EMOTIONAL INTELLIGENCE AND MATHEMATICS ANXIETY'S IMPACT ON MATHEMATICS PERFORMANCE OF STUDENTS WITH AND WITHOUT MLD

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This study investigated the relationship between non-cognitive factors (mathematics anxiety, Emotional Intelligence, and mathematics self-concept) and mathematics performance in students with and without Mathematics Learning Disability (MLD). Participants were 340 3rd, 4th, and 5th grade students from a public elementary school. Results showed that students with MLD had significantly lower mathematics performance compared to their peers. Mathematics anxiety was found to have a negative impact on mathematics performance among students without MLD. While low Emotional Intelligence scores were significant predictors of lower math performance for students with and without MLD. Additionally, mathematics self-concept mediated the relationship between mathematics anxiety and mathematics performance. These findings have important implications for educators who work with students with and without MLD.

Keywords: Equity, Inclusion, and Diversity, Elementary School Education, Students with Disabilities, Mathematical Knowledge for Teaching

Introduction

Students with Mathematics Learning Disability

Students with math learning disabilities (MLD) often encounter challenges in grasping mathematical concepts and skills, resulting in lower performance compared to their peers (Lei et al., 2018, 2020ab). Beyond struggling with mathematical content, individuals with MLD may also manifest non-cognitive characteristics that further influence their mathematical performance. These characteristics include math anxiety, a diminished math self-concept, and low emotional intelligence. While these non-cognitive factors can play a role in the academic outcomes of students with MLD, their precise impact varies. Some students may face substantial negative effects on their math performance, while others may not be as adversely affected. It is crucial to recognize that not all students with MLD will necessarily exhibit these non-cognitive characteristics, and the severity of effects on MLD can differ from one student to another, resulting in varying impacts on math performance (Lei, 2021; Lei & Xin, 2023).

Mathematics Anxiety (MA)

Researchers have linked math anxiety with poor math performance of students across educational levels (Ashcraft, 2002). Math anxiety is defined as “a negative reaction to math and to mathematical situations” (Ashcraft & Ridley, 2005, p. 315) which negatively affects math performance. Individuals with math anxiety develop feelings of tension when introduced to academic and daily life situations involving math and solving number problems (Richardson & Suinn, 1972). Math anxiety limits efficiency in solving simple math problems and negatively impacts performance on standardized tests, numerical reasoning courses and math-problem solving (Chang & Beilock, 2016).

Emotional Intelligence

Emotional intelligence includes the ability to recognize, understand, and manage one's own emotions, as well as the emotions of others. Emotional intelligence, also known as emotional self-efficacy, examines individuals' emotional characteristics and self-perceptions. It is typically assessed using self-reporting measures (Petrides et al., 2007). Emotional intelligence impacts academic performance and affects the allocation of time and resources by educators when structuring academic interventions (Perera & DiGiacomo, 2013). However, the relationship between emotional intelligence and student achievement has been a topic of debate among scholars. Mavroveli and Sanchez-Ruiz (2011) found that young learners' mathematics performance could be improved by achieving higher emotional intelligence scores. Additionally, the study reported that students with disabilities had lower emotional intelligence scores compared to their peers.

Mathematics Self-concept

A positive math self-concept, characterized by confidence, a sense of efficacy, and a belief in one's mathematical abilities, has been found to be a robust predictor of improved math performance (Wigfield et al., 2015). Ahmed et al. (2012) investigated the reciprocity between self-concept and anxiety in mathematics and found that lower mathematics self-concept leads to higher mathematics anxiety. In addition, Meece et al. (2006) established a positive association between math self-concept and math achievement, indicating that students with higher levels of self-concept tend to perform better in mathematics. This relationship suggests that individuals who possess a strong belief in their mathematical abilities are more likely to approach mathematical tasks with confidence, persistence, and a growth mindset, leading to improved performance outcomes.

We intended to answer following research questions:

1. What are the relationships between mathematics performance and student noncognitive characteristics (i.e., mathematics anxiety, mathematics self-concept, and emotional intelligence)?
2. Does mathematics self-concept mediate the relationship between mathematics anxiety and mathematics performance, and does this apply to both groups of students - those with and without MLD?

Research Methodology

Participants

Participants were recruited from the 3rd, 4th, and 5th grades in two ordinary public elementary schools in Shanghai, People's Republic of China. This project sampled 340 elementary students (179 girls and 153 boys) from 9 different classrooms. Among them, 123 students are third graders from three classrooms, 97 students are fourth graders from three classrooms, and 112 students are fifth graders from three classrooms. No individual within the sample received special education services or had documented brain injury or behavioral problems. Student scores in three recent mathematics mid-term and final tests were collected; each test was proctored within one hour, and three distinct mathematics scores (discussed further in the methods section) were computed from test results.

