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The Relationship between Students' Mathematics Learning Environment, Attitude and Achievement: A Mediation Model

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Abstract: *This study investigates the relationship between the perceived mathematics learning environment (MLE), mathematics learning attitude (MLA), and mathematics academic achievement (MAA) among students in grades 7 to 9. The adapted Mathematics Learning Environment Scale and Mathematics Learning Attitude Scale were used for investigation. The research findings indicate a significant positive impact of MLE and MLA on MAA. Additionally, MLA plays a mediating role in the impact of MLE on MAA. These findings can help educators improve mathematics academic achievement by creating a conducive learning environment and cultivating positive attitudes towards mathematics.*

Keywords: *Mathematics learning environment, Mathematics learning attitude, Mathematics academic achievement*

1. Introduction

Attitude originated from social psychology[1]. With the rise of positive psychology in the 21st century, more and more attention has been paid to the role of positive attitudes in education[2]. Many studies have shown that mathematics learning attitude (MLA) is a key factor for students' success in mathematics learning[3]. A positive attitude towards mathematics is mutually beneficial to students' mathematics achievement[4].

Learning environment has been widely studied due to its involvement in students' achievement and emotions[5]. The quality of learning environment is an important factor affecting students' outcomes [6].When students perceive a good classroom environment, their learning will be better[7].The perceived learning environment of students can predict their academic achievement[8].The mathematics learning environment (MLE) made up for the negative impact of gender and low SES on students' mathematics achievement[9].

Research has found that there is a positive correlation between students' perception of classroom environment and their learning attitude[10], and the degree of correlation between the two varies depending on regional differences[11]. A positive learning environment can bring greater student participation and motivation, thus improving academic achievement[12]. The classroom environment promotes learning motivation and classroom participation[13] , and the higher students' participation, the better their academic performance [14].

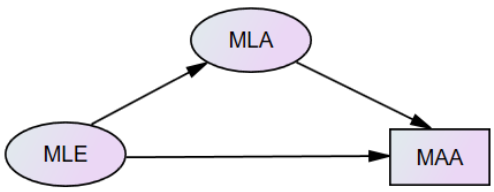

Figure 1: Preliminary mediation model of this study.

Based on the above, we can know that students' mathematical learning environment (MLE) and mathematical learning attitude (MLA) play a crucial role in their mathematical academic achievement (MAA).However, there is limited understanding of how these factors interact to influence MAA. Especially whether MLA plays a mediating regulatory role in the impact of MLE on MAA has not been studied yet. Therefore, this study aims to investigate the relationship between MLE, MLA, and MAA,

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and to test a mediation model (see Figure 1) that explains this relationship.

1.1. Research questions

This paper explores the relationship between MLE, MLA, and MAA, with a focus on the mediating effect of MLA. Through questionnaire survey, SPSS and AMOS software are used to conduct correlation analysis, path analysis and mediating effect test on the data, and the following research questions will be discussed:

Question 1: Is the MAA of middle school students related to the MLE and MLA? Can these two serve as predictive variables of MAA?

Question 2: Does MLA have a mediating effect in the relationship between MLE and MAA?

1.2. Hypotheses

Based on reviewing relevant literature and considering the research objectives, this study proposes the following research hypotheses.

H1:MLE significantly positively affects MAA.

H2:MLA significantly positively affects MAA.

H3:MLE significantly positively affects MLA.

H4:MLA is a mediator variable between MLE and MAA.

1.3. Definition of Terms

1.3.1. Mathematics Learning Environment(MLE)

The study of learning environment originated from Lewin's field theory[15]. The theory believes that people's behavior is the result of the combined action of environment and people's internal factors, which can be represented by the function B=f (P, E).In addition, two terms “alpha press” and “beta press” are proposed in field theory. The former represents the environment observed by external observers, while the latter represents the environment perceived by milieu inhabitants.

The perceived learning environment is defined as “the social, psychological, and pedagogical contexts in which learning occurs and which affect student achievement and attitudes”[16].This includes various aspects such as instruction quality, classroom climate, teacher-student interaction, peer relationships, and available resources that can impact students' motivation, engagement, and academic achievement[17-18] .

