

A Determination of Turkish Student's Achievement Using Hierarchical Linear Models in Trends in International Mathematics-Science Study (TIMSS) 2011

Ezel Tavşancıl and Seher Yalcın

*Ankara University, Faculty of Educational Science,
Department of Measurement and Evaluation, Ankara, Turkey
E-mail: etavşancıl@ankara.edu.tr, yalcins@ankara.edu.tr*

KEYWORDS Student. Education. School. Assessment. Multilevel Modeling

ABSTRACT The purpose of this study is to determine the relationship between features of schools and students' mathematics success in the TIMSS (Trends in International Mathematics-Science Study) which was administered to 8th grade students in 2011. As a correlational survey study, the population of the study, the characteristic sample for TIMSS applications, and this sample are all designated by using a two-stage stratified clustering model. The relationships between mathematics success and variables at student and school-levels have been tested with a two-level hierarchical-linear model. According to the findings of the study, there is a difference between students' mathematics scores at different schools. The most explanatory variable defining the variance at the school level is economic affluence of homes within school boundaries; at the student level, the students who have educational resources at home are better off.

INTRODUCTION

TIMSS (Trends in International Mathematics-Science Study) is a study that Turkey participates in to evaluate students' success in international fields and to compare its current educational system with those in other countries. The study is conducted in science and mathematics fields once every four years. The TIMSS helps countries to evaluate mathematics success with respect to process and class (Ministry of National Education [MoNE] 2011). Turkey participated in TIMSS applications for the first time in 1999.

TIMSS provides participant countries with a wide range of resources so they can test for changes in educational programs and educational studies and comment on results. In TIMSS questionnaires, students are asked about their teachers and about characteristics of their schools (MoNE 2011). As a large-scale assessment study, TIMSS provides opportunity for educators to observe the relationship between

countries' education reforms and students' success.

Student success is influenced by various factors. Researchers seek to determine how students' academic success relates to student, teacher, family, and school characteristics that are involved. Along with the considerable importance of determining variables related to student success in science and considering students' failures in science subjects where mathematical operations are needed, it is necessary to determine which variables are primarily related to students' success in mathematics.

Considering some research conducted to determine which variables determine students' success in mathematics (Afana et al. 2013; Akyuz 2014; Akyuz and Berberoglu 2010; Carnoy et al. 2015; Chen 2013; Ghagar et al. 2011; Is Guzel and Berberoglu 2010; Kozina 2015; Liou 2010; Mohammadpour 2012; Phan 2008; Rimm-Kaufman et al. 2015), almost all researchers (Akyuz 2014; Akyuz and Berberoglu 2010; Chen 2013; Is Guzel and Berberoglu 2010; Kozina 2015; Mohammadpour 2012; Phan 2008) state that availability of educational resources at home indicate students' mathematics success. Some researchers (Akyuz 2014; Chen 2013; Is Guzel and Berberoglu 2010; Ghagar et al. 2011; Kozina 2015; Liou 2010; Mohammadpour 2012; Norton and Zhang 2013; Rimm-Kaufman et al. 2015) state that certain positive characteristics in students (attitude, self-

Address for correspondence:

Seher Yalcın

Ankara University, Faculty of Educational Sciences,

Department of Measurement and Evaluation,

Cebeci Campus, 06590 Ankara/Turkey

Telephone: +90-312-363 33 50

Fax: +90-312-363 61 45

E-mail: yalcins@ankara.edu.tr

confidence, engagement) are related to mathematics success. Furthermore, some researchers (Chen 2013; Mohammadpour 2012; Phan 2008) state that key background characteristics of teachers correspond to students' mathematics success, and according to some researches (Afa-na et al. 2013; Chen 2013; Is Guzel and Berberoglu 2010; Ghagar et al. 2011; Kozina 2015; Mohammadpour 2012; Phan 2008), characteristics at the school level (resources, environment, climate) are also seen to be related to mathematics success in students.

TIMSS 2011 application will provide an opportunity for researchers to see the results of educational reforms that were implemented. It is specifically necessary to determine mathematics success. In accordance with multilevel data structure, considering the limited studies explaining student success in mathematics, it is important to focus on student and school level variables, determining which specific factors are related to mathematical success.