Using standardized diagnostic criteria (Cai et al., 2013), MLD group students are individuals with standard scores in the standardized mathematics test—as well as in three recent math tests—which ranked at the bottom 20% of the class. Control group students are those with standard scores in standardized mathematics tests—as well as in three recent math tests—which ranked in the top 20% of the class. There were two exclusion criteria. Firstly, students with Motivation Adaption Assessment Test (MAAT) scores (Zhou, 1991) lower than two standard deviations were excluded; the MAAT tested student learning motivation. Secondly, intellectually impaired students were also excluded based on daily observations of mathematics teachers. No student's IQ score was below 80. There were no students excluded from MAAT and IQ tests.

We received the permission from all students' parents. The two groups had no significant difference in learning motivation but had significant difference in terms of mathematics scores. The mathematics achievements of both groups had no gender difference ($t = 1.65$, $p = 0.10$).

Measures

Mathematics Achievement

Three measures of mathematics were administered: calculation fluency, numerical operations, and math reasoning (problem solving). **Calculation fluency** was adopted from WIAT-III (Wechsler, 2009) and included two subtests: addition fluency and subtraction fluency. In each subtest, children were asked to solve as many additions or subtractions as possible within a 60-second time limit. Each subtest included two pages (24 problems per page). A participant's score was the total number of addition and subtraction problems completed within the time limit (96 problems total). **Numerical operation** was also adopted from WIAT-III (Wechsler, 2009) and required children to solve mathematical operations. The task contains 38 items. **Mathematics reasoning** was assessed with the math standard achievement test (MSAT), which was based on the National Standards for Mathematics Curriculum of China. The test included 30 items: 26 items were multiple choice questions, and 4 items were fill-in questions (e.g., *Based on the map you have in front of you, how long will it take Fang to go to the bookstore, if she first passes by Hong's home?*).

The Trait Emotional Intelligence Questionnaire-Child Form (TEI)

TEI contained 75 short statements with 5-point Likert scale response options (Mavroveli et al., 2008). The respondents were asked to rate each statement (e.g., "*I always find the words to show how I feel*") using a 5-point scale that ranged from strongly disagree to strongly agree. The TEI comprises nine facets (i.e., adaptability, affective disposition, emotion expression, emotion perception, emotion regulation, low impulsivity, peer relations, self-esteem, and self-motivation) and it has demonstrated satisfactory reliability and validity in children between 8 and 12 years (Mavroveli et al., 2008; Mavroveli & Sanchez-Ruiz, 2011). The Chinese TEI was prepared with a user interface appropriate to the age of the respondents and pretested on a small group of subjects to assess comprehension and ease of answering. For each participant, scores on the nine facets and on global trait EI were computed. In this sample, Cronbach's alpha was 0.93.

Mathematics Anxiety Scale for Children (MASC)

MASC contains 22 items. Children rated these items according to a 4-point scale in terms of how much anxiety they experienced. A rating of four points represents *extremely nervous*, three points *very nervous*, two points *a little nervous*, and one point represents *not nervous* (Chiu & Henry, 1990). The total score on these 22 items indicates the student's mathematics anxiety level. Moreover, MASC includes four different factors. Factor one was defined by eight of the items which were relevant to the *evaluation of mathematics learning*. Factor two was defined by six items; these items were *concerned* with the activity or process of learning mathematics. Factor three was defined by five items which related to *solving math problems* in a non-testing situation. For example, item two ("*Reading and interpreting graphs or charts*"), item three ("*Listening to another student explain a math problem*"), item nine ("*Picking up a math book to begin working on a homework assignment*"), item ten ("*Working on a mathematical problem*"), and item 14 ("*Being told how to interpret mathematics statements*"). Factor three was labeled as mathematics problem solving. Factor four was relevant to mathematics teacher anxiety.

Theoretical Framework and Procedures

A multivariate analysis was employed within the Structural Equation Modeling (SEM) framework to explore the relationship between math anxiety and math achievement and between the TEI and math achievement. A full sample (*n* = 326) was used to fit the multivariate structure. In subsequent analytical steps, the model was fit by MLD (*n* = 75) and non-MLD group (*n* = 251). The coefficient of determination (R^2) was used to evaluate the model fit. To further explore the data, a mediation model was adopted with the full sample (*n* = 326). In the next phase of the analysis, the mediation model was implemented to fit the MLD (n = 75) and non-MLD group (n = 251) data. The comparative fit index (CFI; cutoff > .90; Bentler, 1990) and the standardized root mean square residual (RMSEA; cutoff < .08; Bentler, 1995) were used to evaluate the mediation model fit. The lavaan package (Rosseel, 2012) was utilized for data analysis using the software R (R Core Team, 2020).