Research has shown that there are differences in individual’s perceptions, group’s perceptions, and external observer’s perception for the same environment[19].Nevertheless, Ellis, Malloy, Meece, and Sylvester found moderately strong correlations ($0.4<r<0.54$) between outside observer and student perceptions of the mathematics classroom environment[20]. Therefore, in this study, we used the method of student perception to measure MLE. At the same time, MLE is defined as the subjective experience of students in a mathematical learning setting, including their perceptions of social, psychological, and pedagogical.

1.3.2. Mathematics Learning Attitude(MLA)

Attitude is described as the tendency to respond to an object in a positive or negative way. Similarly, mathematics attitude is defined as the degree of positive or negative emotions related to mathematics[21-22]. As research deepens, attitude is defined as a tendency to evaluate a certain object based on three components: cognitions, affective reactions, and behavioural intentions[23]. Ajzen (1993) proposed the ABC Attitude Model[24],conceptualizing attitudes as three measurable mixtures, namely affect (A), behaviour (B) and cognition (C).

In this study, MLA is defined as a positive or negative evaluation tendency of students towards mathematics learning,which includes the three components of ABC: (1) Affect: mainly referring to emotions (e. g.,the enjoyment or anxiety that arises when learning mathematics as a subject that is interesting, dull, or difficult) and beliefs (e. g., confidence in learning the subject of mathematics) when learning mathematics; (2) Cognition here specifically refers to the perception of the usefulness of mathematics;(3)Behavior refers to students' behavioral tendencies in mathematics classrooms, which are related to their motivation to learn mathematics.Based on the above, the measurement of MLA in this study includes five variables, namely Confidence in Learning Mathematics (CM), Anxiety in Learning Mathematics (AM), Employment in Learning Mathematics (EM), Motivation to Learn Mathematics (MM), Perceived Value of Mathematics (VM).

2. Method

2.1. Participants and Collection of Data

Middle school students from Guangdong Province participated in this study. 302 samples were collected using a simple online random sampling method.Researchers required volunteers to fill out questionnaires and ensured that their privacy was protected, and the collected data was used only for research purposes. Effective sample 292 (effective rate 96.69%), of which grade 7 accounts for 33.56%, grade 8 accounts for 29.11%, and grade 9 accounts for 37.33%.

2.2. Instruments

The questionnaire distributed online consists of four parts and a total of 58 items. The first part is used to collect basic information of participants.The second part is Mathematics Learning Attention Scale (MLAS, 28 items), used to measure students' MLA.The third part is Mathematics Learning Environment Scale (MLES, 25 items), used to measure students' MLE; The fourth part uses self reporting to collect students' usual math exam scores to measure their MAA.

2.2.1. Mathematics Learning Environment Scale (MLES)

The earliest Learning Environment Inventory (LEI) originated from the Harvard Project Physics, which was developed by Walberg and Anderson (1968) to evaluate the learning environment in physics classrooms.This instrument still has a significant impact today[25] and the work of Walberg and Anderson valuable for studying learning environments[26]. Moos(1974) classified various aspects of the human environment into three dimensions: relationship (R), personal development (P) and system maintenance and change (S)[27], and further developed the Classroom Environment Scale (CES) based on these dimensions [28].LEI and CES quickly gained widespread application and provided a blueprint for later scale development.However, since these two scales mainly consider general classroom environmental factors, they do not take into account some personalized factors that affect the classroom environment. Therefore, Fraser (1986) designed a more personalized questionnaire: What Is Happening in This Class? (WIHIC)[29].WIHIC was later modified by Fraser, McRobbie and Fisher (1996) from the original 9-scale to 7-scale [30], which was successfully applied in research around the world, such as SingaporeK[31], Taiwan, and Australia[32].With the development of constructivism, Constructivist Learning Environment Survey (CLES) developed by Taylor, Fraser and Fisher (1997) has been applied to different regions and different disciplines[33].

