of their teacher education program. These PSTs had recently completed their second curriculum and instruction course in mathematics education and their fourth and final practicum placement, providing them with relevant experiences to draw upon during the workshop. Participation in the workshop was offered after the completion of their course work and was entirely voluntary for all PSTs. PSTs' responses to conversation prompts and reflective feedback were anonymized with the help of a colleague not directly involved with the class.

Instruments

To facilitate open dialogue among PSTs, I developed three distinct sets of conversation cards, each containing 30 to 40 cards. These cards feature prompts, questions, and vocabulary aimed at exploring various aspects of mathematics learning, teaching practices, and personal experiences with the subject. The content of the cards is derived from my own research and includes responses, reactions, and emotions related to learning and teaching mathematics encountered in my role as a MTE. I designed the conversation cards to prompt PSTs to reflect on their beliefs about mathematics and reinforce their conceptual understanding through language. The conversation cards often spark positive and negative memories of mathematics from PSTs and sometimes emotional responses that are intense. I am mindful to caution PSTs of the strong feelings related to mathematics anxiety that some people may experience and remind myself as well as others to remain sensitive to their participation.

Procedures

During the mathematics confidence workshop, PSTs engaged in small-group discussions using the conversation cards. Each set of cards was utilized in specific activities (see Appendixes A, B and C) aimed at unpacking PSTs' individual perceptions of mathematics. The activities encouraged participants to share personal experiences, articulate their beliefs, and explore their emotional connections to the subject. Below, I outline three activity examples and offer samples from the conversation cards for reference as well as strategies for implementing the cards in practice. At the end of this paper, I provide the full sets of conversation cards that MTEs can use with their PSTs.

Data Collection

Data for this study were collected through multiple methods. Audio recordings of the small-group discussions were made to capture the conversations as PSTs interacted with the conversation cards. Additionally, participants were asked to write reflections following the workshop, allowing them to articulate their thoughts and feelings about their experiences during the activities. These reflections provided valuable insights into the emotional impact of the conversations on their beliefs about mathematics.

Data Analysis

The audio recordings of the discussions were transcribed and analyzed using thematic analysis to identify common themes and patterns in PSTs' emotional responses and beliefs. The themes were shared with PST participants for accuracy and verification. The written reflections were also examined to supplement the findings from the discussions, providing a comprehensive understanding of how the conversation cards influenced PSTs' confidence and engagement with mathematics.

Activities for Using Conversation Cards

I use a variety of activities with the conversation cards to stimulate dialogue among PSTs. To foster a trusting and supportive environment, I encourage PSTs to engage in discussions without a designated facilitator. This approach allows for organic conversation, where PSTs can freely participate while remaining sensitive to their peers' emotions and experiences. Establishing this trust is important, as it enables participants to share openly and feel comfortable expressing their thoughts.

The first activity involves using a specific set of conversation cards (see Appendix A), where PSTs take turns turning over one card at a time and discussing the statement written on it. After discussing the statement, if a participant agrees with it, they may choose to keep the card. If multiple participants wish to keep the same card, each must present a compelling argument for why they should have it. If no one agrees with the statement or feels strongly about it, the card is placed in a discard pile. The objective is for each participant to select a set of cards (4 – 6) that best represent their thinking on the topic. As a follow-up, I encourage groups to examine the discard pile and reflect on their decision-making process regarding which cards to keep or discard.

The second activity, using a different set of conversation cards (see Appendix B), involves spreading all the cards face down in front of the group. Each member randomly selects six cards. Participants take turns reading aloud the statements on their cards. After each reading, they may choose to keep the card as one of their six or discard it, selecting a new card in its place. This activity ensures that participants always hold six cards, facilitating a dynamic exploration of their beliefs and feelings about mathematics. Additionally, group members can engage in a collaborative discussion about each card, selecting those that most accurately represent the collective feelings or beliefs of the group. I encourage dialogue for each card to reach a consensus on whether to keep or discard it. This process allows for conversation and debate, enabling group members to discover additional meaningful cards. After groups finalize their selections, I ask each group to share their chosen six cards with the other groups. This sharing stimulates further discussion, comments, and questions, creating an enriching environment for collective learning.

The third activity, called The Word Sort (see Appendix C), is another engaging strategy where PSTs analyze the vocabulary associated with mathematical concepts. In this activity, participants consider words related to division, including everyday terms (e.g., share, group, equal, same) as well as technical vocabulary (e.g., divisor, dividend, quotient). By grouping and regrouping these words according to their own criteria, PSTs engage in discussions about the meanings and connections among them. This sorting activity often leads to rich conversations about the concept of division, drawing on PSTs' firsthand experiences and prompting new insights into the teaching and learning of the topic.

Findings

Following the conversation card activities, I prompted PSTs to reflect on the impact of their experience engaging in these discussions on their future teaching approaches and their relationship with mathematics. The voices of the PSTs who participated in these conversations reveal insights of interest to MTEs. Thematic analysis of the reflections yielded two primary categories: (1) PSTs expressing and unpacking their emotional reactions to mathematics, and (2) PSTs' desire to shift the conversation toward building confidence for themselves and their future students.

Unpacking Emotions

After engaging in conversations with their peers, PSTs wrote reflections that highlighted their emotional experiences. For example, Sandy expressed the shared emotions within the group, citing past encounters with inadequate teaching and the discomfort of "being put on the spot in class," which heightened her anxiety surrounding the subject. Alayne noted similar feelings, writing, "When we broke up into groups to discuss our conversation cards, I was surprised to hear how many of my classmates shared the same struggles and insecurities as I did throughout my education."

Iain remarked that the activities "would be beneficial for certain elementary grades (as well as being beneficial for anyone in general to express how they feel about math), as it allows students to realize they are not alone if they are struggling in some way." Similarly, Joannie emphasized, "They [future students] are able to talk out loud about their math anxieties if they are experiencing those feelings and realize that other students may be feeling the same way." Yannick found collaborating with peers on activities and participating in discussions transformative, stating, "Not only could I share my opinion but I could also listen to the opinions of others. This has helped me tremendously in terms of seeing things from a different perspective and to shine things in a different light than I am used to." Coral echoed this sentiment, writing, "We all benefit in not only becoming better learners but also better teachers," highlighting the value of collaborative learning experiences in fostering both personal growth and professional development.

