

# Research on the Influence of Teacher Variables on Students' Mathematical Achievements

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**Abstract.** *Based on the TIMSS2015 data, this study applied a hierarchical linear model to explore the influence of teacher variables on students' mathematics scores. Teacher variables were composed of teacher characteristic variables, teacher teaching variables, and teacher professional development variables. The teacher's characteristic variables were teaching age, gender, education, mathematics major, and mathematics education. Teachers' teaching variables were teaching expectations, teaching cooperation, teaching enthusiasm, classroom discussion, multimedia use, attention to homework, and emphasis on exams. Teacher professional development variables had mathematics knowledge training, mathematics education training, and mathematics curriculum training. Multi-layer linear analysis found that in the teacher's characteristic variables, the teacher's teaching age, gender, education, and mathematics major have a significant effect on the students' mathematics scores; In the teacher's teaching variables, teachers' teaching expectations, teaching enthusiasm, class discussion, and multimedia use have a significant impact on students' mathematics scores. In the teacher professional development variables, participation in mathematics knowledge training and mathematics education training had a significant positive impact on students' mathematics scores.*

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## Problem

IN the evaluation of education quality, the learning effect of students has always been regarded as an important dimension to examine the effect of education. Among them, student achievement is one of the main indicators reflecting the effect of learning. Teachers are often considered to be the main factor affecting students' academic performance. Therefore, exploring the influence of teacher variables on students' academic performance through research has always been an essential research issue in educational research. The research of this problem can provide theoretical basis for improving students' learning, promoting the fair distribution of educational resources and the effective training of teacher education. It is a critical problem that has been continuously explored in the field of education.

Throughout the study of the influence of teacher variables on students' academic performance, it can be roughly divided into three categories. The first category was to study the influence of teacher characteristic variables on students' academic performance. The conclusions from this problem study are not the same. Huang and Xin found that teachers' gender, teaching age, education, and majors had no significant influence on students' academic performance (Huang & Xin, 2007); whereas Zhang found that teachers' gender, teaching age, and majors had a significant impact on student achievement (Zhang, 2012). The second category was to study the influence of teachers' teaching variables on students' academic performance. Teachers' teaching variables such as teacher's teaching plan, teaching behavior ( Peterson, et al., 1978) (class introduction, classroom language, classroom questions, classroom feedback, class waiting, class summary (Huang, et al., 2009; Zhou & Bao, 2012; Huang, 2016; Gao & Zhang, 2016; Cao & Yu, 2017), teaching strategy (Walsh-Cavazos, 1994), teaching attitude (B ilent & Erden, 2006) were important factors affecting students' academic performance, and some teachers' teaching variables such as teacher's teaching cooperation and classroom discussion had no significant influence on students' academic performance (Zhang, 2010). The third category was to study the influence of teacher professional development variables on students' academic performance. Zhang and Xin found that teachers' preparation methods, peer listening courses, and teaching and research participation had no significant effect on student achievement (Zhang, 2010); but Zhao and Yan found that teachers' preparation ways, training participation, peer-to-peer assessment, and teaching and research participation have a significant impact on student achievement (Zhao, et al., 2013). From these studies we can find that although the teacher variables were closely related to the students' academic performance, the conclusions had not yet reached a consistent agreement. There are two reasons for this: first, the measurement tools developed by the researchers were different, and the quality of the different measurement tools was directly related to the research results. Herlihy et al

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indicated that the validity and reliability of the teacher evaluation system affect the conclusion of the role of teacher variables on student achievement (Herlihy, et al., 2005); second, the statistical analysis methods of choice are different, previous studies have not considered the Hierarchical nesting structure of teacher and student data, and traditional regression analysis of teacher variables and student variables as independent variables may cause bias in the results.

