Role of Teacher Quality and Working Conditions in TIMSS 2019 Mathematics Achievement[*]

Öğretmen Kalitesi ve Çalışma Koşullarının TIMSS 2019 Matematik Başarısındaki Rolü

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ABSTRACT: This correlative study examined the role of teacher qualities and working conditions in 4th and 8th-grade Turkish students' mathematics achievement in TIMSS 2019. Teacher qualifications were defined based on the teacher questionnaire used in TIMSS 2019 and were discussed in three categories: personal characteristics, teacher qualifications, and teacher practices. Data were analyzed using multilevel regression analysis. According to the results, working conditions explained most of the variance in the achievement scores (49% in the 4th-grade and 40% in the 8th-grade), while teachers' characteristics explained the least variance (19% in the 4th-grade and 11% in the 8th-grade). Teacher qualifications explained about one-third of the between-schools variance (35% in the 4th-grade and 26% in the 8th-grade). Teacher practices explained the one-fifth of the between-schools variance (23% in the 4th-grade and 27% in the 8th-grade). Some variables had a high correlation with TIMSS achievement in 4th and 8th-grade, such as teachers' age, experience, teaching limited by students not ready for instruction, and parental pressure on teachers. Other significant predictors were having a major in education and mathematics, bringing interesting materials to class, using long-term assessment projects, having too many administrative tasks, and the number of students in the class.

Keywords: Teacher quality, working conditions, mathematics, teacher questionnaire, TIMSS 2019.

ÖZ: İlişkisel desende tasarlanan bu araştırmada öğretmen kalitesinin ve çalışma koşullarının, 4. ve 8. sınıf Türk öğrencilerinin TIMSS 2019 matematik başarısındaki rolü incelenmiştir. Öğretmen kalitesi, TIMSS 2019'da kullanılan öğretmen anketine dayalı olarak tanımlanmıştır ve üç kategoride ele alınmıştır: Kişisel özellikler, öğretmen nitelikleri ve öğretmen uygulamaları. Araştırma verisi çok düzeyli regresyon kullanılarak analiz edilmiştir. Araştırmanın sonuçlarına göre başarıdaki varyansı en fazla çalışma koşulları (4. sınıfta %49 ve 8. sınıfta %40) ve en az öğretmenlerin kişisel özellikleri açıklamaktadır (4. sınıfta %19 ve 8. sınıfta %11). Okullar arası varyansın üçte birini öğretmen nitelikleri (4. sınıfta %35 ve 8. sınıfta %26) ve beşte birini öğretmen uygulamaları (4. sınıfta %23 ve 8. sınıfta %27) açıklamaktadır. Öğretmenlerin yaşı, deneyimi, öğretimi sınırlandıran öğrenciden kaynaklı sorunlar ve velilerden çok fazla baskı hissetme gibi bazı değişkenler 4. ve 8. sınıftaki TIMSS başarısı ile yüksek korelasyon göstermiştir. Başarıyı yordayan diğer bazı önemli değişkenler ise şunlardır: Eğitim ve matematik alanlarında uzmanlaşma, sınıfa ilginç materyaller getirme, değerlendirmede uzun süreli projeler kullanma, çok fazla idari göreve sahip olma ve sınıftaki öğrenci sayısı.

Anahtar kelimeler: Öğretmen kalitesi, çalışma koşulları, matematik, öğretmen anketi, TIMSS 2019.

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Several factors related to student, home, school, curriculum, and teaching methods correlate with school achievement. Besides, it is emphasized that teacher quality plays a critical role in student achievement. Teachers are one of the school-related factors that most correlate with the development of students' knowledge and skills (Harris & Sass, 2011; Provasnik & Young, 2003; Rice, 2003).

It has been an issue that has been inquired about since 1960, that is characteristics and behaviors of teachers affect student achievement positively (Hill et al., 2005). Toraman (2019) stated that effective teacher characteristics include competence in subject matter knowledge, teaching skills, personal characteristics, and professional development. However, there is no consensus yet on the teachers' important qualifications in explaining students' achievement (Harris & Sass, 2011; Lee & Lee, 2020; Rivkin et al., 2005; Scheerens & Blömeke, 2016).

The number of studies investigating the relationship between teacher characteristics and student achievement is quite high. Several variables such as experience, education level, certification status, participation in professional development activities, general skills, pedagogical content knowledge, and practices have been addressed within the scope of teacher quality (Goe, 2007; Harris & Sass, 2011; Lee & Lee, 2020; Liang et al., 2015).

Apart from the critical variables in teacher quality, many studies categorize these qualities. For example, according to Scheerens and Blömeke (2016), teacher quality is a multidimensional concept that includes cognitive (knowledge) and non-cognitive factors (e.g., beliefs, attitudes). Goe (2007) presented a new teacher quality model with concrete indicators. There are four categories of teacher quality: personal characteristics, teacher qualifications, teacher practices, and teacher effectiveness.

There are contradictory results in the literature regarding the relationship between teachers' experience and student achievement. For example, according to Hong (2012), teachers' experience predicts mathematics achievement in Trends in International Mathematics and Science Study (TIMSS), positively in developing countries and negatively in developed countries. Hegarty and Rutkowski (2019) also stated no strong evidence for the correlations between student achievement and teacher effectiveness described by the common variables in TIMSS for different countries. On the contrary, it was found that teachers' subject matter knowledge and pedagogical content knowledge, which are the variables not measured within the scope of TIMSS, correlated with students' mathematics achievement (Baier et al., 2019).

International exams such as TIMSS and Programme for International Student Assessment (PISA) provide the most comprehensive data about teacher characteristics and students' scores. TIMSS is survey research first conducted in 1995 and is held every four years. According to the TIMSS 2019 mathematics achievement test scores, Turkey ranked 23 out of 58 countries in the 4th-grade level, indicating that Turkey was above the TIMSS international average (Ministry of National Education [MONE], 2020). According to previous assessments, there had been an increase in mathematics scores compared to the last eight years and more students ranked among high (28% proportion) and advanced (15% proportion) international benchmark. In the 8th-grade level, Turkey ranked 20 out of 39 countries, indicating that Turkey was below the TIMSS international average (MONE, 2020). According to previous assessments, more

students ranked among intermediate (24% proportion), high (20% proportion) and advanced (12% proportion) international benchmark.