These reflections collectively illustrate how the conversation card activities facilitated emotional unpacking and reinforced the importance of community among PSTs. By sharing their experiences and anxieties, PSTs gained insights into their own feelings about mathematics and recognized the shared nature of these emotions, thereby fostering a supportive environment that can enhance their confidence in teaching mathematics.

Building Confidence

PSTs conveyed a notable shift in their perceptions of mathematics, expressing increased confidence in the subject. For example, Corey articulated a connection with peers and a growing comfort with mathematics, stating, "By breaking it down and discussing how we felt about mathematics, both positively and negatively, I was able to establish a sense of connection with my classmates, which in turn made me feel more comfortable making mistakes. This was definitely an 'aha' moment for me."

PSTs also reflected on the issue of mathematics anxiety and its implications for their future classrooms. Sharon noted that the sharing activity prompted PSTs to consider strategies for "alleviating math anxiety in our future students." Teo acknowledged the benefits of using the activities in future practice, stating, "Allowing students to talk about their feelings of math and their experiences will lead the way for them to create relationships to lean on one another in their future studies." Gurpreet emphasized the importance of addressing the "real issue of math anxiety" through open dialogue, recognizing the conversation cards as effective tools for facilitating these discussions and "promoting a safe learning environment."

These reflections from PSTs illuminate the pivotal role of conversations within a supportive environment in reshaping beliefs about mathematics and addressing mathematics anxiety in both current practice and future classrooms.

Discussion

PSTs' voices showed that using conversation card activities to unpack emotions related to mathematics may support confidence building and have implications for their future teaching approaches. Through peer discussions, PSTs such as Sandy and Alayne shared common experiences of anxiety and insecurity connected to past educational challenges, highlighting the importance of community in addressing these feelings. As Peker and Ertekin (2011) recommend, PSTs benefit from a comprehensive approach that focuses on cognitive, emotional, and contextual factors to help mitigate mathematics anxiety. The realization that many classmates echoed similar struggles fostered an environment of empathy and support, which Iain regarded as important for fostering resilience in young learners.

Joannie emphasized the significance of providing future students with opportunities to share their anxieties, a practice that could help counterbalance previous negative experiences with healthier narratives. This idea resonates with the findings from Gutiérrez et al. (2023), which advocate for the importance of emotional expression in the mathematics classroom. The collaborative nature of these activities transformed perspectives; for instance, Yannick noted that engaging in focused discussions allowed him to listen to diverse opinions, thereby broadening his understanding of mathematical challenges. This connection to collaborative conversation reflects the value of creating spaces where PSTs can articulate and negotiate their learning experiences together.

PSTs expressed a notable shift toward increased confidence in their mathematical abilities, as illustrated by Corey, who described how discussing their feelings led to greater comfort with making mistakes. While comfort with the subject is an important step, it is essential to recognize that confidence encompasses a broader belief in one's abilities to tackle mathematical tasks effectively (Ren & Smith, 2018). This newfound sense of comfort prompted critical reflections on their future classrooms, with Sharon and Gurpreet advocating for strategies to alleviate mathematics anxiety among their students.

These findings illustrate the transformative power of open dialogue and emotional unpacking, suggesting that creating supportive learning environments is essential for reshaping PSTs' beliefs about mathematics. By equipping PSTs with the tools to foster a positive mathematical experience in their future students, MTEs can contribute to a more favorable perception of mathematics education.

Strengths and Limitations

The findings from this study offer several key takeaways that support the formative education of PSTs. The findings encourage PSTs and potentially early-career mathematics educators to acknowledge their beliefs and emotional responses to learning, engaging with, and teaching mathematics. This self-awareness fosters a positive attitude toward mathematics education. As well, the study contributes to building confidence among PSTs, as they begin to recognize the complexities involved in learning and teaching mathematics. Engaging in conversations about their experiences allows PSTs to navigate their anxieties and develop a more nuanced understanding of their future roles as educators.

The study's limitations should also be acknowledged. The small sample size of PSTs who participated in the required mathematics methods course may restrict the breadth of the findings. Participation in the conversation prompts and reflective feedback was voluntary. Reflections were not part of class assignments which may have impacted the degree to which PSTs were willing to share. A more extensive and diverse sample to further explore the dynamics described in this study may potentially lead to richer insights into the experiences of PSTs in mathematics classrooms.

Concluding Thoughts and Future Considerations

Utilizing conversation cards has proven to be a valuable tool for engaging PSTs in meaningful exchanges (Throop-Robinson, 2020), thereby deepening understandings of the impact of mathematics anxiety on both teaching and learning. These activities facilitated rich discourse among PSTs, fostering a culture of empathy and mutual understanding as they listened to and responded to each other's feelings and ideas. Such collaborative discussions help create a supportive environment that allows PSTs to navigate their anxieties and build confidence in their mathematical abilities.

Moving forward, it is essential to acknowledge how emotional connections to mathematics contribute to classroom discourse and support these affective aspects of learning. Future research could focus specifically on individual PSTs who identify as experiencing mathematics anxiety and are willing to engage with the activities described in this study. Tracking their journeys from recognizing past experiences to forming new emotional connections with mathematics may provide valuable insights for others who share similar feelings.

Additionally, exploring the potential of conversation cards in formative assessment through ongoing dialogue and observation holds promise for enhancing teaching practices. This approach can empower PSTs to carry these strategies into their future classrooms, promoting an environment that addresses mathematics anxiety while fostering a positive mathematical identity among their students.

Lastly, I include complete sets of conversation cards for use with PSTs and other mathematics educators in Appendix D. I encourage MTEs to review the questions and prompts thoroughly before offering them for discussion with PSTs and to anticipate potential responses for each card individually. Please refer to the activities described above to orchestrate the conversations, being mindful that individual responses, questions, and comments will be unique to every situation. It is my hope that additional questions and prompts from PSTs will emerge and new cards added to these sets over time.