Objectives

The purpose of this research is to determine the relationship between school features and students' mathematics success through the TIMSS, which was administered to 8th grade students in 2011. In accordance with the purpose of the study, the research questions are listed below:

1. Is mathematical success of students different among schools?
2. Which features of students (home educational resources, students' attitude towards mathematics, family's interest, engagement of students in mathematics lessons, and family education level) are related to their mathematics success?
3. Which features of schools (economically disadvantaged students attend, teachers' understanding of school programme's gains, expectations of the teacher about student success, and family support for student success) are related to students' mathematics success?

METHODOLOGY

Research Design and Population

As student and school features that relate to student success in mathematics are determined in the study, a correlational survey model is used.

The population of the study has the characteristics of a sample for 2011 eighth-grade TIMSS applications in Turkey. The sampling model that TIMSS generally uses is a two-staged stratified sampling model. In this research, the analysis is carried out with the data obtained from 6,885 students and 238 schools, as there are no answers regarding the questionnaire of an eighth-grade-level school.

Measurement Tools

In this study, the data obtained from the mathematical success test that is used in TIMSS student and school questionnaires are used (Foy et al. 2013). In determining variables that are in student and school questionnaires, different models are tried consisting of variables gathered in proper categories, and by making benefit of literature relating to students' success in mathematics. After tests are done, the last model is reported. Explanations regarding chosen variables on the student and school-levels in the study are presented in the Appendix.

Statistical Analysis

As data show a hierarchical structure at the student and school-levels, HLM -a multilevel statistical technique- is used in the analysis. In the social sciences, many data come in hierarchic or nested structures. The aim of HLM is to determine the direct effects of explanatory variables at individual and group-levels, and to determine the relationship between explanatory variables at the individual and group-levels (Hox 1995). Being a parametric statistic technique, HLM has various assumptions. HLM's assumptions are as follows: variances of errors are equal and independent, and errors at both the first and second-levels are distributed normally (Raudenbush and Bryk 2002). In this research, these assumptions are visually tested by obtaining HLM-7 and SPSS-20 programmes to draw scatter diagrams, and it is seen that the assumptions are verified. Variables that contain missing values are imputed with series averages.

In the study, plausible values that are calculated in order to estimate students' success in mathematics through the TIMSS are also used. For the first research question a one-way-ANOVA model with random effect is used, for the second research question a regression-model with

random-coefficient is used, and for the third research question a regression with means as outcomes model is used. In order to study independent effects of level-one and level-two variables and to produce better intersection parameter values, level-one variables are centralized around group mean centering and level-two variables are centralized around grand mean centering (Raudenbush and Bryk 2002).

RESULTS

At the end of the analysis of the first research question, it is predicted that the average mathematics success values for all schools are $t=105.111$ and $\gamma_{00}=449.313$. Mathematics success is shown to be significantly different among schools ($\chi^2_{237}=3879.170, p<.05$). A parameter gathered from an one-way-ANOVA model with random effect is the intra-class correlation coefficient. As a result of the calculation, it is seen that 69 percent of the whole range of students' mathematics success stems from differences between students, and the remaining 31 percent stems from differences between schools. For the second research question, in order to determine which student features relate students' mathematics success, a regression-model with random-coefficient is started with five explanatory variables, and it is seen that all of these variables are significant. Results of the analysis are presented in Table 1.

On the student-level, it is seen that there is a positive significant relation between students' home educational resources and their mathematics success ($\gamma_{10}=11.102, p<.05$). There is a negative significant relation between family's interest and students' mathematics success ($\gamma_{20}=-3.299, p<.05$). This situation shows that as students get more help from their families, their mathematics success decreases. It is seen that there is a positive significant relation between stu-

dents' attitude towards mathematics and their mathematics success ($\gamma_{30}=6.567, p<.05$). There is also a positive significant relationship between the success of students and variables regarding the engagement of students in mathematics lessons ($\gamma_{40}=3.883, p<.05$) and family education level ($\gamma_{50}=9.268, p<.05$).