The Mathematics Learning Environment Scale (MLES) used in this study is mainly adapted from WIHIC and CLES.To ensure that MLES is suitable for evaluating Chinese middle school students' perception of the mathematics classroom environment, six factors from WIHIC were selected. Since the 21st century, China's basic education mathematics curriculum reform has always advocated the connection between mathematics and real life. Therefore, the personal relevance in CLES was included in MLES.The MLES is presented in the form of a Likert 5-point scale, consisting of 7 factors and 28 items (see Table 1). After testing, the Cronbach's a of MLES is 0.930, indicating that the scale has very high reliability.

Table 1: Variables Description in MLES.

Variables	No. of Items	Source	Moos's Classification	Cronbach's a
Student Cohesiveness	4	WIHIC	R	0.622
Cooperation	4	WIHIC	P	0.674
Teacher Support	4	WIHIC	R	0.737
Equity	4	WIHIC	S	0.733
Involvement	4	WIHIC	R	0.715
Task Orientation	4	WIHIC	P	0.709
Personal Relevance	4	CLES	R	0.685
MLE(Total)	28			0.930

2.2.2. Mathematics Learning Attitude Scale (MLAS)

Based on the ABC Attitude Model, this study identified the five components of MLA as CM, AM, EM,MM and VM. According to Tapia and Marsh, these are the main components of mathematics attitudes[34].Therefore, this study developed the Mathematics Learning Attitude Scale (MLAS) based on these five components. Considering content validity, MLAS is mainly adapted from Fennema Sherman Math Attention Scales (FSMAS;1976)[35] and the student questionnaire of Trends in International Mathematics and Science Study(TIMSS; 2003).The final MLAS is a 5-point Likert scale with 25 items, and Cronbach's Alpha reliability score is 0.826. The Cronbach's Alpha reliability scores for each subscale range from 0.52 to 0.815, which is an acceptable level of reliability as a subscale, according to Abe and Gbenro [36].(Table 2)

Table 2: Variables Description in MLAS.

Variables	No. of Items	ABC Attitude Model	Cronbach's a
Confidence in Learning Mathematics(CM)	6	Affect	0.542
Anxiety in Learning Mathematics(AM)	4	Affect	0.815
Enjoyment in Learning Mathematics(EM)	5	Affect	0.673
Motivation to Learn Mathematics(MM)	5	Behaviour	0.615
Perceived value of mathematics(VM)	5	Cognition	0.627
MLE(Total)	25		0.826

3. Results

3.1. Correlation analysis among Students' Mathematics Learning Environment, Attitude and Achievement

To explore the direction and degree of correlation between variables, this study first conducted correlation analysis in SPSS.Table 3 shows the results of the correlation analysis. From Table 3, it can be seen that MAA is significantly positively correlated with MLE and MLA ($p<0.01$), with correlation coefficients of 0.790 and 0.667, respectively. MLE and MLA are also significantly positively correlated ($r=0.610, p<0.01$).According to Cohen (1988), $r \geqslant 0.5$ indicates high correlation. Therefore, it can be concluded that there is a strong pairwise positive correlation between MAA, MLE, and MLA.

Table 3: Correlations among variables in the measurement model

Variable	SC	Co	TS	Eq	In	TO	PR	MLE	CM	AM	EM	MM	VM	MLA	MAA
SC	1														
Co	.692**	1													
TS	.726**	.696**	1												
Eq	.704**	.711**	.756**	1											
In	.657**	.704**	.715**	.707**	1										
TO	.688**	.719**	.688**	.747**	.716**	1									
PR	.501**	.472**	.492**	.525**	.500**	.566**	1								
MLE	.846**	.855**	.871**	.883**	.859**	.875**	.670**	1							
CM	.200**	.205**	.259**	.236**	.329**	.311**	.287**	.310**	1						
AM	0.04	0.09	0.111	0.078	0.109	0.112	0.075	0.106	.594**	1					
EM	.408**	.444**	.501**	.456**	.495**	.516**	.373**	.546**	.656**	.624**	1				
MM	.446**	.482**	.454**	.527**	.466**	.529**	.332**	.554**	0.11	-.265**	.210**	1			
VM	.567**	.574**	.617**	.611**	.566**	.615**	.443**	.682**	.353**	.305**	.550**	.319**	1		
MLA	.458**	.497**	.542**	.526**	.548**	.579**	.422**	.610**	.799**	.695**	.891**	.340**	.719**	1	
MAA	.630**	.655**	.702**	.711**	.688**	.683**	.566**	.790**	.443**	.230**	.614**	.484**	.593**	.667**	1