The research on the influence of teacher variables on students' academic performance has made two new developments in recent years. On the one hand, the quality of the measuring tools has improved. With the international emphasis on basic education, the emergence of international evaluation projects such as TIMSS and PISA has largely contributed to the improvement of the quality of measurement tools, which has led researchers to pay attention to the development of measurement tools, thereby promoting the quality of measurement tools. On the other hand, the methods of education statistics have been improved and improved. Samples of social science research often come from different levels and units. The resulting data is usually multi-level nested data, and the general statistical methods have problems for the processing of nested data. Therefore, with the continuous development of social sciences, Hierarchical linear models have begun to enter the eyes of educational researchers. This model solves the limitations of traditional regression analysis in dealing with multi-level nested data and becomes a new method of educational statistics research. In this context, we try to directly use the eighth-grade measurement data in TIMSS2015, and use the Hierarchical Linear Model (HLM) to analyze the influence of teacher variables on students' mathematics scores. In order to find teacher variables that can promote student achievement, this study proposes the following three questions:

- *Question 1: How does the teacher characteristic variable affect student mathematics scores?*
- *Question 2: How does the teacher's teaching variable affect student mathematics scores?*
- *Question 3: What effect does the teacher's professional development variable have on student mathematics?*

## **Methodology**

### ***Data Selection***

The TIMSS project focuses on the development of students' mathematical and scientific academic achievements. TIMSS2015 collects information from students, teachers, and schools and encodes data by standardizing tests, questionnaires, and observing video lessons.

In TIMSS2015, a total of 45 countries participated in the eighth-grade standardized test. This study selected data from all countries participating in the eighth grade test and referred to it as TIMSS2015 data. All data is from the official TIMSS website (<http://timssandpirls.bc.edu/timss2015/>).

The subjects of this study were selected from the data of TIMSS2015. After eliminating the missing values of the relevant variables and satisfying at least 20 students per teacher, there are 45,321 student samples, the ratio of male to female is 1:1.4; the number of teachers is 1,806, and the ratio of male to female is 1:1.2.

## ***Variable Selection and Description***

Based on the data of TIMSS2015, this study explored the influence of teacher variables on students' mathematics scores based on the control of student variables in the nested relationship between students and teachers. Based on previous researches, the recent exploration of student family factors, teacher teaching factors and teacher professional development factors were introduced. At the same time, the TIMSS2015 standardized test questions and questionnaires were also adjusted and introduced into the study. Therefore, the dependent variable of this study is the student's mathematics score. The independent variable is divided into two layers:

- The first level is the student variables, which are divided into student background variables and learning motivation variables. Among them, student background variables: gender, age, family book collection, home computer, home learning desk, mobile phone, parental education (mother education, father education); learning motivation variables: mathematics learning interest, mathematics self-confidence. According to the Pearson correlation analysis, the mother's education and father's education are highly correlated, so the principal component analysis is used to form a new variable of parental education; other variables are not highly correlated. **Table 1** shows the definition and scoring of student variables.
- The second level is the teacher variable, which is divided into teacher characteristic variables, teacher teaching variables and teacher professional development. Among them, teacher characteristic variables: teaching age, gender, education, mathematics major, mathematics education major; teacher teaching variables: teaching expectation, teaching cooperation, teaching enthusiasm, classroom discussion, multimedia use, attention to homework, emphasis on exams; teacher profession development variables: mathematics knowledge training, mathematics education training, mathematics curriculum training. After Pearson correlation analysis, the teacher variables did not reach a high level of correlation. **Table 2** shows the definition and scoring method of teacher variables.

## ***Data Analysis***

Based on the data of TIMSS2015, this paper uses SPSS22.0 to organize data and use HLM6.08 for Hierarchical linear analysis. Taking the student's mathematics score as the dependent variable, without adding the independent variable, a zero model is established to test whether the sample data is suitable for Hierarchical linear analysis. On this basis, students and teacher variables are added to the previous model one by one to es-