Results

The current study aims to examine the effects of two independent variables on three dependent variables within a multivariate framework using SEM. The two independent variables are MA and TEI, and the three dependent variables are numerical operation, calculation fluency, and mathematics reasoning.

A full sample of 326 was employed to explore the structural model. Bootstrapping was employed with 2000 iterations to estimate the 95% confidence interval for standardized coefficients. Path coefficients indicated that MA significantly predicted calculation fluency (β = -0.14, 95% CI [-0.25, -0.05] and math reasoning (β = -0.11, 95% CI [-0.21, -0.01], and TEI significantly predicted numerical operation (β = -0.17, 95% CI [0.07, 0.26]; see Figure 1 for path coefficients), controlling for grade and gender. The R^2 values were 0.52, 0.33, and 0.40 for numerical operation, calculation fluency, and math reasoning, respectively, indicating that 52%, 33%, and 40% of the variance in the numerical operation, calculation fluency, and math reasoning was explained by MA and TEI (see Table 1).

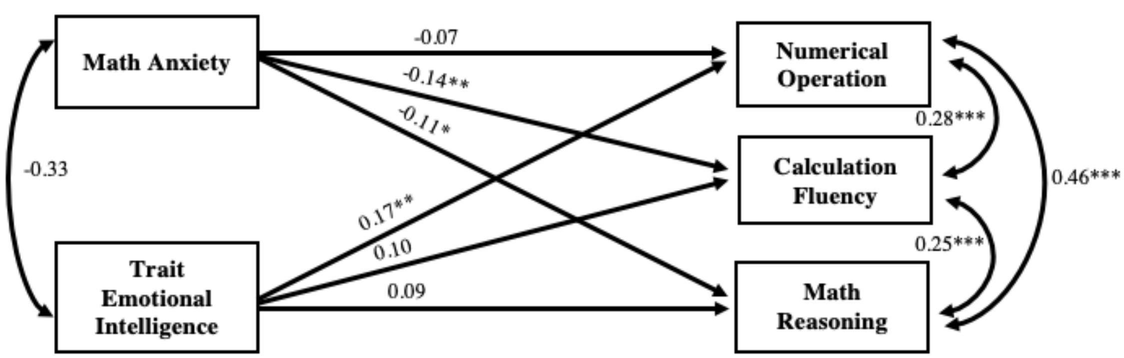

Figure 1. Baseline Model for Full Sample (N = 326)
*$p < 0.05$, **$p < 0.01$, ***$p < 0.00$

Table 1. Baseline Model Regression Coefficients for Full Sample (N = 326)

Regressions	Estimate	*SE*	*Z*	*p*
Numeric Operation ~ MA	**-0.07** [-0.15, -0.01]	0.04	-1.64	0.10
Calculation Fluency ~ MA	**-0.14** [-0.25, -0.05]	0.05	-2.83	< 0.01
Math Reasoning ~ MA	**-0.11** [-0.21, 0.01]	0.05	-2.24	< 0.05
Numeric Operation ~ TEI	**0.17** [0.07, 0.26]	0.05	3.46	< 0.01
Calculation Fluency ~ TEI	**0.10** [-0.02, 0.20]	0.06	1.71	0.09
Math Reasoning ~ TEI	**0.09** [-0.02, 0.19]	0.05	1.72	0.09

After further examining the model, the results from group without MLD (n = 251) revealed that MA significantly predicted calculation fluency (β = -0.15, 95% CI [-0.26, -0.03]) and math reasoning (β = -0.10, 95% CI [-0.19, -0.02]), and TEI significantly predicted math reasoning (β = 0.10, 95% CI [0.01, 0.19]) and numerical operation (β = 0.13, 95% CI [0.03, 0.24]) while controlling for grade and gender. The R^2 values for the model without MLD group were 0.48, 0.38, and 0.43 for numerical operation, calculation fluency, and math reasoning, respectively, indicating that 48%, 38%, and 43% of the variance in the numerical operation, calculation fluency, and math reasoning was explained by MA and TEI. Interestingly, controlling for grade and gender, the results from group with MLD (n = 75) showed that TEI was a significant predictor to predict numerical operation (β = 0.29, 95% CI [0.09, 0.50]; see Table 2). The R^2 values for the model without MLD group were 0.57, 0.34, and 0.60 for numerical operation, calculation fluency, and math reasoning, indicating that 57%, 34%, and 60% of the variance in the numerical operation, calculation fluency, and math reasoning was explained by MA and TEI. The overall result suggested that there was a group difference in terms of using MA and TEI to predict numerical operation, math reasoning, and calculation fluency.