Note: ** $p< 0.01$; SC=Student Cohesiveness; Co=Cooperation; TS=Teacher Support; Eq=Equity; In=Involvement; TO=Task Orientation; PR=Personal Relevance; MLE=Mathematics Learning Environment; CM=Confidence in Learning Mathematics; AM=Anxiety in Learning Mathematics; EM=Enjoyment in Learning Mathematics; MM=Motivation to Learn Mathematics; VM=Perceived Value of mathematics; MLA=Mathematics Learning Attitude; MAA=Mathematics Academic Achievement.

Specifically, the four MLE factors of teacher support, equity, investment, and task orientation have a stronger correlation with MLA ($0.542<r<0.579, p<0.01$).Further analysis revealed that the MLE factor of task orientation was highly correlated with the three MLA factors of EM, MM and VM ($0.516<r<0.615$,

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p<0.01).The VM factor of MLA is highly correlated with the 6 factors (except for personal relevance out of the 7 factors) of MLE (0.566<r<0.617, p<0.01). This indicates that task orientation and VM play a crucial role in these variables.

It should be noted that there is no significant correlation between AM and MLE, but a positive correlation with CM (r=0.594, p<0.01), and a negative correlation with MM (r=-0. 265, p<0.01).Due to the fact that all items measuring AM are scored in reverse (the lower the score, the better the math learning attitude), the relevant directions here need to be specifically explained.Under the premise of reverse scoring, there is a positive correlation between AM and CM, indicating that the more confident students are in learning mathematics, the less anxiety they will experience.Similarly, there is a negative correlation between AM and MM, indicating that the stronger a student's motivation to learn mathematics, the more anxiety they will experience.

3.2. Path analysis among Students' Mathematics Learning Environment, Attitude and Achievement

To verify the hypotheses proposed in this study, a mediation model (Figure 2) was analyzed using standardized regression coefficients and significance test results in AMOS 26.0. The MLE served as the independent variable, MAA as the dependent variable, and MLA as the mediating variable in the model.

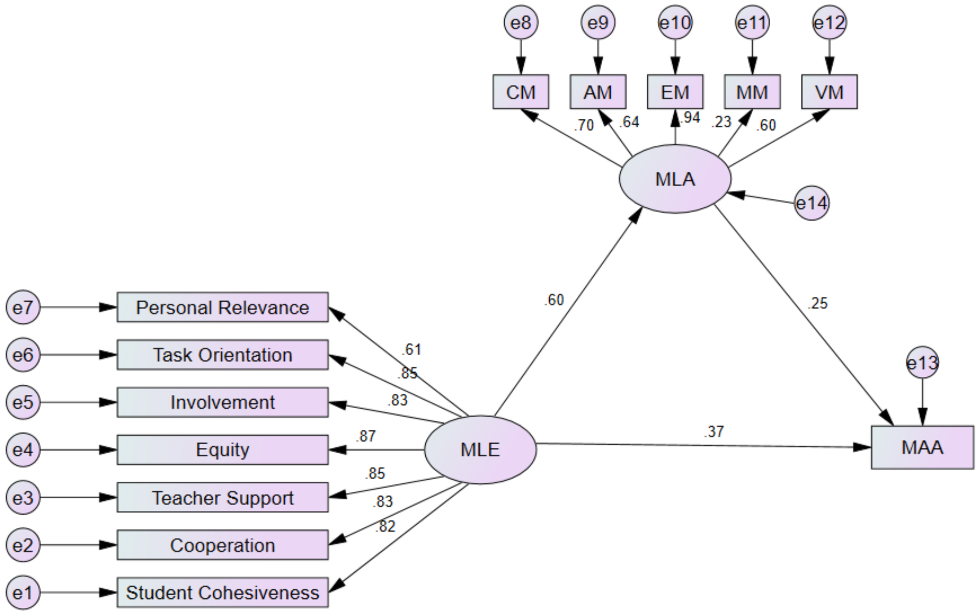

Figure 2: Schematic diagram of mediation model.