TIMSS is one of the most comprehensive international comparative studies that assess 4th and 8th-grade students' knowledge and skills in mathematics and science. It collects nationally representative data from large teacher, student, and school characteristics samples. The TIMSS results provide insight into education policymakers, administrators, teachers, and researchers about the issues surrounding education systems and reforms (Martin & Mullis, 2012). Countries make important decisions and changes in their education systems considering the TIMSS results. However, few studies examine the teacher questionnaire, which includes variables related to teachers that play a critical role in mathematics achievement in the TIMSS. Some studies discussed TIMSS items to evaluate the instructional quality (Eriksson et al., 2019) and participation in professional development activities (Liang et al., 2015).

Many studies in the literature examine student, home, and school-related variables related to TIMSS mathematics achievement. Some variables related to students, such as confidence in mathematics, like learning mathematics, and value mathematics, were determined to be associated with TIMSS mathematics achievement (Akyüz-Aru, 2020; Çavdar, 2015; Şahin & Boztunç-Öztürk, 2018; Sarıer, 2020). In general, the literature findings indicated that teaching limited by students' needs, challenges, parental involvement, home educational resources, job satisfaction, and experience significantly predicted students' mathematics achievement (e.g., Akyüz, 2006; Akyüz-Aru, 2020; Batı, 2021; Çavdar, 2015; Sarı et al., 2017; Sarıer, 2020; Yetkiner Özel & Özel, 2013). However, this finding could vary by country. For example, teaching limited by students' needs was not correlated with mathematics achievement on TIMSS 2015 in Dinaric region countries such as Albania, Croatia, Kosova, and Serbia (Elezović et al., 2022); but was negatively correlated in Turkey (Sarı et al., 2017). In addition, the studies have shown that there were many differences between schools in Turkey, and therefore multilevel analyzes should be made according to schools (Akyüz-Aru, 2020; Arıkan et al., 2020; Sarı et al., 2017). However, Suna and Özer (2021) pointed out that the difference in achievement between schools decreased partially in TIMSS 2019 compared to other TIMSS assessments.

Because this current study examined all the questions in the TIMSS 2019 teacher questionnaires and inquired the teacher-level variables that explained the differences between schools, it would contribute to the literature. Also, it was important for the studies to examine different variables related to teachers. The findings and results of the study would guide policymakers to take concrete and practical steps to improve education policies and TIMSS scores. Besides, as a result of this research, a description of essential teacher qualifications for students' mathematics achievement would provide guidelines for effective teacher training programs and comprehensive planning of in-service training programs for teachers.

Study Goal

The study aimed to explore the role of teacher quality and working conditions in 4th and 8th-grade Turkish students' mathematics achievement in TIMSS 2019. It also aimed to reveal to what extent teacher attributes were influential in students'

mathematics achievement and improve the TIMSS teacher questionnaire. The research questions are as follows:

1. To what extent do teachers' characteristics predict 4th and 8th-grade students' mathematics achievement in TIMSS 2019?

2. To what extent do teacher qualifications predict 4th and 8th-grade students' mathematics achievement in TIMSS 2019?

3. To what extent do teachers' practices predict 4th and 8th-grade students' mathematics achievement in TIMSS 2019?

4. To what extent do working conditions predict 4th and 8th-grade students' mathematics achievement in TIMSS 2019?

Method

Study Sample

TIMSS 2019 assessment employed a two-stage random sample design (LaRoche et al., 2020). In the first stage, the sample of schools was selected in which each school had a chance of selection proportional to the number of their eligibility. In the second stage, one or more entire classes of sampled schools were selected with equal probability.

The sample consisted of 4th and 8th-grade Turkish students at public and private schools in 2019 and their mathematics teachers. Details about the sample are presented in Table 1.

Table 1

Demographic Characteristics of Teachers

Variables	Category	4th-Grade		8th-Grade	
		f	%	*f*	%
Gender	Female	110	62.1	93	53.1
	Male	67	37.9	82	46.9
Majored area	Education and mathematics	109	61.6	96	54.9
	Education	3	1.7	31	17.7
	Mathematics	63	35.6	42	24.0
	Other	2	1.1	6	3.4
Educational status	Undergraduate	166	93.8	163	93.1
	Postgraduate	10	5.7	12	6.9
	No response	1	.6	-	-
Experience	Five and below	77	43.5	52	29.7
	6 – 10 years	38	21.5	49	28.0
	11 – 15 years	31	17.5	36	20.6
	16 – 20 years	19	10.7	27	15.4
	21 years or more	12	6.8	11	6.3

As seen in the table, there were 4028 students, 181 teachers, and 180 schools in the 4th-grade. There were 4077 students, 181 teachers, and 181 schools in the 8th-grade. Following the missing data and extreme values analysis, the sample included 3942 students, 177 teachers, and 177 schools in the 4th-grade; 3922 students, 175 teachers, and 175 schools in the 8th-grade. As seen from the table, there was one teacher in each school.

According to Table 1, 177 mathematics teachers in the 4th-grade participated in this survey, with 110 female (62.1%) and 67 male (37.9%). More than half of the teachers' majors were education and mathematics (f=109, 61.6%). Almost all teachers had only one bachelor's degree (f=166, 93.8%), and ten teachers had master's or doctorate degrees (5.7%). Almost half had five years or less teaching experience (f=77, 43.5%).

In addition, 175 mathematics teachers in the 8th-grade participated in this survey, with 93 female (53.1%) and 82 male (46.9%). More than half of the teachers' majors were education and mathematics (f=96, 54.9%). Almost all teachers had only a bachelor's degree (f=163, 93.1%), and 12 teachers had master's or doctorate degrees (6.9%). More than half had ten or fewer years of teaching experience (f=101, 57.7%).

Also, in the final analysis, 3942 4th-grade students participated in our survey, with 2052 girls (52.1%) and 1882 boys (47.7%), and eight students did not report their gender. In 8th-grade, 3922 students were incorporated into the analysis, with 1954 girls (49.8%) and 1950 boys (49.7%), and 18 students did not report their gender.

Instruments

The study was performed using TIMSS 2019 data from the official website of TIMSS (International Association for the Evaluation of Educational Achievement, 2021). Mathematics achievement test for Turkish students and the teacher questionnaire for mathematics teachers in 4th and 8th-grade were obtained.