Table 2. Baseline Models for MLD and No MLD Groups

	Group: MLD				Group: No MLD			
Regression	Estimate	*SE*	*Z*	*p*	Estimate	*SE*	*Z*	*p*
Numeric Operation ~ MA	**0.06** [-0.12, 0.23]	0.09	0.69	0.49	**-0.09** [-0.18, 0.00]	0.05	-1.81	0.07
Calculation Fluency ~ MA	**-0.08** [-0.31, 0.14]	0.12	-0.71	0.48	**-0.15** [-0.26, 0.03]	0.06	-2.58	< 0.05
Math Reasoning ~ MA	**0.03** [-0.19, 0.26]	0.12	0.24	0.81	**-0.10** [-0.19, -0.02]	0.04	-2.42	< 0.05
Numeric Operation ~ TEI	**0.22** [-0.01, 0.43]	0.11	1.98	0.05	**0.13** [0.03, 0.24]	0.05	2.54	< 0.05
Calculation Fluency ~ TEI	**0.29** [0.09, 0.50]	0.10	2.81	< 0.01	**0.03** [-0.08, 0.15]	0.06	0.43	0.67
Math Reasoning ~ TEI	**-0.10** [-0.32, 0.10]	0.11	-0.95	0.34	**0.10** [0.01, 0.19]	0.05	2.28	< 0.05

Subsequently, we implemented a mediation model using maximum likelihood estimation in SEM to explore the underlying mechanisms of the relationship between the two independent variables and three dependent variables (n = 326) with self-concept selected as a mediator. Four direct paths from MA to self-concept, from self-concept to numeric operation, from self-concept to math reasoning, and from self-concept to calculation fluency were specified. Certain fit statistics, such as RMSEA, indicated a fit below the desired level of acceptability in our model ($\chi^2(14)$ = 491.91, $p < 0.05$; CFI = 0.97; RMSEA = 0.13(90% CI [0.09, 0.18]); notably, the small sample size may have led to an artificially larger RMSEA value (Kenny et al., 2015), so we include the 90% confidence interval. Figure 2 displays standardized path coefficients. The results indicated that MA had a significant direct effect on self-concept (β = -0.44, 95% CI [-0.55, -0.31]). The direct effects from self-concept to numerical operation (β = 0.31, 95% CI [0.23, 0.39), to calculation fluency (β = 0.27, 95% CI [0.17, 0.37]), and to math reasoning (β = 0.28, 95% CI [0.19, 0.37]) were also significant (see Figure 2). Using 2000 bootstrapped samples, significant indirect effects from MA to numerical operation (β = 0.31, 95% CI [0.23, 0.39]), calculation fluency (β = 0.27, 95% CI [0.17, 0.37]), and math reasoning (β = 0.28, 95% CI [0.19, 0.37]) through self-concept were observed, while controlling for grade and gender. The full mediation model structure was supported.

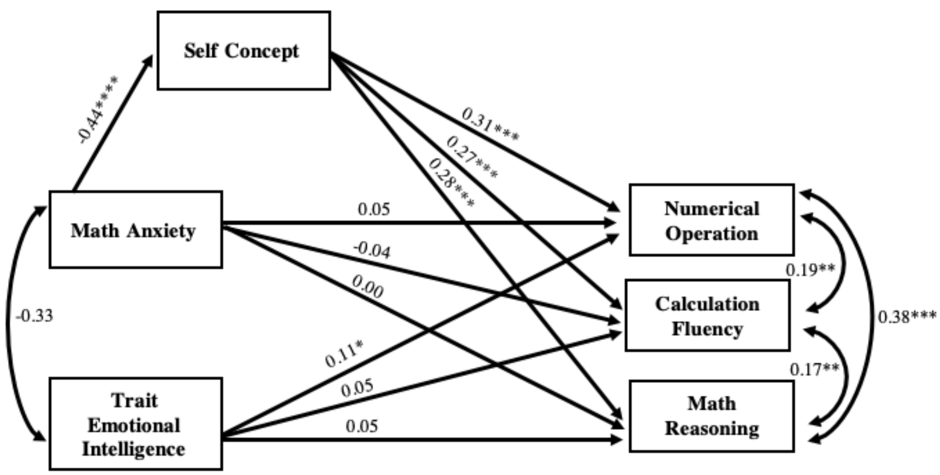

Figure 2. Mediation Model for Full Sample (N = 326)