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Appendix A
Conversation card activities: Beliefs about mathematics

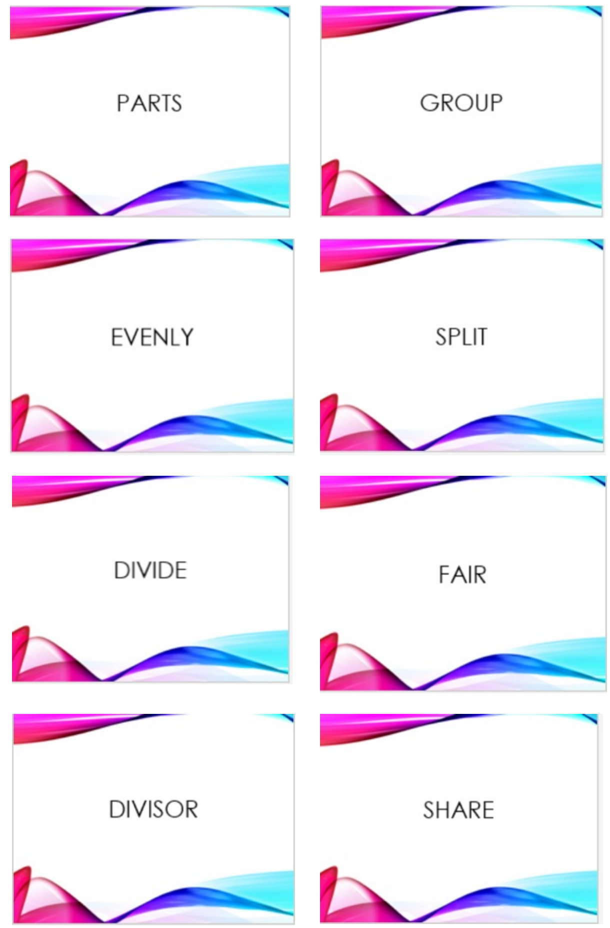
Activity	Process	Sample Cards
Emotions Count: Reflecting on beliefs about mathematics	• The objective is for each PST to share from experience their emotions about mathematics. • Teachers alternate turning over one card at a time. • After reading the statement aloud, each teacher completes the phrase and offers a connection or a reflection about the sentence. • Teachers may comment or reflect on the contributions of others as the conversation unfolds. • NB: In some cases, groups may discuss several cards at once or, depending on individual experiences, focus specifically on just one or two.	The most challenging experience I had with mathematics was… When I encounter a mathematics problem I feel… I'm successful at mathematics when I … The one thing that bugs me about mathematics is… I'm confident about doing mathematics because… When I was a student in school, mathematics was… I'm nervous about doing mathematics because… When I solve a mathematics problem I feel…

Appendix B

Conversation card activities: The nature of mathematics

Activity	Process	Sample Cards
What is mathematics?: Connecting with the nature of mathematics	• The objective is for each teacher to select a set of cards (4–6) that best represents their thinking about what they believe mathematics to be. • Teachers alternate turning over one card at a time. • After reading the statement aloud, teachers decide whether they agree with it or not, and why. • If more than one teacher agrees with the statement, each person will present a persuasive argument to decide who will hold the card in their hand. • If no one agrees with the statement or does not have strong feelings, the card is discarded.	Mathematics is a study of patterns and relationships. Mathematics is made up of facts that explain the world we live in. Mathematics is a language that uses carefully defined terms and symbols. Mathematics exists naturally and is discovered by people called mathematicians. Mathematics gives us definite answers or facts that cannot be questioned. Mathematics is always changing and therefore we cannot depend on it. Mathematics is done in specific and organized processes; it follows a kind of recipe. There is no one way to do mathematics; there is no universal step-by-step mathematical process.

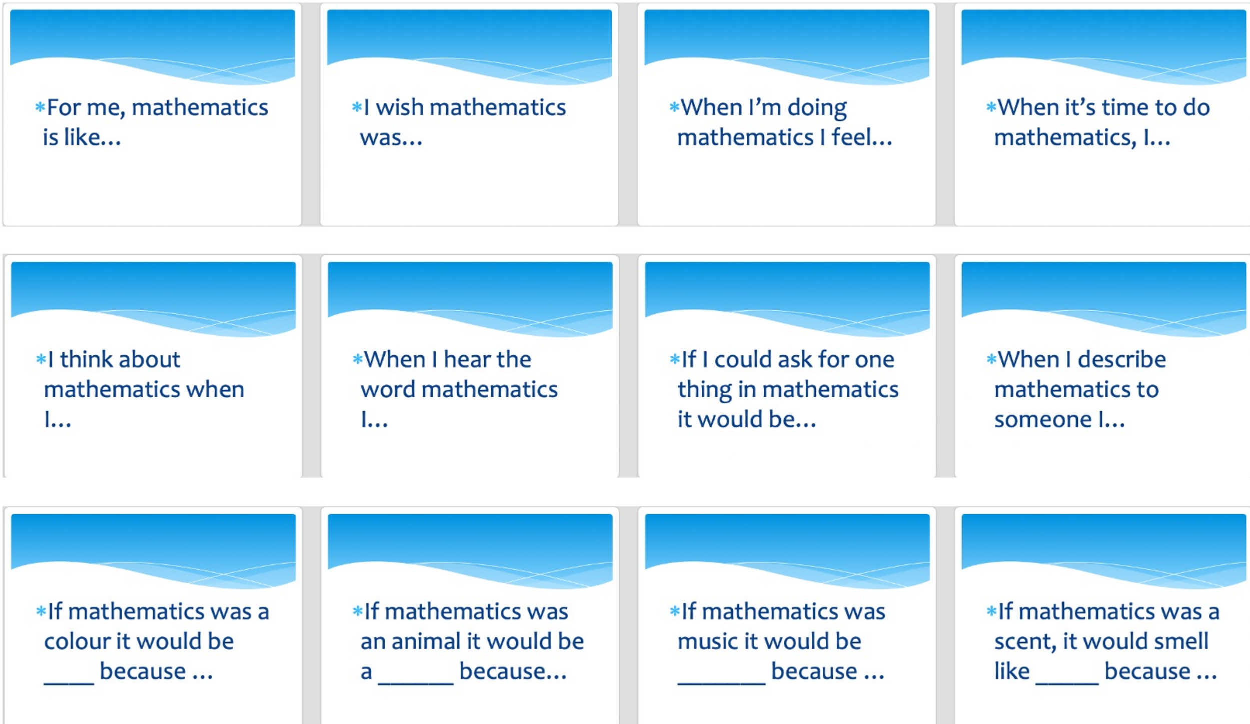
Appendix C
Conversation card activities: Mathematical vocabulary