Overly large samples on which analysis are made may prevent significance in practice, even though results may be statistically significant. For this reason, the size of the effect of all significant variables is calculated by dividing the gamma-coefficient (γ) by the square root of between-group variance in the unconditional model (standard deviation) (von Secker and Lissittz 1999). An increase of one standard deviation in the "home educational resources" variable is expected to cause an increase of 0.18 standard deviation in average mathematics success. It can be said that even though family interest regarding school practices has a statistically significant relationship with student engagement in mathematics classes, the effects are not significant in practice. An increase of one standard deviation in students' attitude toward mathematics is expected to cause a 0.11 increases in standard deviation in the mathematics success mean, and an increase of one standard deviation in family education level is expected to cause a 0.15 standard deviation increase in average mathematics success.

Considering correlations between variables on the student-level, it can be seen that there is no relation between home educational resources and attitude toward mathematics, and other variables have low-level relations. It can be said that the relationships between student variables are valued at between .03 and .43, and they are low and significant ($p<.05$) enough that they will not cause a multicollinearity problem. Variance components' estimates regarding the regression-

Table 1: Estimates of fixed effects which belong to regression-model with random coefficient

Fixed effects	Coefficient	SH	t	p	Effect size
Average mathematics success, $\tilde{a}_{00}$	449.280	4.272	105.174	0.00*	
Home educational resources, $\tilde{a}_{10}$	11.102	1.198	9.270	0.00*	0.18
Family interest in school practices, $\tilde{a}_{20}$	-3.299	0.464	-7.106	0.00*	-0.05
Attitude towards mathematics, $\tilde{a}_{30}$	6.567	0.363	18.093	0.00*	0.11
Student engagement in mathematics lessons, $\tilde{a}_{40}$	3.883	0.556	6.984	0.00*	0.06
Family education level, $\tilde{a}_{50}$	9.268	1.272	7.288	0.00*	0.15

* $p<0.05$

Table 2: Variance components' estimates regarding regression-model with random coefficient

<i>Random effects</i>	<i>SS</i>	<i>Variance</i>	<i>sd</i>	$\div^2$	<i>p</i>
School-level, u_0	62.772	3940.307	236	4090.263	0.00*
Home educational resources, u_1	7.666	58.771	236	275.745	0.04*
Family interest regarding school practices, u_2	2.264	5.127	236	244.618	0.34
Attitude towards mathematics, u_3	2.338	5.464	236	268.882	0.07
Student attention in mathematics lessons, u_4	3.837	14.719	236	286.324	0.01*
Family education level, u_5	9.155	83.810	236	274.501	0.04*

* $p < 0.05$

model with random coefficient between variables at the student-level are presented in Table 2.

When residual variance (τ_{00}) values obtained from the one-way-ANOVA model with random effect, and the regression-model with random coefficient are compared, home educational resources, attitude toward mathematics, student engagement and attention in mathematics lessons, and family education level all of which are explanatory variables at the student-level explain 21 percent of variances at the student-level. In order to determine which school features relate to students' mathematics success according to TIMSS 2011 data (the third research question), a regression with means as outcomes model is used. To specify which school features relate to students' success, four variables have been chosen for study, and at the end of the analysis, all of these variables are found to be significant. Estimates of fixed effects that belong to the regression with means as outcomes model are presented in Table 3.

At the end of the analysis, the coefficient of the schools that economically disadvantaged students attend shows that there is a negative significant relationship between schools that economically disadvantaged students attend and the success of the students ($\gamma_{01} = -22.210$, $p < .05$). This result is proof that students at schools that house more economically disadvantaged students have lower mathematics success. There is a positive significant relationship between teachers' understanding about the gains of the school programme and mathematics success ($\gamma_{02} = 15.080$,