In the TIMSS 2019 mathematics achievement test of 4th graders, 50% of the total test score was from the numbers, 30% was from measurement and geometry, and 20% was from data. In the test of the 8th graders, 30% of the total test score was from numbers, 30% was from algebra, 20% was from geometry, and 20% was from data and probability.

Each of the 4th-grade and 8th-grade teacher questionnaires had 23 items. Both questionnaires were very similar. Some items were identical, but some sub-items were different. Both surveys included questions about teachers' personal information (e.g., teaching experience, age, gender), thoughts about being a teacher (e.g., job satisfaction), their workplaces and working conditions (e.g., school environment, number of students in the class), mathematics topics taught to the TIMSS class, mathematics teaching activities, assessment practices, homework assignments, and professional development activities.

Design and Procedure

This study used the predictive correlational design in which the correlations between variables were examined, and the other variables were predicted based on one or more variables without any intervention or manipulation (Fraenkel & Wallen, 2010).

The study aimed to determine the predictive level of teacher characteristics on students' mathematics achievement.

According to Goe's teacher quality model (2007), the questionnaires applied to 4th and 8th-grade teachers were categorized. Two achievement points are required to determine the category of teacher effectiveness, so the other three categories (i.e., personal characteristics, teacher qualifications, and teacher practices) were used in the study.

Personal characteristics involve (i) attitudes and beliefs that are resistant to change; (ii) stable or generational characteristics such as race and ethnicity; and (iii) the features that can be changed, such as the ability to communicate with a second or third different language, collaboration skills, job satisfaction, self-confidence in teaching mathematics, gender, and age. Teacher qualifications refer to the knowledge and experiences that a teacher brings to the classroom - for example, teaching practices and experience, higher education programs, internships, and professional development. Teacher practices include a teacher's behaviors, in-class practices, teaching planning, and strategies in the classroom, such as paying attention to the consistency between teaching practices and assessment procedures, setting explicit learning goals and student performance expectations, using formative assessment, and active learning techniques.

The mathematics teachers' answers to the TIMSS 2019 teacher questionnaire were examined considering teacher quality (personal characteristics, teacher qualifications, and teacher practices) and working conditions. The given four categories and relevant variables are shown in Table 2. Also, information about the questionnaire items and the scale scores calculated by TIMSS was given below. Dummy coding was used for categorical variables. All the yes/no sub-questions (e.g., Do you participate in professional development activities?) were coded as (1) yes and (0) no. The item code "ATB…" was for 4th-graders, and the code "BTB…" was for 8th-graders.

Table 2

Teacher Quality and Working Conditions Variables

Category	Variables
Teacher characteristics	(1) Gender*, (2) age, (3) job satisfaction
Teacher qualifications	(1) Teaching experience, (2) major in education and mathematics*, (3-9) participating in professional development activities in the past two years* (activities for mathematics content, mathematics pedagogy/instruction, mathematics curriculum, integrating technology into mathematics instruction, improving students' critical thinking or problem-solving skills, mathematics assessment, addressing students' needs), (10-16) the need for professional development activities in the future* (activities for mathematics content, mathematics pedagogy/instruction, mathematics curriculum, integrating technology into mathematics instruction, improving students' critical thinking or problem-solving skills, mathematics assessment, addressing students' needs), (17) hours spent on professional development in the past two years
Teacher practices	(1-8) In-class teaching practices (e.g., relate the lesson to students' daily lives, bring interesting materials to class**), (9-16) guiding students (e.g., ask students do the exercises on their own), (17) allowing students to use calculators*, (18) the frequency of assigning mathematics homework, (19-23) mathematics assessment (e.g., use long-term projects)

Working conditions	(1) School emphasis on academic success, (2) safe and orderly schools, (3) student-oriented problems/classroom teaching limited by students not ready for instruction, (4) classroom size, (5) availability of a computer for students in the classroom*, (6-13) working conditions (e.g., the excessive number of students in

* Categorical. ** It is only available in the 4th-grade.

Teachers' job satisfaction was a scale measured by TIMSS (ATBGTJS, BTBGTJS). The 4-point Likert-type scale (i.e., often, sometimes, rarely, and never) consisted of five items such as "I am content with my profession as a teacher" and "My work inspires me." The Cronbach alfa coefficient was .92 in 4th-grade and .93 in 8th-grade. Teachers' high scores on this scale refer to high job satisfaction.

School emphasis on academic success was a scale measured by TIMSS (ATBGEAS, BTBGEAS). The 5-point Likert-type scale (i.e., very high, high, medium, low, very low) consisted of 12 items such as "Parental involvement in school activities" and "Students' desire to do well in school." The Cronbach alfa coefficient was .89 in 4th-grade and .90 in 8th-grade. Teachers' high scores on this scale refer to high job satisfaction.

Safe and orderly schools were a scale by TIMSS (ATBGSOS, BTBGSOS). The 4-point Likert-type scale (e.g., agree a lot, agree a little, disagree a little, disagree a lot) consisted of eight items such as "I feel safe at his school" and "The students respect school property." The Cronbach alfa coefficient was .90 in 4th-grade and .88 in 8th-grade. Similarly, teachers' high scores on this scale meant that they accepted the school as a safe place.

The scale "classroom teaching limited by students not ready for instruction" was created by TIMSS (ATBGLSN, BTBGLSN). The 3-point Likert-type scale (i.e., not at all, some, a lot) consisted of eight items such as 'Uninterested students" and "The students respect school property.". The Cronbach alfa coefficient was .82 in 4th-grade and .83 in 8th-grade. Teachers' higher scores indicated fewer factors limiting teaching.