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Furthermore, MLD group was used to further explore the mediation structure. Both models were controlled for grade and gender. In the group without MLD (n = 251), the model demonstrated a poor fit of the data ($\chi^2(4)$ = 18.465, $p < 0.05$; CFI = 0.98; RMSEA = 0.12 (90% CI [0.07, 0.18]). The results indicated that MA has a significant direct effect on self-concept (β = -0.41, 95% CI [-0.55, -0.24]); see Table 3). In addition, the direct effects from self-concept to numerical operation (β = 0.25, 95% CI [0.16, 0.34]), to calculation fluency (β = 0.26, 95% CI [0.15, 0.36]), and to math reasoning (β = 0.19, 95% CI [0.11, 0.26]) were significant. Significant indirect effects from MA to numerical operation (β = 0.00, 95% CI [-0.10, 0.10]), calculation fluency (β = -0.05, 95% CI [-0.16, 0.05]), and math reasoning (β = -0.04, 95% CI [-0.12, 0.04]) via self-concept were identified. The results were consistent with the model using the full sample size. In the group with MLD (n = 75), the model fit the data relatively well $\chi^2(4)$ = 7.974, $p > 0.05$; CFI = 0.97; RMSEA = 0.12 (90% CI [0.00, 0.23]). Notably, only the partial mediation from MA to numerical operation through self-concept was supported because a significant direct path (β = 0.22, 95% CI [0.06, 0.36]) and a significant indirect path (β = -0.18, 95% CI [-0.30, -0.09]) from MA to numerical operation were observed (see Table3).

In conclusion, the full mediation structure was presented in the non-MLD group, while the partial mediation structure was presented in the MLD group. There exist significant relationships between predictors and the mediator, and significant relationships between the mediator and the outcome variables (indirect effects).

Table 3. Models for MLD and No MLD Groups with Self Concept as a Mediator

	Group: MLD				Group: No MLD			
Regression	**Estimate**	***SE***	***Z***	***p***	**Estimate**	***SE***	***Z***	***p***
Self Concept ~ MA	**-0.47** [-0.64, -0.27]	0.09	-4.94	< 0.001	**-0.41** [-0.55, -0.24]	0.08	-5.33	< 0.001
Numeric Operation ~ Self Concept	**0.39** [0.25, 0.51]	0.07	5.64	< 0.001	**0.25** [0.16, 0.34]	0.05	5.20	< 0.001
Calculation Fluency ~ Self Concept	**0.19** [-0.02, 0.40]	0.11	1.78	0.08	**0.26** [0.15, 0.36]	0.05	4.83	< 0.001
Math Reasoning ~ Self Concept	**0.05** [-0.16, 0.24]	0.11	0.49	0.63	**0.19** [0.11, 0.26]	0.04	4.69	< 0.001
Numeric Operation ~ MA	**0.22** [0.06, 0.36]	0.07	3.01	< 0.01	**0.00** [-0.10, 0.10]	0.05	0.03	0.98
Calculation Fluency ~ MA	**-0.01** [-0.27, 0.27]	0.14	-0.03	0.98	**-0.05** [-0.16, 0.05]	0.05	-1.03	0.31
Math Reasoning ~ MA	**0.05** [-0.19, 0.28]	0.12	0.40	0.69	**-0.04** [-0.12, 0.04]	0.04	-0.91	0.37
Numeric Operation ~ TEI	**0.17** [-0.05, 0.37]	0.10	1.64	0.10	**0.09** [-0.01, 0.19]	0.05	1.82	0.07
Calculation Fluency ~ TEI	**0.26** [0.07, 0.48]	0.11	2.53	< 0.05	**-0.02** [-0.12, 0.10]	0.05	-0.30	0.76
Math Reasoning ~ TEI	**-0.11** [-0.32, 0.08]	0.11	-1.01	0.31	**0.07** [-0.02, 0.16]	0.05	1.62	0.11

Conclusions and Implications

The study found that for students both with and without MLD, mathematics outcomes were impacted by low TEI scores. Mathematics anxiety was found to have a negative impact on math performance, and the relationship was partially mediated by mathematics self-concept. The findings emphasize the importance of addressing non-cognitive factors, such as mathematics anxiety and emotional intelligence, to improve the mathematics performance of students with and without MLD. The findings highlight the negative impact of mathematics anxiety on mathematics performance and the importance of addressing low mathematics self-concept to improve mathematics performance. Therefore, it is important for educators to address mathematics anxiety and provide support to individuals who experience it in order to help them develop positive attitudes toward mathematics and to improve mathematics performance. The findings have important implications for educators and policymakers who should consider non-cognitive factors in designing interventions to improve mathematics performance, particularly for students with MLD.

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