Table 4 presents the results of the regression coefficient test. From Table 4, it can be seen that MLE has a significant positive impact on MAA, with standardized regression coefficients β= 0.374, and the significance test result p<0.001, accepting hypothesis H1. MLA also has a significant positive impact on MAA, with standardized regression coefficients β=0.248, and the significance test result p<0.001, accepting hypothesis H2. MLE has a significant positive impact on MLA, with standardized regression coefficients β=0.596, and the significance test result p<0.001, accepting hypothesis H3.

Table 4: Regression coefficient test of structural equation model.

Hypothesis	Paths	b	β	SE	t	p	Findings
H1	MLE→MAA	7.030	0.374	1.274	5.518	<0.001	Accept
H2	MLA→MAA	4.309	0.248	1.190	3.621	<0.001	Accept
H3	MLE→MLA	0.645	0.596	0.076	8.491	<0.001	Accept

In order to more accurately compare the relationship between the magnitude of each effect in the model, the total effect, direct effect and indirect effect in the model were calculated by effect decomposition, and the bootstrap method was used to sample 5000 times for bias correction. Table 5 shows the decomposition results of the mediation model effects. Results show that the direct effect of MLE on MAA is 0.374, the indirect effect of MLE on MAA through MLA is 0.148. The proportion of indirect effects to the total effect is 0.148/0.522=28.35%.The significance test result of mediating effect

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is p=0.003<0.01, and the 95% confidence interval does not contain 0. Therefore, the hypothesis of mediating effect is valid and H4 is verified.

Table 5: Decomposition of mediation model effects.

Type	Effects	SE	95% Lower	95% Upper	p
Total Effects	0.522	0.098	0.455	0.799	0.007
Direct Effects	0.374	0.104	0.251	0.636	0.007
Indirect Effects	0.148	0.037	0.095	0.222	0.003

4. Discussion and Conclusion

The main purpose of this study is to investigate the relationship between MLE, MLA, and MAA. The results of correlation analysis and path analysis both indicate a significant correlation between MLE, MLA, and MAA.Additionally, MLE and MLA can predict MAA.

Firstly, MLE has a significant positive impact on MAA, meaning that the better students perceive the mathematics learning environment, the higher their mathematics academic achievement,which is consistent with the previous research results of Fraser and Fisher [8].When the classroom environment is cohesive, targeted, teacher-student relationship is harmonious, students cooperative learning and full involvement, students' MAA is generally good.

Secondly, MLA has a significant positive impact on MAA. The more positive a student's attitude towards mathematics learning, the higher their academic achievement in mathematics. The relationship between these two has been established in many literature [37-38]. A positive attitude towards mathematics learning includes recognizing the value of mathematics, having confidence in learning mathematics well, and enjoying the process of learning mathematics, and so on. These non-intelligent factors play an important regulatory role in students' learning behavior, which in turn is beneficial for their academic achievement.

Thirdly, MLE has a significant positive impact on MLA. This is consistent with the research results of Ogbuehi and Fraser[10]. Students perceive that the more ideal the learning environment, the more likely they are to develop a positive learning attitude.This further indicates that MLE is one of the key factors in the formation and change of MLA. Specifically, this study found that four MLE factors (teacher support, equity, investment, and task orientation) have a particularly prominent impact on MLA.To some extent, this shows that the mathematics classroom which is more inclined to construction is more closely related to students' positive attitude towards mathematics learning.

Finally, the mediating effect test confirmed that MLA is the mediator between MLE and MAA.That is to say, the perceived mathematics learning environment of students affects their attitudes towards mathematics learning, thereby affecting their academic achievements in mathematics.This result is similar to the research findings of Kloosterman[39]. Kloosterman found that the impact of classroom atmosphere on students' learning outcomes is mediated by motivational variables. In this study, motivation to learn mathematics (MM) was included in MLA.This study found that MAA plays a mediating role between MLE and MAA, which has not yet appeared in previous studies. This result better reveals the mechanism by which the MLE affects MAA. It has strong theoretical and practical significance.

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