However, some questions were not considered scale items in the teacher questionnaire. Teachers' in-class teaching practices were measured with eight items using a 4-point Likert-type scale (every or almost every lesson, about half of the lessons, some lessons, never). The items were as follows (ATBG12, BTBG12):

1. Relate the lesson to students' daily lives,

2. Ask students to explain their answers,

3. Bring interesting materials to class,

4. Ask students to complete challenging exercises that require them to go beyond the instruction,

5. Encourage classroom discussions among students,

6. Link new content to students to students' prior knowledge,

7. Ask students to decide their own problem-solving procedures,

8. Encourage students to express their ideas in class.

Teachers' guidance practices in the class were measured with eight items in a 4-point Likert type scale (i.e., every or almost every lesson, about half of the lessons, some lessons, never). The items were as follows (ATBM02, BTBM15):

1. Ask to listen to the teacher when explaining new mathematics content,

2. Ask to listen to the teacher when explaining how to solve problems,

3. Ask to memorize rules, procedures, and facts,

4. Ask to practice procedures on students own,

5. Ask to apply what students have learned to new problem situations on their own,

6. Work problems together in the whole class with direct guidance from the teacher,

7. Work in mixed ability groups,

8. Work in same ability groups.

Teachers' mathematics assessment practices were measured with five items in the 3-point Likert type scale (i.e., a lot, some, none). The items were as follows (ATBM07, BTBM20):

1. Observing students as they work for assessing mathematics,

2. Asking students to answer questions during class for assessing mathematics,

3. Include the lesson short, regular written assessments,

4. Use longer tests (e.g., unit tests or exams),

5. Use long-term projects.

Teachers' working conditions in class and school were measured with eight items in the 4-point Likert type scale (agree a lot, agree a little, disagree a little, disagree a lot). The items were as follows (ATBG09, BTBG09):

1. Too many students in the classes,

2. Having too much material to cover in class,

3. Having too many teaching hours,

4. Need more time to prepare for class,

5. Need more time to assist individual students,

6. Feeling too much pressure from parents,

7. Difficulty keeping up with all of the changes to the curriculum,

8. Having too many administrative tasks.

Although all items in the teacher questionnaire were examined in this study, some variables were not included in the analysis. These variables had more than 20% missing data (e.g., If the students in the class did not have a computer/tablet, the teachers left the items about using computers in classroom activities blank.). Also, some variables had no variance (e.g., the number of students who had difficulty understanding the language of the test, the duration of the mathematics lesson, the current state of teaching TIMSS subjects). These variables were not shown in Table 2.

Data Analysis

This study tested the predictive level of teacher quality (personal characteristics, teacher qualifications, and practices) and working conditions on mathematics achievement by using multilevel regression analysis. The analysis used the TIMSS mathematics achievement scores as the dependent variable and teacher quality and working conditions as independent variables. Students' mathematics scores were five plausible values (ASMMAT01-ASMMAT05 and BSMMAT01-BSMMAT05).

TIMSS assessments were completed using a stratified two-stage cluster sample design. There was a hierarchical structure since the data were collected from the students and their teachers. Accordingly, in multilevel regression analysis, students were at the first level, and the teachers were at the second level. Since there was a teacher in each school, there were also schools at the second level. In this study, teacher quality and working conditions were variables at the teacher/school level (between variables). There was no variable at the student level (within variables). Teacher-level variables are shown in Table 2.

Also, Arıkan et al. (2020) suggested using sample weights and plausible values in data analysis in large-scale international assessments. Thus, a multilevel structure was taken into account using five plausible values and sample weights. For level one, the product of class weights and student weights (WGTADJ2, WGTFAC2, WGTADJ3, WGTFAC3), and for level two, the product of school weights (WGTADJ1, WGTFAC1) were used accordingly. Before analyzing multilevel regression models, whether the variability at the group level is sufficient was also checked (Şen, 2020).

The multilevel regression analyses were performed using the MPLUS 6.12 program, which could take into account the characteristics of TIMSS data (Muthén & Muthén, 2015). In statistical analysis, the α value was set at .05. The standardized β coefficient was used to interpret the regression coefficients. Also, the effect size index (f^2) was calculated by using the explained variance for the overall model (Cohen, 1992). The effect size index is interpreted as small between .02-.14, a medium between .15-.34, and large between .35 and above. This formula is as follows:

$$f^2 = \frac{R^2}{1 - R^2}$$

Before the data analysis, the missing data pattern was examined using Little's MCAR test. The test results revealed .11% missing data in the 4th-grade, which was not statistically significant (p=.25). It was measured at .08% for the 8th-grade, which was insignificant (p=.10). In other words, the data from the 4th and 8th-grade teachers were missing completely at random. Since many variables contained missing data, the missing data were handled using multiple imputations. MPLUS 7.4 programs were used and weighted least squares mean-variance adjusted (WLSMV) was chosen as the parameter estimator. The questionnaire items contained more than 15% missing data, and an 8th-grade mathematics teacher who did not answer at all and her students were not included in the analysis.

Also, the extreme values were examined using a box plot. Teachers and students with extreme values were excluded from the analysis. The analysis process was carried out using the data from 177 teachers and 3942 students in the 4th-grade and 175 teachers and 3922 students in the 8th-grade.

In addition, normality and multicollinearity problems, linearity assumptions, and homogeneity of variances were examined. When Q-Q plot was examined (Alpar, 2013), it was seen that the values of some variables were separated from the expected values (straight diagonal line). Accordingly, it indicated that the normal distribution is not met for some variables (e.g., the kurtosis value of school emphasis on academic success was 1.21 in 8th-grade; experience kurtosis value was -1.71 in 4th-grade). In addition, these values did not range from -1 to +1. Since the normal distribution was not achieved, the

weighted least squares mean adjusted parameter estimation method (WLSM) was used in the multilevel regression analysis.

Lastly, VIF values were between approximately 1.01 and 2.08. Since VIF values were less than 10, it is assumed that there was no multicollinearity problem (Stevens, 2009). The relationships between standardized errors and predicted values were checked with scatter plots to examine the linearity and variance homogeneity. In the residual scatter plots, the residuals were randomly distributed around zero in a rectangular form, and the errors had a normal distribution. Accordingly, linearity and variance homogeneity were assumed to be provided (Alpar, 2013; Stevens, 2009).

Ethical Procedures

Ethics committee approval is not required for this study. No suspicious process was carried out in the analysis of the research data. The authors paid attention not to interfere with the research data except for the necessity of analysis and to interpret the results objectively.

Results

In this section, first of all, the necessity of multilevel analysis was examined, and the intra-class correlation coefficient was calculated. Then, the findings regarding the level of predicting mathematics achievement of teachers' personal characteristics, teacher qualifications and practices, and working conditions for 4th and 8th-grade were presented.