Table 1. Definition and Scoring of Student Variables.		
Variable	Variable Description	Scoring Method
Student Variable		
Age	Calculated from the year of birth and month	Continuous type
Gender	Student gender	Discrete 2- point scoring, 1 for women, 2 for men
Family Collection	Family book collection	Discrete 5- point scoring, the higher the score, the more books
Home Computer	Is there a computer in the house?	Discrete 2- point scoring, 1 is yes, 2 is no
Home Desk	Does the student have a desk?	Discrete 2- point scoring, 1 is yes, 2 is no
Mobile Phone	Does the student have a mobile phone?	Discrete 2- point scoring, 1 is yes, 2 is no
Parental Education		(new variables formed by mother's education and father's education)
Math Interest	Do students like to learn mathematics?	Discrete 4- point scoring, the higher the score, the lower the mathematical interest
Mathematics Self-Confidence	Learning mathematics confidence	Discrete 4- point scoring, the higher the score, the lower the confidence

establish five models. For example, model 2 is based on model 1 to add student learning motivation variables, and finally form a complete Hierarchical linear model. On the basis of controlling student variables, the influence of teacher variables on students' mathematics scores is investigated.

The specific model is expressed as follows:

First level: student level

Dependent variable:

$$Y_{ij} = \beta_{0j} + r_{ij}$$

Second level: teacher level

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{teach year}) + \gamma_{02}(\text{gender}) + \dots + \mu_{0j}$$

subscripts "j" and "i" in the expression of the Hierarchical linear model represent the teacher's number and the student's individual number, respectively, and "ij" is the i<sup>th</sup> student in the j<sup>th</sup> class.  $\beta_{0j}$  represents the mathematical average of the students taught by the j<sup>th</sup> teacher. If the difference between teachers reaches a significant level, it is necessary to further analyze which factors of the teacher make the students' mathematics scores show significant differences.

The establishment of a Hierarchical linear model is presented in **Table 3**.

**Table 2. Teacher Variables of the Definition and Scoring.**

Variable	Variable Description	Scoring Method
<b>Teacher Variable</b>		
<b>Teacher Characteristic Variable</b>		
Teaching Age	Years of teaching	Continuous type
Gender		Consistent with student gender
Education		Discrete 7- point scoring, the higher the score, the higher the education
Mathematic Major	Whether the field of study is mathematics	Discrete 2- point scoring, 1 is yes, 2 is not
Mathematics Education	Is the field of study a mathematics education?	Discrete 2- point scoring, 1 is yes, 2 is not
<b>Teacher Teaching Variable</b>		
Teaching Expectation	Teachers' expectations for classroom teaching	Discrete 5- point scoring, the higher the score, the lower the expectation
Teaching Cooperation	Degree of cooperation between teachers	Discrete 4- point scoring, the higher the score, the lower the cooperation frequency
Teaching Passion	Degree of love for teaching	Discrete 4- point scoring, the higher the score, the lower the level of enthusiasm
Class Discussion	Frequency of discussion among students in the classroom	Discrete 4- point scoring, the higher the score, the lower the discussion frequency
Multimedia Use	Whether to use multimedia in classroom teaching	Discrete 2- point scoring, 1 is yes, 2 is not
Pay Attention To Homework	Frequency of arranging math assignments	Discrete 5- point scoring, the higher the score, the more important
Pay Attention To The Exam	Emphasis on classroom tests	Discrete 3- point scoring, the higher the score, and the less important it is.
<b>Teacher Professional Development Variable</b>		
Mathematical Knowledge Training	Whether to participate in mathematics knowledge training	Discrete 2- point scoring, 1 for participation, 2 for not participating
Mathematics Education Training	Whether to participate in mathematics education training	Discrete 2- point scoring, 1 for participation, 2 for not participating
Mathematics Course Training	Whether to participate in mathematics training	Discrete 2- point scoring, 1 for participation, 2 for not participating

## Results

According to the statistical principle of the Hierarchical linear model, in order to explore the influence of teacher variables on students' mathematics scores, the first is to establish a zero model to estimate the contribution of teacher-to-teacher differences and intra-teacher differences (student differences) to the total difference, if the difference

<b>Table 3. Establishment of Hierarchical Linear Model.</b>	
<b>Student Variable</b>	<b>Teacher Variable</b>
Zero Model	
Model 1	Student background variable: Gender, age, family book collection, home computer, home desk, mobile phone, parental education
Model 2	Students learn motivation variables: Mathematical learning interest, mathematics self-confidence
Model 3	Teacher feature variables: Teaching age, gender, education, mathematics major, mathematics education
Model 4	Teacher teaching variables: Teaching expectations, teaching cooperation, teaching enthusiasm, class discussion, multimedia use, attention to homework, and emphasis on exams
Model 5	Teacher professional development variables: Mathematical knowledge training, mathematics education training, mathematics course training

between teachers is significant, it is necessary to further analyze which teacher variables make the students' mathematics scores show significant differences. The zero model results are presented in **Table 4**.