Activity	Process	Sample Cards
Word Sort: Reviewing conceptual understanding of mathematics	• The objective is for teachers to build their conceptual understanding of mathematics through exploration of the words commonly used with each topic. • As a group, teachers look at all the words on the cards and discuss their associations, similarities, and differences. • Round 1: Teachers make decisions about how to group the words together into four groups. They provide a title for each grouping. • Round 2: As above, making three groups and re-naming the groupings, as necessary. • Round 3: As above, making two groups.	

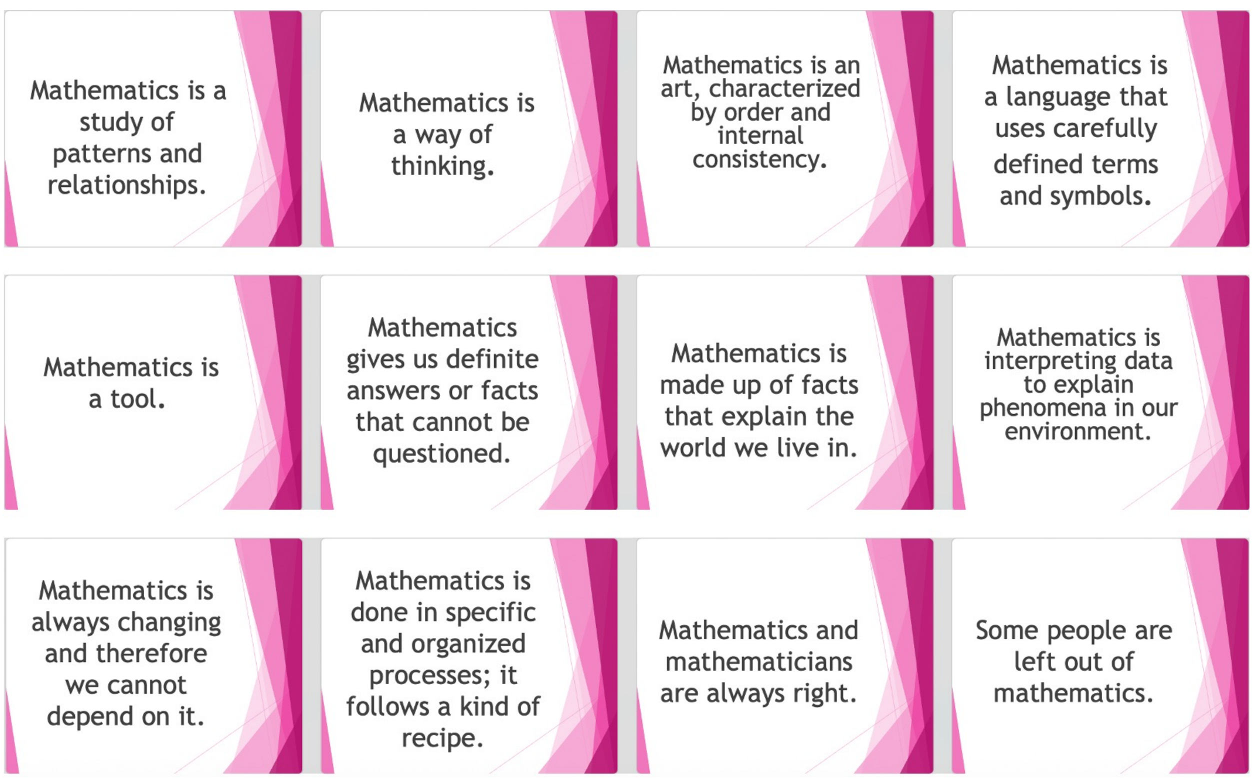
Appendix D
Conversation cards

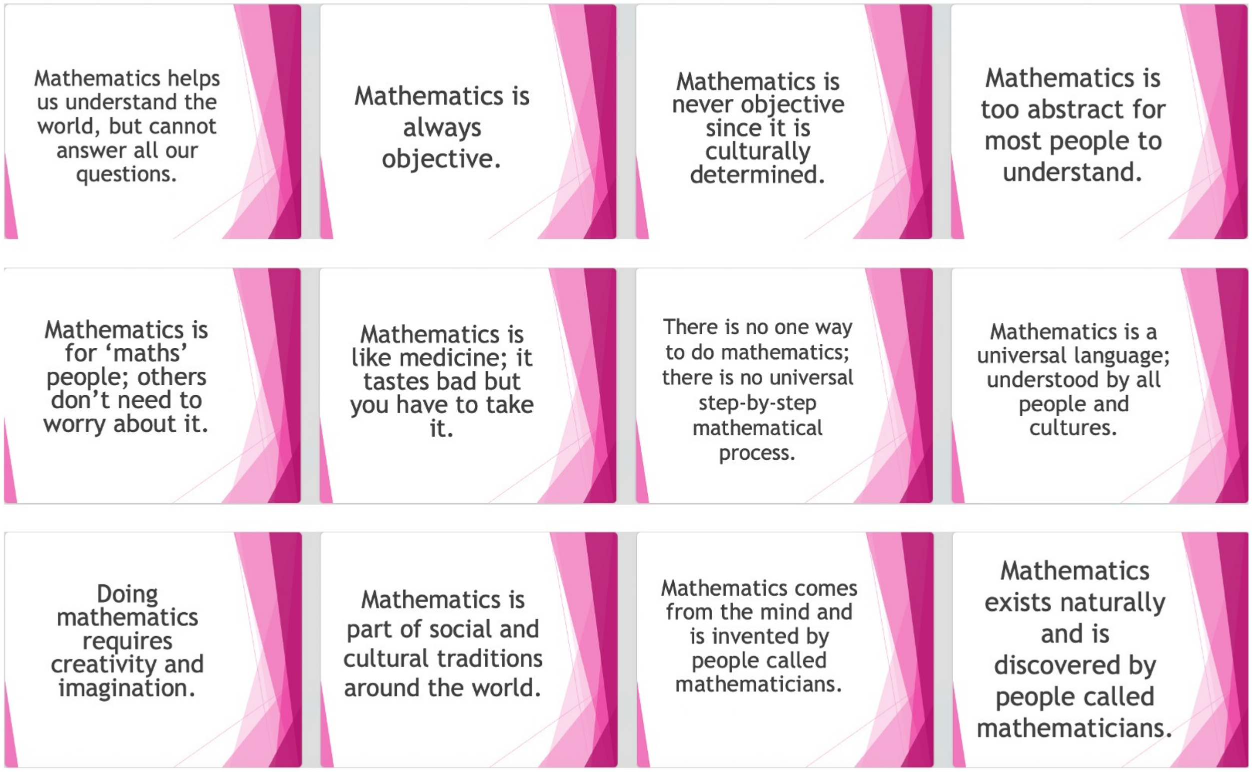
Emotions count: Reflecting on beliefs about mathematics