The intra-class correlation coefficient was calculated as .427 in the 4th-grade level and .395 in the 8th-grade level. These values represented that students' mathematics scores were not independent, and the scores of students who had the same math teacher (or at the same school) were correlated. In the 4th-grade, 43% and in the 8th-grade, 40% of the total variance came from teacher variance. Also, in the 4th-grade, 57%, and the 8th-grade, 60% of the total variance came from teacher variance. Therefore, multilevel regression analyses were necessary. Analysis results for each teacher quality category (personal characteristics, teacher qualifications, and teacher practices) and teachers' working conditions are below.

Teacher Characteristics Predicting 4th-Grade and 8th-Grade Students' Mathematics Achievement

Table 3 shows the variables related to teacher characteristics, multilevel regression equation results, and the standardized β coefficients in the 4th and 8th-grade levels. The independent variables related to the teachers' characteristics in the TIMSS 2019 research involved gender, age, and job satisfaction.

Table 3

Teacher Characteristics Predicting Mathematics Achievement

Variables	4th-Grade		8th-Grade	
	Coefficient	Std. Error	Coefficient	Std. Error
1. Gender (Female)	-.080	.078	-.069	.079
2. Age	.397***	.081	.310***	.088
3. Job satisfaction	.105	.078	.011	.070
Between-class explained variance	18.5%		10.7%	
f^2	.23		.12	

*p<.05. **p<.01. ***p<.001.*

As seen in Table 3, the age of teachers predicted mathematics achievement in both 4th (β=.40) and 8th (β=.31) grade levels. Gender and job satisfaction were not included in the regression equations as they did not show a significant correlation with mathematics achievement. Also, there was a positive relationship between age and mathematics scores.

In 4th-grade, the results showed that the variables of teacher characteristics explained 18.5% of the variance, and the regression equation had a medium effect size (f^2=.23). Also, in the 8th-grade, teacher characteristics' variables explained 10.7% of the variance, and the regression equation had a small effect size (f^2=.12).

Teacher Qualifications Predicting 4th-Grade and 8th-Grade Students' Mathematics Achievement

Table 4 shows the variables related to teacher qualifications, multilevel regression equations' results and the standardized β coefficients in the 4th and 8th-grade. The independent variables related to the teachers' qualifications in the TIMSS 2019 involved teaching experience, major in education and mathematics, professional development activities participated in the last two years and the need for future professional development activities. The professional development topics were related to mathematics content, mathematics pedagogy/instruction, mathematics curriculum, integrating technology into mathematics instruction, improving students' critical thinking or problem-solving skills, mathematics assessment, addressing individual students' needs.

Table 4

Teacher Qualifications Predicting Mathematics Achievement

Variables	4th-Grade		8th-Grade	
	Coefficient	Std. Error	Coefficient	Std. Error
1. Experience	.383***	.080	.415***	.102
2. Major in education and mathematics	.132	.068	.176*	.080
3. Mathematics content (participating in PD)	.017	.114	.021	.135
4. Mathematics pedagogy/instruction (participating in PD)	-.072	.116	.003	.121
5. Mathematics curriculum (participating in PD)	-.117	.098	.040	.099
6. Integrating technology into mathematics instruction (participating in PD)	.130	.084	.098	.123
7. Improving students' critical thinking or problem-solving skills (participating in PD)	.013	.099	.016	.110
8. Mathematics assessment (participating in PD)	-.157	.095	-.079	.113
9. Addressing individual students' needs (participating in PD)	.275**	.085	.145	.127
10. Mathematics content (the need for PD)	-.213	.131	.073	.129
11. Mathematics pedagogy/instruction (the need for PD)	.030	.115	-.189	.110
12. Mathematics curriculum (the need for PD)	.101	.128	-.064	.103
13. Integrating technology into mathematics instruction (the need for PD)	-.010	.082	.160	.110
14. Improving students' critical thinking or problem-solving skills (the need for PD)	-.040	.127	-.006	.124
15. Mathematics assessment (the need for PD)	-.127	.109	-.030	.134
16. Addressing individual students' needs (the need for PD)	-.040	.104	-.098	.125
17. Hours spent on professional development in the past two years	.012	.078	-.072	.115
Between-class explained variance	35.0%		26.1%	
f^2	.54		.35	

PD= Professional Development. *$p<.05$. **$p<.01$. ***$p<.001$.

In order of importance, the significant predictors of mathematics achievement in 4th-grade were teachers' experience (β=.38) and participating in professional development in the last two years and addressing individual students' needs (β=.28). Other variables related to teacher qualifications were not significant predictors of mathematics achievement. Accordingly, while the other variables were constant, as the experience of the 4th-grade teacher increased, mathematics achievement would also increase. Similarly, the teacher's professional development in the last two years and addressing students' needs increased student achievement.

In order of importance, the significant predictors of mathematics achievement in 8th-grade were teachers' experience (β=.42) and major in education and mathematics (β=.18). Other variables related to teacher qualifications were not significant predictors of mathematics achievement. Accordingly, while the other variables were constant, as the experience of the 8th-grade teacher increased, mathematics achievement would also increase. Similarly, teachers' majors were education and mathematics, which increased their achievement.

In 4th-grade, the results showed that teacher qualifications' variables explained 35% of the variance, and the regression equation had a large effect size (f^2=.54). Also, in the 8th-grade, teacher qualifications' variables explained 26.1% of the variance, and the regression equation had a large effect size (f^2=.35).

Teacher Practices Predicting 4th-Grade and 8th-Grade Students' Mathematics Achievement

Table 5 shows the variables related to teacher practices in TIMSS class, the results of multilevel regression equations, and the standardized β coefficients in the 4th and 8th-grade. The independent variables related to the teachers' practices in the TIMSS 2019 research involved in-class teaching practices, practices for guiding students, allowing students to use calculators, frequency of assigning mathematics homework, and mathematics assessment practices. Bringing exciting materials to the class was only available in the 4th-grade.