$p < .05$). As the number of teachers who understands the gains of the programme increases, their rate of success also rises. There is a positive significant relation between the success of students and the expectations of teachers about student success ($\gamma_{03} = 13.180$, $p < .05$) and family support ($\gamma_{04} = 14.527$, $p < .05$). This situation shows that as the teacher's expectations increase and as the student is supported by his or her family, mathematics success also increases. Considering effect size, it is expected that an increase of one standard deviation will result in the following: a 0.36 standard deviation decrease in average mathematics success in regards to students' being in economically disadvantaged schools; a 0.24 increase in standard deviation in average mathematics success in relations to teachers' understanding of gains; a 0.22 increase in standard deviation in average mathematics success with teacher's expectation variable; a 0.23 increase in standard deviation with family support for student's success variable. Concerning correlations at the school-level, it is seen that there is a negative relation ranging between -.11 and -.44 between the state of economically disadvantaged students' attendance in schools and other variables, and that there are significant relations on medium and low-levels ranging between .32 and .44 between other variables.

Considering estimates of the variance components that belong to the regression with means as outcomes model, residual variance ($\tau_{00} = 2269.320$) between schools is smaller than variance ($\tau_{00} = 3879.170$) that is obtained from the one-way-ANOVA model-with random effect. This

Table 3: Estimates of fixed effects which belong to regression with means as outcomes model

<i>Fixed effects (Model for school averages)</i>	<i>Coefficient</i>	<i>SH</i>	<i>t</i>	<i>p</i>	<i>Effect Size</i>
Average mathematics success, $\tilde{a}_{00}$	449.339	3.46	129.730	0.00*	
Schools with economically disadvantaged students, $\tilde{a}_{01}$	-22.210	3.71	7.363	0.00*	-0.36
Teachers' understanding of gains, $\tilde{a}_{02}$	15.080	5.37	3.635	0.01*	0.24
Teacher expectation for student success, $\tilde{a}_{03}$	13.180	4.71	3.972	0.01*	0.22
Family support for student success, $\tilde{a}_{04}$	14.527	4.23	3.432	0.00*	0.23

decrease is caused by including school-level features to model. τ_{00} values that are obtained from the one-way-ANOVA model with random effect and the regression with means-as outcomes model are compared. According to this result, second-level explanatory variables explain 41 percent of second-level variance. Because the chi square value is significant, four explanatory variables on the school-level do not explain variability in constants all at once ($\chi^2_{233}=1969.915$, $p<.05$).

DISCUSSION

As students' home educational resources increase, their success in mathematics also increases. In many studies (Afana et al. 2013; Akyuz 2014; Akyuz and Berberoglu 2010; Kozina 2015; Mohammadpour 2012; Nonoyama-Tarumi 2008; Phan 2008) it is stated that there is a relation between the opportunities a student has at home and his or her success. This finding explains that students whose families are not financially affluent are disadvantaged regarding mathematics success. There is a significant relation in a negative direction between family interest in school practices and student mathematics success. This shows that as family control increases, mathematics success decreases. In the study by Kilic and Askin (2013) about HLM in TIMSS 2011 mathematics applications, it was concluded that families' that ask students about what they had learnt at school did not create any difference in mathematics success among students. In addition, it was found that when families actively check whether students have completed their homework, students' mathematics success is negatively affected, meaning that these students' mathematics success were lower than those of students who were not actively monitored. This finding is consistent with the finding obtained from this research.

It is concluded that there is a significant positive relationship between students' attitude toward mathematics and mathematics success. As can be seen in these studies (Akyuz 2014; Ghagar et al. 2011; Kozina 2015; Mohammadpour 2012; Yildirim et al. 2013), the students who like mathematics more have greater success in their lessons. There is a positive relationship between student engagement in mathematics lessons and mathematics success. This finding is consistent with the results of studies conducted by Akyuz

(2014), Rimm-Kaufman et al. (2015), and Norton and Zhang (2013).

At the student-level, another variable that is related to success in mathematics is family education level. There is a positive significant relation between family education level and student mathematics success. Specifically, Akyuz (2014) and Carnoy et al. (2015) stated that there is a relationship between family education level and student success. The data obtained from this study turned out to be consistent with their findings.