It can be seen from **Table 4** that the intra-class correlation coefficient ICC of the student's math score is 0.68, which means that about 68.42% of the total difference in the student's math score is caused by the teacher variable. At the same time, when the ICC is greater than 0.138, the difference between groups is significant (Dedrick, et al., 2009). This indicates that there is a significant difference between teachers, that is, the difference in mathematics scores of different teachers has reached a significant level ( $p < 0.001$ ), which is consistent with previous empirical findings (Li & Ni, 2006).

Because of the significant differences among teachers, this study adds the three aspects of teacher variables to the second level of independent variables, and examines their influence on students' mathematics scores, thus providing some theoretical references for the improvement of teachers' teaching process. Due to space limitations, the full results of each model are listed in **Table 5**.

### ***The Influence of Teacher Characteristic Variables on Students' Mathematical Achievements***

**Table 4. Estimation of Differences between Teachers and within Teachers in Mathematics Scores.**

	Variance	Standard Error	Contribution Rate
Inter-Teacher	8,900.70	94.34	68.42%
Intra-Teacher	4,107.92	64.09	31.58%

Model 3 is to examine the impact of teacher characteristic variables on students' mathematical performance. The survey results showed: teacher's teaching age ( $b = 1.09$ ,  $p < 0.001$ ), gender ( $b = -8.98$ ,  $p = 0.025$ ), education ( $b = 48.84$ ,  $p < 0.001$ ), mathematics major ( $b = 12.20$ ,  $p = 0.005$ ). The impact on students' mathematics scores has reached a significant level. Compared with teachers with shorter teaching ages, teachers with longer teaching ages will have better mathematics scores for teachers who teach older classes. Female teachers have better math scores than those taught by male teachers. The higher the teacher's academic qualifications, the better the mathematics scores of the students in the taught class will be. Students in classes taught by non-mathematics teachers have higher math scores than those who were taught by teachers who graduated from mathematic major. In addition, the teacher characteristic variable explained 15.12% of the student's average math score difference.

### ***The Influence of Teachers' Teaching Variables on Students' Mathematical Achievements***

Model 4 includes the teacher's teaching variables based on Model 3, aiming to examine the influence of teacher's teaching variables on students' mathematics scores. The results of Model 4 indicate: teacher's teaching expectations ( $b = -23.53$ ,  $p < 0.001$ ), teaching enthusiasm ( $b = 9.72$ ,  $p = 0.002$ ), class discussion ( $b = 18.01$ ,  $p < 0.001$ ), multimedia use ( $b = -11.90$ ,  $p = 0.005$ ) has a significant impact on students' math scores. The higher the teacher's teaching expectation and the higher the frequency of multimedia use, the more helpful the mathematics scores of the students in this class. The higher the number of class discussions, the less effective the teaching. The teacher's enthusiasm for teaching has a negative predictive ability for students' mathematics scores. This may be due to the occurrence of the "Simpson's Paradox" or the poor original grades of the corresponding students of the teachers. The specific reasons still need further investigation and research. In addition, the teacher's teaching variables reduce the variance of students' mathematics scores to 6556.75, explaining 8.85% of the students' average math scores.