Table 5

Teacher Practices Predicting Mathematics Achievement

Variables	4th-Grade		8th-Grade	
	Coefficient	Std. Error	Coefficient	Std. Error
1. Relate the lesson to students' daily lives	-.094	.114	.051	.112
2. Ask students to explain their answers	.018	.103	.030	.118
3. Bring interesting materials to class	-.215*	.099	-	-
4. Ask students to complete challenging exercises that require them to go beyond the instruction	.117	.107	.240*	.109
5. Encourage classroom discussions among students	.038	.098	.007	.118
6. Link new content to students to students' prior knowledge	.081	.106	.165	.109
7. Ask students to decide their own problem-solving procedures	.068	.119	-.145	.104
8. Encourage students to express their ideas in class	.129	.136	-.106	.099
9. Ask to listen to the teacher when explaining new mathematics content	-.166	.155	.062	.166
10. Ask to listen to the teacher when explaining how to solve problems	.078	.141	-.090	.170

Variables	4th-Grade		8th-Grade	
	Coefficient	Std. Error	Coefficient	Std. Error
11. Ask to memorize rules, procedures, and facts	-.193*	.077	-.094	.105
12. Ask to practice procedures on students own	-.170	.108	-.113	.103
13. Ask to apply what students have learned to new problem situations on their own	.104	.123	.184	.108
14. Work problems together in the whole class with direct guidance from the teacher	.024	.096	.100	.114
15. Work in mixed ability groups	-.108	.111	-.192	.116
16. Work in same ability groups	-.083	.096	.160	.111
17. Allowing students to use calculators	-.088	.084	-.169	.097
18. Frequency of assigning mathematics homework	-.029	.079	-.065	.073
19. Observing students as they work for assessing mathematics	-.026	.109	-.041	.118
20. Asking students to answer questions during class for assessing mathematics	.033	.122	.027	.083
21. Include the lesson short, regular written assessments	.034	.085	-.035	.094
22. Use longer tests (e.g., unit tests or exams)	.010	.083	.007	.091
23. Use long-term projects	-.055	.092	-.342***	.092
Between-class explained variance	23.4%		27.1%	
f^2	.31		.37	

*$p<.05$. **$p<.01$. ***$p<.001$.

In the 4th-grade, the significant predictors of mathematics achievement were the variables of bringing interesting materials to the class ($\beta=-.22$) and asking students to memorize rules, procedures, and facts ($\beta=-.19$). Accordingly, while the other variables were constant, the increase in those variables decreased mathematics achievement. Other variables related to teacher practices were not significant predictors of mathematics achievement.

In the 8th-grade, the significant predictors of mathematics achievement were the variables of using long-term projects for assessment ($\beta=-.34$) and asking students to complete challenging exercises that require them to go beyond the instruction ($\beta=.24$). Accordingly, asking students to do challenging exercises positively correlated with achievement, but using long-term projects was negatively associated with achievement. It was also determined that other variables related to teacher practices were not significant predictors of mathematics achievement.

In the 4th-grade, the results showed that teacher practices explained 23.4% of the variance, and the regression equation had a medium effect size ($f^2=.31$). Also, in the 8th-grade, teacher practices explained 27.1% of the variance, and the regression equation had a large effect size ($f^2=.37$).

Working Conditions Predicting 4th-Grade and 8th-Grade Students' Mathematics Achievement

Table 6 shows the variables related to teachers' working conditions, the results of multilevel regression equations, and the standardized β coefficients in the 4th and 8th-grade. The independent variables related to the working conditions in the TIMSS 2019 were schools' emphasis on academic success, safe and orderly schools, classroom teaching limited by students not ready for instruction, number of students in the class, availability of a computer for students in the classroom and the variables about working conditions in class and school (e.g., too many students in the classes).

Table 6

Working Conditions Predicting Mathematics Achievement

Variables	4th-Grade		8th-Grade	
	Coefficient	Std. Error	Coefficient	Std. Error
1. School emphasis on academic success	.107	.084	.037	.097
2. Safe and orderly schools	.149	.086	-.013	.097
3. Classroom teaching limited by students not ready for instruction	.468***	.058	.407***	.056
4. Number of students in the class	-.143*	.073	-.083	.099
5. Availability of a computer for students in the classroom	.168*	.073	.090	.066
6. Too many students in the classes	.119	.088	-.053	.089
7. Having too much material to cover in class	-.022	.103	.233	.156
8. Having too many teaching hours	-.291**	.097	-.147	.144
9. Need more time to prepare for class	.179*	.078	.031	.084
10. Need more time to assist individual students	-.115	.071	-.116	.081
11. Feeling too much pressure from parents	.276***	.072	.387***	.073
12. Difficulty keeping up with all of the changes to the curriculum	.089	.082	.023	.078
13. Having too many administrative tasks	-.098	.069	-.186**	.070
Between-class explained variance	49.2%		39.8%	
f^2	.97		.66	

*p<.05. **p<.01. ***p<.001.

In order of importance, the significant predictors of mathematics achievement in 4th-grade were classroom teaching limited by students not ready for instruction (β=.47), having too many teaching hours (β=-.29), feeling too much pressure from parents (β=.28), needing more time to prepare for class (β=.18), availability of a computer for students in the classroom (β=.17), and the number of students in the class (β=-.14). Other variables related to working conditions were not significant predictors of mathematics achievement. Accordingly, there was a positive correlation between achievement and teaching limited by students, feeling too much pressure from parents,

needing more time to prepare for class, and availability of a computer for students in the classroom. There was a negative correlation between achievement and having too many teaching hours, and the number of students in the class.

In order of importance, the significant predictors of mathematics achievement in 8th-grade were classroom teaching limited by students not ready for instruction (β=.41), feeling too much pressure from parents (β=.39), and having too many administrative tasks (β=-.19). Other variables related to teacher conditions were not significant predictors of mathematics achievement. Accordingly, there was a positive correlation between achievement and teaching limited by students and parental pressure. Teachers' having too many administrative tasks was negatively associated with achievement.

In 4th-grade, the results showed that working conditions explained 49.2% of the variance, and the regression equation had a large effect size (f^2=.97). Also, in the 8th-grade, working conditions explained 39.8% of the variance, and the regression equation had a large effect size (f^2=.66).

Discussion and Conclusion

The current study revealed that the most explaining variance of mathematics achievement in TIMSS 2019 was the teachers' working conditions (49% in the 4th-grade and 40% in the 8th-grade). Sarı et al. (2017) stated that the regression model, in which the predictors of TIMSS 2015 mathematics achievement in the 8th-grade were examined, explained 29% of the variance between schools. Similarly, there were school-level variables in the model, such as teaching limited by student needs, schools' emphasis on academic success, safe and orderly schools, teachers' job satisfaction, and challenges of teaching. Several studies pointed out significant differences between schools (e.g., Akyüz-Aru, 2020; Çavdar, 2015; Eriksson et al., 2019; Mohammadpour & Ghafar, 2014; Suna & Özer, 2021).