It is concluded that student success in mathematics at the school-level has a highly significant relationship with variables such as schools with economically disadvantaged students, teachers' understanding of gains, teacher expectation for student success, and family support. According to results, in the schools where the ratio of disadvantaged student is less, students' mathematics success increases. This situation shows that having a family with a good economic background tends to increase a student's success in mathematics. This finding is consistent with findings obtained at the student-level. Afana et al. (2013), Yildirim et al. (2013), and Akyuz (2014) also express that schools with a majority of affluent students are more successful.

CONCLUSION

According to the result of the analysis at the student-level, as home educational resources, student engagement in mathematics lessons, attitude towards mathematics, and family education level increase, students' success in mathematics increases. It is found that as teachers' ratio of understanding of gains of the programme increases, mathematics success also increases. This situation can be interpreted as the principle that teachers' understanding of gains increases the state of earning gains.

Student engagement in mathematics lessons is actually related to features of teachers as well. A teacher's ability to give lectures, to capture students' attention during lessons, and to give students interesting things to do relating to the lesson are among professional competences that teachers should have. Teachers' competency levels may influence students' engagement and attachment to the lessons.

Variables that are chosen at the student-level explain 21 percent of variance, while variables at the school-level explain 41 percent of variance. It is seen that the unexplained differences between students is at a level above the school-level.

RECOMMENDATIONS

According to the findings from this study, giving teachers on-the-job training about understanding the gains of the programme is recommend, as is the arranging of lesson contents regarding mathematics teaching at universities. Moreover, promoting on-the-job training activities, providing undergraduate education, and continuing professional development in teachers' development of competency should each be given more importance by stakeholders in education.

The features that students' unexplained variance relates to can be determined through modelling studies. If the students who participated in TIMSS applications are contacted with interviews, information that cannot be obtained from questionnaires and variables that can explain variances at the student-level can be determined.

REFERENCES

- Afana Y, Lietz P, Tobin M 2013. The relationship between school resources and grade 8 mathematics achievement: A comparison of Palestinian Authority, Israeli Hebrew and Israeli Arab schools in TIMSS 2007. *Journal for Educational Research Online*, 5(1): 59-89.
- Akyuz G 2014. The effects of student and school factors on mathematics achievement in TIMSS 2011. *Education and Science*, 39(172): 150-162.
- Akyuz G, Berberoglu G 2010. Teacher and classroom characteristics and their relations to mathematics achievement of the students in the TIMSS. *New Horizons in Education*, 58(1): 77-95.
- Carnoy M, Khavenson T, Ivanova A 2015. Using TIMSS and PISA results to inform educational policy: A study of Russia and its neighbours, *Compare: A Journal of Comparative and International Education*, 45(2): 248-271.
- Chen Q 2013. A Multilevel Analysis of Mathematically Low-achieving Students in Singapore. *Paper presented at 5th IEA International Research Conference*, 26-28 June, National Institute of Education, Singapore.
- Foy P, Galia J, Li I (Eds.) 2013. *TIMSS 2011 User Guide for the International Database*. Chestnut Hill, MA: Boston College.
- Ghagar MN, Othman R, Mohammadpour E 2011. Multilevel analysis of achievement in mathematics of Malaysian and Singaporean students. *Journal of Educational Psychology and Counseling*, 2: 285-304.
- Hox JJ 1995. *Applied Multilevel Analysis*. Amsterdam: TT-Publicaties.
- Is Guzel C, Berberoglu G 2010. Students' affective characteristics and their relation to mathematical literacy measures in the programme for international student assessment (PISA) 2003. *Eurasian Journal of Educational Research*, 40: 93-112.
- Kilic S, Askin OE 2013. Parental influence on students' mathematics achievement: The comparative study of Turkey and best performer countries in TIMSS 2011. *Procedia-Social and Behavioral Sciences*, 106: 2000-2007.
- Kozina A 2015. Aggression in primary schools: The predictive power of the school and home environment. *Educational Studies*, 41(1-2): 109-121.
- Liou Pey Yan 2010. *Cross-national Comparisons of the Association Between Student Motivation for Learning Mathematics and Achievement Linked with School Contexts: Results from TIMSS 2007*. PhD Dissertation, Unpublished. Minneapolis: University of Minnesota.
- Milli Egitim Bakanligi 2011. *TIMSS 2007 Ulusal Matematik ve Fen Raporu (TIMSS 2007 Report of the National Math and Science)*. Ankara: Egitim Arastirma ve Gelistirme Dairesi Yayinlari.
- Mohammadpour E 2012. Factors accounting for mathematics achievement of Singaporean eighth-graders. *The Asia-Pacific Education Researcher*, 21(3): 507-518.
- Nonoyama-Tarumi Y 2008. Cross-national estimates of the effects of family background on student achievement: A sensitivity analysis. *International Review of Education*, 54(1): 57-82.
- Norton S, Zhang Q 2013. Chinese students' engagement with mathematics learning. *International Journal for Mathematics Teaching and Learning*, 5: 1-24.
- Phan Ha T 2008. *Correlates of Mathematics Achievement in Developed and Developing Countries: An HLM Analysis of TIMSS 2003 Eighth-grade Mathematics Scores*. PhD Dissertation, Unpublished. Tampa: University of South Florida.
- Raudenbush SW, Bryk AS 2002. *Hierarchical Linear Models: Applications and Data Analysis Method*. 2nd Edition. London: Sage Publications.
- Rimm-Kaufman SE, Baroody AE, Larsen RAA, Curby TW, Abry T 2015. To what extent do teacher-student interaction quality and student gender contribute to fifth graders' engagement in mathematics learning? *Journal of Educational Psychology*, 107(1): 170-185.
- von Secker CE, Lissitz RW 1999. Estimating the impact of instructional practices on student achievement in science. *Journal of Research in Science Teaching*, 36(10): 1110-1126.
- Yildirim HH, Yildirim S, Ceylan E, Yetisir I 2013. *Türkiye Perspektifinden TIMSS 2011 Sonuçları (Results of TIMSS 2011 from Turkey's perspective)*. May, TED-MEM Analiz Dizisi I, Ankara.