### ***The Influence of Teachers' Professional Development Variables on Students' Mathematical Achievements***



Model 5 is based on Model 4 and incorporates three variables of teacher professional development. The main examination is the influence of teacher professional development (mathematics knowledge training, mathematics education and mathematics training) on students' mathematics scores. The results of Model 5 analysis show that teachers' mathematics knowledge training ( $b = -9.98$ ,  $p = 0.041$ ) and mathematics education training ( $b = -14.15$ ,  $p = 0.005$ ) have significant influence on students' mathematics scores. The mathematics course training ( $b = 8.11$ ,  $p = 0.078$ ) had no significant effect on the student's mathematics scores. This shows that teachers' participation in mathematics knowledge training and mathematics education training will have a positive effect on classroom teaching, so that the average mathematics score of the students taught is higher. These three variables explain the student's average math score difference of 1.13%.

## Conclusion and Discussion

Teachers are a pivotal factor influencing students' learning outcomes. The study found that, in overall, the addition of teacher variables has led to a significant decline in teacher variability. The teacher characteristic variable explained 15.12% of the difference in the average mathematics score of the students; the teacher teaching variable explained 8.85% of the difference in the average mathematics score of the students; the teacher professional development variable explained 1.13% of the difference in the average mathematics score of the students. Specifically, the results of each variable's impact on student mathematics are also presented in Table 5. These findings provide a basis for improving teachers' classroom teaching, strengthening teachers' professional development, and formulating relevant educational policies.

### *The Teacher's Teaching Age Has a Significant Impact on the Student's Mathematical Performance*

The results in **Table 5** show that the teacher's teaching age can have a significant predictive effect on students' mathematics scores. At the same time, in the literature that has explored the relationship between teachers' teaching age and students' mathematics scores, the conclusions are not completely consistent. For example, the relationship between teachers' teaching age and the student's learning is positively related, or only affects the student's learning to a certain extent, or the two do not matter (Huang & Xin, 2007; Zhang, 2012; Zhang, 2010; Xie, et al., 2008; Xin, et al., 2004). This shows that it is not the teacher's teaching age that has a direct impact on the students' mathematics scores. However, These factors affect teachers' understanding of the knowledge and grasp of the teaching process, making teachers with a longer teaching age pay more attention to the combination of mathematical knowledge and students' cognitive level and laws, thus showing that the students' mathematical results will be better. This shows that relevant education departments and schools should not exclude new teachers. They should pay more attention to the development trend of new teachers and provide more

**Table 5. The Influence of Teacher Factors on Students' Mathematics Scores.**

Hierarchical Linear Model	Variable	Fixed Effect		Random Effect		
		Regression Coefficient (B)	SEM	Inter-teachers	Intra-teachers	Interpretation Rate
Zero Model				8,900.70	4,107.92	
				7,196.61	3,822.46	19.15%/6.94%
Model 1		Student Background Variable				
	Gender	4.04***	0.70			
	Age	-6.92***	0.61			
	Family Book Collection	7.87***	0.31			
	Home Computer	7.31***	0.67			
	Home Desk	0.19	0.75			
	Mobile Phone	1.38	0.83			
	Parental Education	8.66***	0.50			
				8,474.77	3,204.58	/16.16%
Model 2		Student Learning Motivation Variable				
	Mathematical Learning Interest	-7.31***	0.39			
	Mathematics Self-Confidence	-25.23***	0.52			
				7,193.02	3,204.52	15.12 % /
Model 3		Teacher Characteristic Variable				
	Teaching Age	1.09***	0.18			
	Gender	-8.98*	4.01			
	Education	48.84***	3.36			
	Mathematic Major	12.20**	4.26			
	Mathematics Education	-5.25	3.82			
				6,556.75	3,204.09	8.85 % /
Model 4		Teacher Teaching Variable				
	Teaching Expectation	-23.53***	2.45			
	Teaching Cooperation	3.94	2.29			
	Teaching Passion	9.72**	3.11			
	Class Discussion	18.01***	2.33			

(Continued)

	Multimedia Use	-11.90**	4.20		
	Pay Attention To Homework	-1.13	1.84		
	Pay Attention To The Exam	-5.21	3.90		
				6,482.58	3,204.15 1.13 % /
	Teacher Professional Development Variable				
Model 5	Mathematical Knowledge Training	-9.98*	4.89		
	Mathematics Education Training	-14.15**	4.94		
	Mathematics Course Training	8.11	4.61		

Note: \*:  $P < 0.05$ , \*\*:  $P < 0.01$ , \*\*\*:  $P < 0.001$ . Interpretation rate refers to the percentage of decrease in teacher-to-teacher variation between teachers and teachers compared to the previous model after adding a new factor.

channels for the communication between new teachers and expert teachers. This is more conducive to narrowing the differences in teaching mathematics among students.