*My favorite thing in mathematics is…	*My learning style helps me learn mathematics because …	*My teacher supported me in mathematics learning because …	*I'm successful at mathematics when I …
*I am persistent in mathematics because …	*I like mathematics drills because …	*For me, knowing how to solve a problem is important because …	*I take my time in mathematics because …
*I take pleasure in solving problems because …	*The one thing I love about mathematics is…	*I like mathematics because…	*I love mathematics because…
*My least favorite thing in mathematics is…	*My teacher didn't support me in mathematics learning because …	*My patience wears thin in mathematics because …	*My learning style doesn't support mathematics learning because …
*I cringe at solving problems because …	*One negative word that describes mathematics is ________ because …	*I feel rushed in mathematics because …	*I don't like mathematics drills because …
*The one thing that bugs me about mathematics is…	*Mathematics is hard because…	*I avoid mathematics when…	*I am mathematics anxious because…



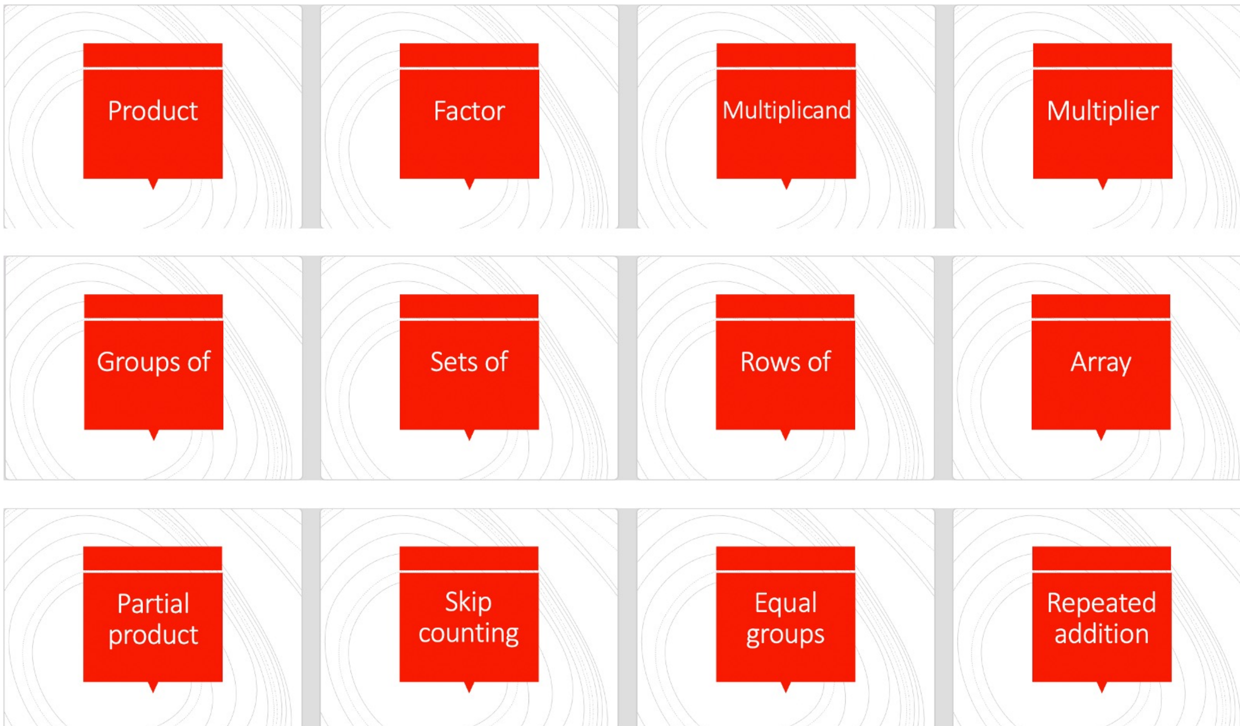
What is mathematics?: Connecting with the nature of mathematics





Word sort: Reviewing conceptual understanding of mathematics—Division

Word sort: Reviewing conceptual understanding of mathematics—Multiplication



JOURNAL OF MATHEMATICS EDUCATION AT TEACHERS COLLEGE | FALL 2025 | VOLUME 16, ISSUE 2

NOTES FROM THE FIELD

Beyond Memorization: Advocating Derivation and Proof in School Mathematics

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ABSTRACT This paper advocates for the teaching and emphasis of derivation and proof in school mathematics as a means to foster deeper conceptual understanding and reduce overreliance on rote memorization. By examining the derivation of key geometric formulas-such as the volumes of a cylinder, cone, prism, and pyramid, as well as the shortest distance between two points on a sphere in latitude and longitude-it demonstrates how students can engage meaningfully with mathematical ideas. Through logical reasoning, spatial visualization, and mathematical connections, derivation empowers learners to appreciate mathematics as a coherent and purposeful discipline. The paper calls for an instructional shift toward reasoning-based learning in school curricula to cultivate critical thinking and lasting comprehension.