In the current study's working conditions category, the most influential variable at both grades was teaching limited by students not ready for instruction. It was measured by TIMSS and could be considered a factor of school climate (Elezović et al., 2022). It examined teachers' perceptions of the severity of limitations that negatively correlated with classroom atmosphere, problematic student behaviors such as disruptive or disinterested actions, and lack of basic nutrition. The current study concluded that a decrease in the related variable might lead to an increase in the mathematics achievement of Turkish students. The literature findings also supported that classroom factors and challenges significantly correlated with students' mathematics achievement, which overlapped with the current results (Akyüz, 2006; Sarı et al., 2017). However, this result could vary according to different countries.

Another variable in teachers' working conditions related to students' mathematics achievement in both grades was parental pressure on teachers. It was found that an increase in this variable increased mathematics achievement. Similarly, Güven and Sezer (2020) found that parental pressure had a positive relationship with mathematics achievement in Turkey, Germany, and the USA, while there was no significant relationship in Finland. Nevertheless, it was not clearly understood how parents exerted pressure on teachers (such as shouting, complaining to authority, forcing them into teaching activities). For example, the literature suggested that parental involvement (e.g., out-of-school math support) significantly and positively correlated

with mathematics achievement at both grade levels (Sarı et al., 2017; Yalcin et al., 2017). Similarly, Batı (2021) stated that parental involvement (e.g., out-of-school math support), educational resources at home, parents' perceptions of mathematics, and their children's education significantly predicted students' performances.

In addition, the study found that 4th-grade students' mathematics achievement was positively related with the variables of the need for additional time to prepare for class and availability of a computer for students in the classroom; and negatively correlated with having too many teaching hours and the number of students in the class similar to findings of the studies done by Akyüz (2006) and Mohammadpour and Ghafar (2014). Also, it was determined that having too many administrative duties was negatively related to mathematics achievement in the 8th-grade, similar to Akyüz (2006).

It was also found that other different variables (e.g., schools' emphasis on academic success, safe and orderly schools) in the working conditions category were not a strong predictor of mathematics achievement. Similarly, there were many studies in the literature that the variable of safe and orderly schools was not associated with mathematics achievement (Arifoğlu, 2019; Elezović et al., 2022; Sarı et al., 2017). Similarly, Elezović et al. (2022) pointed out school's emphasis on academic success was not correlated with mathematics achievement. Nevertheless, some studies showed that the school's emphasis on academic success positively correlated with mathematics achievement on TIMSS 2015 (Arifoğlu, 2019; Coşkun, 2021; Sarı et al., 2017).

In the 4th and 8th-grade, teachers' characteristics explained the slightest variance in TIMSS 2019 mathematics achievement (19% in the 4th-grade and 11% in the 8th-grade) and regression equations had small or medium effect sizes. Teachers' age had a positive relationship, but other variables (gender and job satisfaction) had no significant correlation with achievement. Teachers' experience explained the relationship between teachers' age and students' mathematics achievement because older teachers had more experience than younger teachers. Similarly, there was no significant correlation between TIMSS 1999 mathematics achievement and gender in the literature, except for the students of male teachers in Turkey and the Czech Republic and the students of female teachers in Hungary and the Netherlands (Akyüz, 2006). Studies in the literature also found no correlation between job satisfaction and TIMSS 2015 mathematics achievement (Arifoğlu, 2019; Sarı et al., 2017). Nevertheless, some studies showed that teachers' job satisfaction positively correlated with mathematics achievement (Çavdar, 2015; Toropova et al., 2019; Yıldırım & Bilican Demir, 2014).

Teacher qualifications predicted TIMSS 2019 mathematics achievement with large effect size and explained one-third of the between-schools variance (35% in the 4th-grade and 26% in the 8th-grade). The most influential variable in the regression equations was teachers' experience in both grades. Similarly, several studies in the literature suggested that teaching experience was a good predictor of mathematics achievement (e.g., Hong, 2012; Şahin & Boztunç-Öztürk, 2018; Toropova et al., 2019; Yetkiner Özel & Özel, 2013; Zuzovsky, 2009), but some studies indicated no significant relationship between these two variables (e.g., Jepsen, 2005; Palardy & Rumberger, 2008; Sandoval-Hernandez et al., 2015). Rivkin et al. (2005) also stated that teachers had the most professional development in the first year; it continued in the second and third years with a decreasing rate and almost stopped in the three years or above.

Besides, teachers' majoring in education and mathematics had a significant relationship with mathematics achievement in the 8th-grade, but it was not significant in the 4th-grade. In many studies, it had been determined that there was no significant relationship between teachers' major areas and mathematics achievement on TIMSS (e.g., Mohammadpour & Ghafar, 2014; Palardy & Rumberger, 2008; Zuzovsky, 2009). However, it was determined that the mathematics achievement and teachers who majored in mathematics and education were higher in Turkey, Lithuania, the Czech Republic, and Oman (Mohammadpour & Ghafar, 2014; Yetkiner Özel & Özel, 2013). According to the Turkish education system, the "major in education and mathematics" variable could be called "primary mathematics teacher." Nevertheless, Oz (2021) stated that teachers could misunderstand a survey question regarding their major due to the teacher training system. Therefore, it would not be appropriate to describe those teachers as primary school mathematics teachers.

Professional development was also discussed under teacher qualifications. Such practices were widely used to move teaching mathematics from teacher-centered to student-centered (Hwang, 2021). According to the results, participation in professional development activities in the last two years about addressing individual students' needs predicted only 4th-grade mathematics achievement. Similarly, Liang (2015) indicated that TIMSS 2003 or 2017 mathematics assessment in the USA had a significant relationship with other professional development topics such as mathematics content, pedagogy/instruction, and mathematics assessment. However, in the current study, it was observed that other subjects, such as mathematics assessment mathematics curriculum, were not related to achievement. The need for professional development activities did not correlate with mathematics achievement. The TIMSS 2019 teacher questionnaire could be insufficient to define professional development as limited to topics. Similarly, Toraman (2019) also determined that effective teachers should follow the developments in the subject matter area, produce original ideas, learn lifelong, and make self-assessments within the scope of professional development.