APPENDIX

Explanations on chosen variables at student and school level

<i>Student level</i>	
<i>Home Educational Resources</i>	To have a computer, worktable, books, and internet access and to have their own room (state of having "2", state of not having "1")
<i>Student's Attitude Towards Mathematics</i>	a) I enjoy learning mathematics, b) I wish I did not have to study mathematics, c) Mathematics is boring, d) I learn many interesting things in mathematics, e) I like mathematics, f) It is important to do well in mathematics ("4" Agree a lot, "1" Disagree a lot) Cronbach alpha: 0.81*
<i>Family Interest Regarding School Practices</i>	a) My parents ask me what I am learning in school, b) I talk about my schoolwork with my parents, c) My parents make sure that I set aside time for my homework, d) My parents check if I do my homework ("4" every day or almost every day, "1" never or almost never) Cronbach alpha: 0.70*
<i>Student Engagement in Mathematics Lessons</i>	a) I know what my teacher expects me to do, b) I think of things not related to the lesson, c) My teacher is easy to understand, d) I am interested in what my teacher says, e) My teacher gives me interesting things to do ("4" Agree a lot, "1" Disagree a lot) Cronbach alpha: 0.60**
<i>Family Education Level</i>	Not to go to primary school and secondary school "1", secondary school "2", high school "3", university or college "4" and masters/ doctorate "5"
<i>School level</i>	
<i>Percentage of Economically Disadvantaged Students</i>	Between 0% and 10% "1", between 11% and 25% "2", between 26% and 50% "3" and higher than 50% "4"
<i>Teachers' Understanding of Gains in School Programme</i>	The state of teachers' understanding of gains / teacher expectation / family support; very low "1", low "2", average "3", high "4" and very high "5"
<i>Teacher Expectation for Student Achievement</i>	
<i>Family Support for Student Achievement</i>	

* It is the coefficient of internal consistency regarding items. It shows that items represent a homogenous structure, measure only one feature, meaning that reliability of the items is quite good.

** This value's being at an acceptable level point out that items represent a structure that can be counted as homogenous, meaning that the reliability of the items is at an acceptable level.