KEYWORDS *Conceptual Understanding, Derivation, Proof, School Mathematics*

Introduction

In school mathematics teaching, there is an alarming tendency toward emphasizing rote memorization of formulas and procedures rather than fostering genuine understanding through derivation and proof. This prevailing pedagogical approach has raised significant concerns among educators and researchers regarding its impact on students' deep conceptual grasp, critical thinking skills, and long-term retention of mathematical knowledge (Boaler, 2016). Formulas for volumes of solids such as cylinders, cones, prisms, and pyramids, as well as geometric concepts like the shortest distance between two points on a sphere, are often presented as facts to be memorized rather than understood through logical reasoning or derivation. The resulting disconnect reduces mathematics to a collection of disconnected rules, hindering students' ability to apply their knowledge flexibly or appreciate the underlying structure of mathematics (Schoenfeld, 2014).

Derivation and proof are foundational pillars of mathematics. They provide learners with the tools to understand why formulas and relationships hold true, not merely that they exist. For instance, understanding that the volume of a cylinder, expressed as $V=\pi r^2 h$, can be logically deduced from the area of its circular base and its height helps students recognize how mathematical formulas are not merely to be memorized but derived through structured reasoning, a process central to the development of deductive proof skills (Miyakawa, Fujita, & Jones, 2017). Similarly, the volume of a cone, which is exactly one-third that of a cylinder with the same base and height, emerges from geometric reasoning or Cavalieri's Principle, rather than arbitrary acceptance. Cavalieri's Principle states: If two solids have equal heights, and if the areas of their corresponding cross-sections taken at equal distances from their respective bases are always equal, then the two solids have equal volumes. Using this principle, one can show that a cone has one-third the volume of a cylinder. By comparing the cone with a cylinder and a carefully constructed prism, students can visualize that the areas of cross-sections at each height differ by a factor of three, thereby justifying the one-third relationship in volume. Such derivations cultivate deeper mathematical insight by bridging intuitive reasoning with formal justification, thereby enabling learners to reconstruct or modify formulas through logical argumentation, an approach that reflects the central role of proof in linking mathematics as practiced by mathematicians to mathematics as taught in schools (Rocha, 2019).

It is, however, important to specify the grade levels where such proofs and derivations are appropriate. For example, derivations involving prisms and cylinders (using cross-sections or stacking) can be introduced as early as grades 6–8, since they require only basic geometry and arithmetic. Proofs involving cones and pyramids via Cavalieri's Principle are more appropriate for grades 8–10, when students are mature enough to follow abstract reasoning. Advanced topics such as the derivation of the great-circle distance on a sphere, which relies on trigonometry, are best suited for grades 11 and 12, when students have developed sufficient algebraic and trigonometric background. Explicitly linking examples to grade levels ensures that derivation and proof are introduced progressively, making them accessible and meaningful to learners at different stages of development.

In many systems and pedagogical contexts, however, time constraints, curriculum demands, and examination pressures compel teachers to prioritize formula memorization over reasoning. The consequence is a superficial grasp of mathematics where students can reproduce formulas but struggle to explain or derive them. This not only limits students' engagement in the active roles of exploring, conjecturing, and justifying through proof but also undermines their confidence and sustained interest in mathematics (Bleiler-Baxter & Pair, 2017). Moreover, teachers often resist the integration of derivation and proof because they fear it will reduce the time available for procedural drill, an emphasis reinforced by high-stakes examinations (Hiebert & Grouws, 2007). Studies reveal that while conceptual teaching improves long-term achievement, many teachers prefer the certainty of procedural coverage to meet assessment demands (Thompson & Senk, 2012). Addressing these concerns requires practical strategies for integration. One approach is to embed short, intuitive derivations within existing lessons, for instance, spending five minutes showing why the cylinder's volume equals "base area × height" through stacking, before assigning routine practice. Another strategy is the use of visual or hands-on demonstrations, such as water-filling experiments to compare cone and cylinder volumes, which require little extra class time yet leave lasting impressions. Furthermore, schools could align derivation-focused instruction with curriculum objectives, ensuring that it supports, rather than competes with, exam preparation. Technology-based tools like dynamic geometry software also allow quick and interactive visualization of proofs, helping teachers overcome time and resource limitations (Stylianides & Stylianides, 2009).

Mathematical topics such as the volume of prisms and pyramids provide fertile ground for teaching derivation and proof in school mathematics. The volume of a prism, found by multiplying the base area by height, can be understood by considering the prism as a stack of congruent cross-sectional areas along its height. Likewise, the formula for the volume of a pyramid, which is one-third the volume of a prism with the same base and height, can be illuminated through spatial reasoning or geometric dissection, thus demystifying why the factor of one-third appears and how volume relates to base and height in different solids (Mason, Graham, & Johnston-Wilder, 2005). These examples are particularly suitable for junior secondary levels (Grades 7–9), when students are transitioning from concrete to abstract reasoning. Another illustrative example lies in spherical geometry, particularly the determination of the shortest distance between two points on a sphere, expressed in terms of their latitude and longitude coordinates. This concept, fundamental in navigation and geography, is often introduced in a formulaic manner without deriving the great-circle distance formula from basic geometric principles. When students are guided through the reasoning behind the spherical law of cosines or the haversine formula, they develop a concrete understanding of how curvature influences distance and why Euclidean notions of straight lines do not apply on curved surfaces (Feeman & Green, 2015). Such derivations are better suited for upper secondary students (Grades 11–12), where trigonometric concepts are already part of the curriculum.

Recent research underscores the benefits of integrating derivation and proof in mathematics education. Studies indicate that students exposed to reasoning-focused instruction demonstrate higher achievement, better problem-solving abilities, and greater motivation (Stylianides & Stylianides, 2009; Boaler, 2016). Furthermore, national curriculum reforms in countries like Singapore and Finland emphasize conceptual understanding and mathematical reasoning, suggesting a growing consensus on the importance of proof and derivation in school mathematics (Ng & Widjaja, 2015). Despite these developments, many educational systems lag behind, continuing to undervalue derivation and proof in favour of procedural fluency. This paper therefore advocates a renewed emphasis on teaching derivation and proof within school mathematics, arguing that such an approach nurtures mathematical thinking, enhances understanding, and equips students with skills essential for further study and everyday life. By explicitly clarifying which grade levels suit which derivations, providing clear explanations of concepts like Cavalieri's Principle, and offering strategies for practical classroom integration, the study responds to the concerns of both researchers and practitioners. By focusing on classical yet foundational examples, volumes of common solids and shortest distances on spheres, the study illustrates how derivation and proof can be effectively integrated into the curriculum without overwhelming teachers or students.