### ***Teacher's Academic Qualifications, Mathematics Knowledge Training, and Mathematics Majors Will Significantly Affect Students' Mathematics Scores***

The results in **Table 5** show that the higher the teacher's academic qualifications, the better the mathematics scores of the students in the taught class will be. Students who have participated in mathematics knowledge training have better math scores. Students in classes taught by non-mathematics teachers have higher math scores than those who were taught by teachers who graduated from mathematic major. Generally speaking, teachers with high academic qualifications have more knowledge of mathematics, and teachers who participate in mathematics knowledge training will have a better understanding of the methods of teaching mathematics. Comparing the influence of these three variables on students' mathematics scores, it is found that the mathematics knowledge and methods of teaching that teachers have had positive effects on students' mathematics scores. However, students in classes taught by non-mathematics teachers will have higher math scores. There may be two reasons for this. First, compared to non-mathematics teachers, those graduated from mathematic major have more knowledge, but their ability to teach mathematical knowledge to students in the corresponding grade is not as good as non-mathematics teachers. Second, the focus of the two types of teachers is different from that of the current basic education.

Teachers without background of mathematics major will pay more attention to the training of students' mathematics skills. Teachers of mathematics majors pay more

attention to the cultivation of students' mathematical thinking and mathematics thinking. However, for the improvement of students' test scores, it is better to train students' math skills. In addition, mathematics education is designed to help students master the mathematics, skills, ideas, and methods necessary for modern life and further learning. Therefore, in the process of teaching, teachers can not choose the sea tactics solely for the test results, nor can they focus only on the improvement of mathematical thinking and neglect the students' ability to accept at this stage. This shows that the cultivation of mathematical knowledge and skills, mathematical ideas and methods complement each other. Teachers should pay attention to this and organically combine them, so that students can understand the ideas and methods of mathematics in the training of mathematics knowledge and skills. At the same time, it is recommended that the education department or school regularly organize mathematics knowledge training to provide more ways for teachers to master the methods of teaching mathematics.

### ***The Influence of Teachers' Mathematics Education Major and Mathematics Education Training on Students' Mathematical Achievement***

The results in **Table 5** show that there is no significant difference in the mathematics scores of the students taught by the mathematics education majors and the non-mathematics education teachers. Students who have participated in mathematics education training have better math scores. Comparing the influence of two variables on students' mathematics scores, it is found that teachers master more mathematics education theories have positive effects on students' mathematics scores. However, the teaching effects of teachers in mathematics education and non-mathematics education teachers are not significantly different. The reason may be that the teaching of traditional mathematics education theory does not use actual cases as a carrier. Therefore, teachers cannot truly apply the learned education theory to classroom teaching, thus making the effect of educational theory learning greatly compromised. In view of this, it is recommended to combine educational theory and practice when teaching educational theory, to provide teachers with more practical teaching cases, or to answer the problems encountered by teachers in real teaching. In addition, the relevant education departments are also encouraged to regularly organize mathematics education training, and strive to implement education theory into classroom teaching.

Overall, the study has made some meaningful conclusions. At the same time, there are problems in this study, through the interpretation of inter-teacher variation. We find that the addition of teacher variables does cause a large decline in teacher-to-teacher variation, but there are still large inter-teacher differences. There are two reasons for this: First, the TIMSS study is conducted once every four years, so the student's math scores are not continuous, and the characteristics of the student's current math scores cannot be linked to the teacher factors at this time. Secondly, the student's academic performance itself is affected by many factors, and is also affected by the initial mathematics scores, and the students' mathematics scores themselves may also dif-

fer. Therefore, the influence of teacher variables on students' mathematics scores is still somewhat exploratory.

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