Teacher practices predicted TIMSS 2019 mathematics achievement with medium or large effect size and explained the one-fifth of the between-schools variance (23% in the 4th-grade and 27% in the 8th-grade). Teachers' in-class teaching practices included items such as relating to daily life and prior knowledge, responding to student needs and encouraging students to participate in the discussion. The current study showed that asking students to complete challenging exercises, which required them to go beyond the instruction, was an important predictor of mathematics achievement and had a positive relationship in 8th-grade. However, although bringing materials to the classroom was a significant predictor of mathematics achievement but correlated negatively in the 4th-grade. It might stem from teachers' inability to use the materials effectively.

Within the scope of guiding the students in the class, the students were asked to show some behaviors in the lesson (e.g., explaining the problem-solving process, listening to the teacher, applying what they learned). Besides, teachers were asked about their working in mixed and same ability groups. According to the findings, asking students to memorize rules, procedures, and facts predicted 4th-grade mathematics achievement significantly and negatively, resulting from TIMSS questions focused on real-life situations and students' inability to adapt to questions involving daily life

situations. Eriksson et al. (2019) stated that in Sweden, memorizing formulas and listening to the teacher were positive predictors of TIMSS 8th-grade mathematics achievement, whereas relating to daily life was a negative predictor.

Finally, the scope of mathematics included observing students, asking students to answer questions in the class, using short and regular written assessments during the lesson, using long tests (e.g., unit tests or exams), and using long-term projects. According to the regression equation results, long-term projects predicted 8th-grade mathematics achievement significantly and negatively, and the others did not correlate significantly. Similarly, Şahin and Boztunç-Öztürk (2018) determined that teachers' mathematics assessment did not predict achievement.

On the other hand, it is known that teachers' subject matter knowledge and pedagogical content knowledge, which are among the variables that are not measured within the scope of TIMSS, significantly correlated with students' mathematics achievement (Hill et al., 2005; Telese, 2012). Burroughs and Chudgar (2017) found that teacher quality partially influenced teaching. However, the information and knowledge required for mathematics instruction are vast. The importance of specific knowledge and practices in mathematics teaching, such as general pedagogy, subject matter knowledge, field teaching, and the appropriate use of resources, materials, and samples/activities considering students' needs were among the central discussion topics in the literature (Ball et al., 2008; König et al., 2021; Lee & Lee, 2020).

In summary, when the results in the 4th and 8th grades were considered together, the most crucial category was working conditions, and the least important category was personal characteristics. It had been observed that teacher quality and working conditions in the 4th-grade level explained TIMSS 2019 mathematics achievement with a medium or large effect size. It was determined that teachers' working conditions explained the difference between schools' variance in mathematics achievement (49%) with a large effect size. It was also found that teacher qualifications (35%) with large effect size, teacher practices (23%) with medium effect size, and personal characteristics (19%) with medium effect size explained the differences between schools, respectively.

Additionally, it had been observed that teacher quality and working conditions in the 8th-grade explained TIMSS 2019 mathematics achievement with small or large effect size. It was determined that the working conditions of teachers explained the difference between schools in the variance in mathematics achievement (40%) with large effect size. Then, it was determined that teacher practices (27%) with large effect size, teacher qualifications (26%) with large effect size, and personal characteristics (11%) with small effect size explained the differences between schools, respectively.

This study was limited to Turkey data. As seen above, the variables for achievement differed depending on the sociological structure of the countries. This study was also limited to the teacher questionnaire used in the TIMSS 2019. TIMSS has also made changes in the teacher questionnaire in recent years. For example, self-confidence in teaching mathematics and collaboration among teachers were not included in the TIMSS 2019 questionnaire. Additional questions were added, such as the need for professional development activities in the future. However, a new scale prepared by TIMSS on teacher practices was not used in this survey. Also, this study could not examine the relationship of some variables that were not usable for data

analysis. Some variables had a high amount of missing data (e.g., using computers in classroom activities). Most teachers in Turkey responded with the same/closer answers (e.g., the duration of the mathematics lesson).

Indeed, today, many large-scale exams are criticized regarding the variables they attempt to measure. A similar criticism is made for the PISA and No Child Left Behind (NCLB) Act (The Guardian, 2014). Palardy and Rumberger (2008) stated that policies and reform efforts should focus more on teacher practices and attitudes than teachers' qualifications as highlighted in the NCLB Act. According to Eriksson, Helenius, and Ryve (2019), the items measuring the teaching quality on the TIMSS data should be included in the student questionnaire to provide more helpful information. A study conducted on TIMSS 2007 Turkey data revealed that the questionnaire items were ambiguous and had vague wording (Yıldırım & Yıldırım, 2009). It was seen that the students in the same classroom gave different answers about the frequency of activities they did in the classroom.

Implications

Some recommendations are made considering the findings. The teacher questionnaire in TIMSS should include certain variables (e.g., special field teaching techniques), especially determining teachers' mathematics teaching practices because this current study revealed that few variables in teacher practices were associated with mathematics achievement. However, the teacher's in-class practices (such as using activities and student-centered approaches) and subject matter knowledge were also important in increasing achievement. In addition, more professional development questions can be added to the TIMSS teacher questionnaire. Because participation in professional development activities was among the attributes of effective teachers, however, in this current study, it was determined that education subjects had a low correlation. Teachers' working conditions should also be addressed in teacher quality models since, in the current study, the most variance in mathematics achievement was explained by the category of working conditions. Teachers should be provided with in-service training on integrating technology into education because this variable was found to have a high correlation with mathematics achievement.

For researchers, they may conduct. Using multilevel statistical techniques would be more proper in dealing with school-level data. Also, it would be useful to carry out cross-cultural studies with similar study goals and cross-cultural comparisons. Also, to offer suggestions to the education system, researchers may carry out especially intercultural studies on the relationship between teachers' practices and TIMSS achievement.

Statement of Responsibility

The authors declare that the study has no unethical issues and that research and publication ethics have been observed carefully. All authors discussed methodology, formal analysis, the results and contributed to the final manuscript.

Conflicts of Interest

The authors declared no potential conflicts of interest concerning this article's research, authorship, and publication.

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