Some Illustrations

In this section, the derivations and proofs in school mathematics are illustrated.

1. Derivation of volume of a cone formula

The derivation of the volume of a cone formula may not be obvious in school mathematics like that of cylinder. A cylinder can be visualized as a stack of identical circular discs. The volume of a cylinder is obtained as Volume = base area (circle) × height, which gives $V=\pi r^2 h$ This is clear enough. Imagine filling a cone with water and pouring it into a cylinder with the same base and height. It takes exactly 3 full cones to fill the cylinder. But the result comes from solid geometry developed by Archimedes (circa 287–212 BC) and formalized by Cavalieri's Principle (formulated by Bonaventura Cavalieri in the 17th century) which states: If two solids have the same height and the same cross-sectional area at every level (parallel to the base), then they have the same volume. There is also a converse: If the cross-sectional areas are in a constant ratio at every height, then the volumes are in the same ratio.

Let us derive the volume of a cone using integration. Take a right circular cone with height h and base radius r. Place it so that the tip is at the origin and the base is at $x=h$. The equation of the slant side (a straight line from (0,0) to (h,r)) is: $y= (h/r)x$. Rotate this line around the x-axis to form the cone. Using the disk method (see Figure 1):

So, whether you understand it geometrically or through calculus, the volume of a cone is:

$V=\frac{1}{3}\pi r^2 h$

Here is a clear and logical derivation of the formula for the volume of a cone without using calculus, using geometric reasoning. You can derive the volume of a cone geometrically by knowing the formula for a cylinder and observing that a cone with the same base and height fits 3 times into the cylinder based on Cavalieri's Principle. That is:

$$\text{Volume of cone } (V_{cone})=k\times\text{Volume of cylinder}(V_{cylinder}),$$

$$k = \text{constant of proportionality}, 0<k<1$$

$$\Longrightarrow \quad kV_{cylinder} + kV_{cylinder} + kV_{cylinder} = V_{cylinder}$$

$$\Longrightarrow \quad 3kV_{cylinder} = V_{cylinder} \Longrightarrow 3k = \Longrightarrow k=\tfrac{1}{3}$$

$$\therefore \quad V_{cylinder} = \tfrac{1}{3}\pi r^2 h$$

Therefore, the volume of a cylinder is three times the volume of a cone with the same base and height. Just as a cone occupies exactly one-third the volume of a cylinder with the same base and height, a pyramid also occupies exactly one-third the volume of a prism with the same base area and height. This analogy helps students understand the volume relationship without needing calculus.

2. Proving the shortest distance formula on a sphere (the Earth) using longitude and latitude in school mathematics

We want to find the formula for the shortest distance between two places on the Earth's surface using their longitudes and a common latitude. The formula is:

$$\boldsymbol{D_s = \frac{2\sin^{-1}(\cos\alpha\sin\frac{\theta}{2})}{360} \times 2\pi R}$$

where:

D_S is the shortest distance between the two points,

θ is the difference in longitude (in degrees),

α is the common latitude,

R is the radius of the Earth.

But where does this formula come from? Many mathematics textbooks state the formula without explanation (Obasi, 2015). Let us understand how it is derived, as presented in Obasi (2015), and replicate it here for easy reference.

Figure 1

Disk Method

$$V = \pi\int_0^h y^2 dx = \pi\int_0^h \left(\frac{r}{h}x\right)^2 dx = \pi\int_0^h \frac{r^2}{h^2}x^2 dx = \pi\frac{r^2}{h^2}\int_0^h x^2 dx = \pi\frac{r^2}{h^2}\left[\frac{x^3}{3}\right]_0^h = \pi\frac{r^2}{h^2}\left[\frac{h^3}{3}\right] = \frac{1}{3}\pi r^2 h$$

Proof

Understanding the idea. On a flat surface, the shortest distance between two points is a straight line. On a curved surface like the Earth (which is almost a sphere), the shortest path between two points is called a great-circle distance. To understand this, imagine the Earth as a circle and draw two points A and B on the same latitude, but different longitudes. Connect them with a chord (a straight line through the circle). Let the angle between these two points be θ (in degrees). The chord forms part of a sector of a circle. Using the sector formula:

$$D_s = \frac{\vartheta}{360} \times 2\pi R \qquad (1)$$

To determine ϑ, since at small θ, the length of Arc equals the length of the Chord. The length of a chord of a circle is:

$$L = 2r \sin\frac{\theta}{2} \qquad (2)$$

where θ is the angle subtended by the Chord. Similarly, ϑ is the angle subtended by the shortest distance, which is given by

$$L_2 = 2R \sin\frac{\vartheta}{2} \qquad (3)$$

But $r = R\cos\alpha$, then equation (2) becomes

$$L = 2R\cos\alpha \sin\frac{\theta}{2} \qquad (4)$$

Since Chord of a circle is uniform, therefore equation (3) is equal to equation (4), i.e.

$$2R \sin\frac{\vartheta}{2} = 2R\cos\alpha \sin\frac{\theta}{2}$$

$$\sin\frac{\vartheta}{2} = \cos\alpha \sin\frac{\theta}{2}$$

$$\frac{\vartheta}{2} = \sin^{-1}\left(\cos\alpha \sin\frac{\theta}{2}\right)$$

$$\therefore \vartheta = \sin^{-1}\left(\cos\alpha \sin\frac{\theta}{2}\right)$$

Therefore, $\boldsymbol{D_s = \frac{2\sin^{-1}(\cos\alpha\sin\frac{\theta}{2})}{360} \times 2\pi R}$

And this is the shortest distance formula between two points with the same latitude but different longitudes on a sphere like the Earth. This proof shows how the shortest distance formula is derived from basic geometry, not just memorized. Understanding the why behind formulas helps you become a creative and confident problem solver—just like the great mathematicians. Let this motivate you to go beyond formulas and think about the ideas behind them.

3. Proof of why we invert the second fraction when dividing

Why do we invert when dividing two fractions? Teachers often instruct students to "invert the second fraction and multiply" when dividing two fractions. While this rule is mathematically correct, it is frequently taught without explanation, leaving students to accept it as a mysterious trick—what might be called *mathemagic*. However, mathematics should make sense, not just work by rules. The following logical proof explains why the inversion step works, helping students understand the reasoning behind the rule rather than memorizing it blindly.

Let's divide:

$$\frac{a}{b} \div \frac{c}{d}$$

This means: "How many times does $\frac{c}{d}$ fit into $\frac{a}{b}$?" Let x be the answer:

$$\frac{a}{b} = x \times \frac{c}{d}$$

Multiply both sides by $\frac{c}{d}$ to isolate x: $x = \frac{a}{b} \times \frac{d}{c}$

Therefore:

$$\frac{a}{b} \div \frac{c}{d} = \frac{a}{b} \times \frac{d}{c}$$

This logical proof justifies the "invert and multiply" rule.

Conclusion

The overreliance on memorization in school mathematics has created a generation of learners who often lack genuine understanding of mathematical concepts and struggle to apply them flexibly. This paper has demonstrated, through the derivation of formulas for volumes of common geometric solids, cylinders, cones, prisms, and pyramids, as well as the shortest distance between two points on a sphere, that deep mathematical understanding is achievable when students are guided through reasoning and proof. These derivations, when introduced appropriately in school curricula, help students see mathematics not as a set of disconnected rules, but as an elegant and logical system grounded in relationships and patterns. Advocating for derivation and proof in school mathematics is not just a call for curriculum reform, it is a call to transform how students experience and internalize mathematics. When learners are given the tools and time to explore why a formula works, they gain confidence, build critical thinking skills, and develop a more lasting appreciation for the subject. Teachers, curriculum developers, and policymakers must therefore prioritize reasoning, exploration, and derivation as core components of mathematics instruction. Only then can mathematics teaching move beyond mechanical performance and toward meaningful, enduring understanding.

Suggestions

The following suggestions are made:

1. Schools should integrate intuitive and visual derivations of formulas (such as prism and cylinder volumes) at the junior secondary level (Grades 6–8), while reserving more abstract derivations (such as Cavalieri's Principle for cones and pyramids or spherical trigonometry for great-circle distances) for senior secondary levels (Grades 9–12).
2. Teachers can embed short derivations within regular lessons, use hands-on demonstrations (e.g., water-filling experiments for cone and cylinder volumes), and employ dynamic geometry software to visually illustrate proofs without significantly reducing time for procedural practice.
3. Curriculum designers and examination boards should incorporate reasoning-based questions alongside procedural ones, so that teachers are motivated to balance formula memorization with proof, fostering both conceptual understanding and exam readiness.

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Articles

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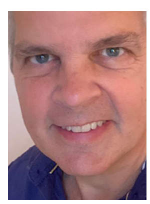

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ACKNOWLEDGEMENT OF REVIEWERS

The Editorial Board would like to acknowledge the following reviewers for their effort and support in reviewing articles for this issue of the *Journal of Mathematics Education at Teachers College.* Without the help of these professionals, it would be impossible to maintain the high standards expected of our peer-reviewed journal.

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JOURNAL OF MATHEMATICS EDUCATION AT TEACHERS COLLEGE

CALL FOR PAPERS

This call for papers is an invitation to mathematics education professionals, especially Teachers College students, alumni, and associates, to submit articles describing research, experiments, projects, innovations, or practices in mathematics education. The journal features full reports (approximately 3500 to 4500 words) and short reports (approximately 500 to 1500 words). Full reports describe findings from specific research, experiments, projects, innovations, or practices that contribute to advancing scholarly knowledge in mathematics education. Short reports ("Notes from the Field") provide examples, commentary, and/or dialogue about practices out in the field of mathematics education or mathematics teacher education; examples from classroom experience are encouraged. Although many past issues of *JMETC* focused around a theme, authors are encouraged to submit articles related to any current topic in mathematics education, from which pertinent themes for future issues may be developed. Articles must not have been submitted to or accepted for publication elsewhere. All manuscripts must include an abstract (approximately 150 words in length) and keywords. Manuscripts should be composed in Microsoft Word and follow APA format. Guest editors will send submitted articles to the review panel and facilitate the blind peer-review process. Articles for consideration should be submitted online at jmetc.columbia.edu, and are reviewed on a rolling basis; however, to be considered for the Spring issue, articles should be received by **January 30th, 2026**.

CALL FOR REVIEWERS

This call for reviewers is an invitation to mathematics educators with experience in reading or writing professional papers to join the review panel for future issues of *JMETC.* Reviewers are expected to complete assigned reviews within three weeks of receipt of the manuscript in order to expedite the publication process. Reviewers are responsible for editorial suggestions, fact and citations review, and identification of similar works that may be helpful to contributors whose submissions appear appropriate for publication. Neither authors' nor reviewers' names and affiliations will be shared with one another; however, reviewers' comments may be sent to contributors of manuscripts to guide revision of manuscripts (without identifying the reviewer). If you wish to be considered for review assignments, please register and indicate your willingness to serve as a reviewer on the journal's website: jmetc.columbia.edu.

CALL FOR EDITOR NOMINATIONS

Do you know someone who would be a good candidate to serve as a guest editor of a future issue of *JMETC?* Students in the Program in Mathematics Education at Teachers College are invited to nominate (self-nominations accepted) current doctoral students for this position. Being asked to serve as a guest editor is a testament to the high quality and standards of the student's work and research. In particular, anyone nominated as a guest editor should be a current doctoral student whose scholarship is of the highest quality, whose writing skills are appropriate for editorial oversight, and whose dedication and responsibility will ensure timely publication of the journal issues. All nominations should be submitted to Ms. Juliana Fullon at jmf2213@tc.columbia.edu.