The Effects of School and Students' Educational Contexts in Korea, Singapore, and Finland using TIMSS 2011

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Abstract

In order to obtain adequate amount of information on what the students have achieved and how students can improve their learning, it is necessary to understand the educational contexts where the learning takes place. In this study, the structural relation between students' mathematics achievement and educational context variables were examined among three countries including Korea, Singapore and Finland using TIMSS 2011 data. The educational contextual variables were selected from the questionnaires for school principals, teachers and students to analyze the intended curriculum of each country. Having mathematics achievement score as an indicator of attained curriculum, this study tries to model the school effectiveness and examine which factors most affect mathematics achievement. A 2-level model of student and school were analyzed. In result, this study found out the educational contextual characteristics of high performance and reasons why these countries outperformed other countries well in spite of many involved factors, and the social and cultural differences between countries.

Key words: Context variables, TIMSS 2011, Mathematics achievement

Introduction

Purpose and educational Significance of the study

Many countries in the world are making efforts to improve their students' achievements as well as their educational systems by establishing quality control systems that monitor educational outcomes: at the national level by implementing national level achievement tests, and at the international level by participating in international studies of student assessment. TIMSS has been a very important quality monitoring system in Korea as it indicates the placement of our students with respect to other countries. In order to obtain an adequate amount of information concerning student achievement and improvements to their learning, it is necessary to understand the educational contexts where the learning takes place. From this standpoint, TIMSS conceptualizes the student achievement model through intended curriculum, implemented curriculum, and attained curriculum in order to explain their achievement level. In this study, the structural relationships between student mathematics achievement and the educational context variables will be examined using TIMSS 2011 data with respect to three countries: Korea, Singapore, and Finland.

Theoretical framework

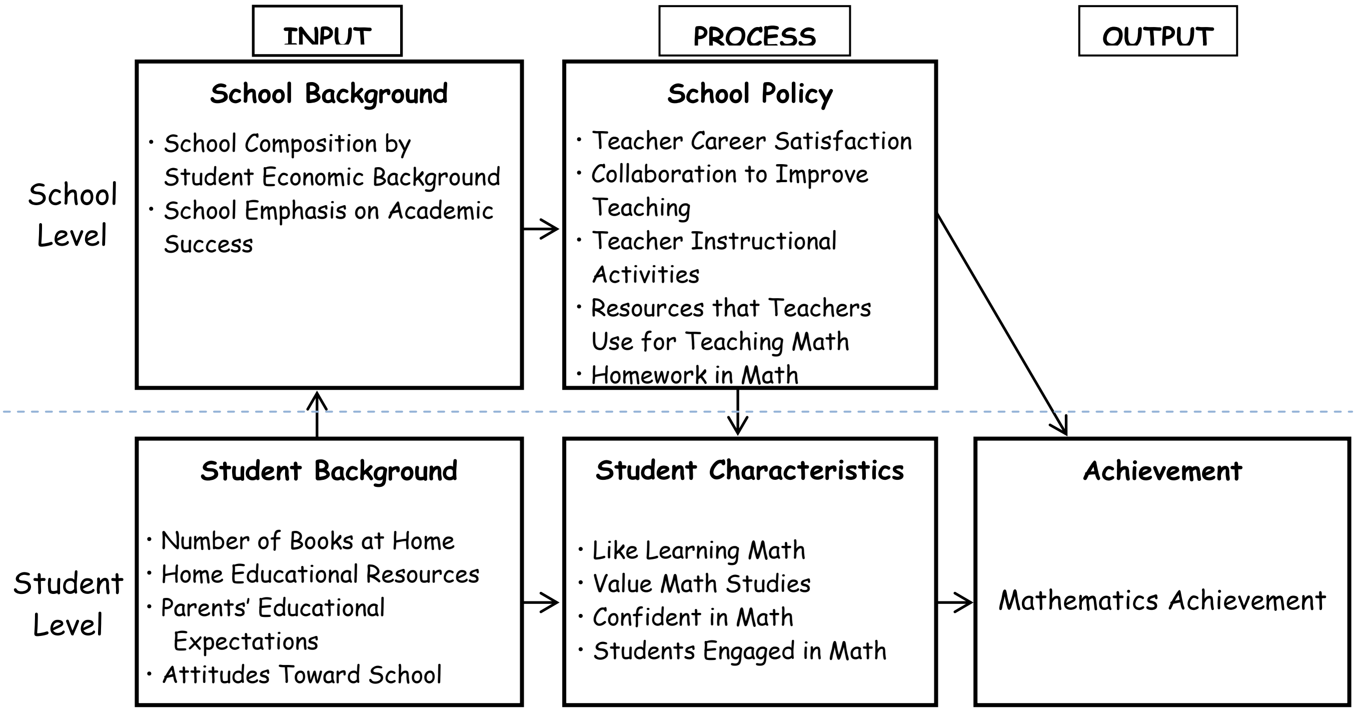
One of the main traditional research areas is the exploration of the student, teacher, and school variables that affect students' academic achievement. Studies on educational contextual variables have been conducted constantly in the U.S. and England since the 1960's. Although studies on the effects of specific variables in various subjects have been conducted internally, research simultaneously considering diverse variables was not systemically organized until the 2000's. Many studies have been conducted to examine the effect of school and teachers in western countries (Coleman et al., 1966; Akiba et al., 2007), but not much research has been conducted to analyze and compare the effects in Asian countries. This study would attempt to obtain implications for the setting of study models and the conducting of research by reviewing the characteristics of preceding studies on the effects of educational contextual variables and by conducting school-effect analysis utilizing the TIMSS 2011 assessment of academic achievement.

Research method

Data sources

To analyze the effects of the educational contextual variables of student, instruction, and teacher-level on achievement, we used the results of the TIMSS 2011 for Korea, Singapore, and Finland. These countries have a set of common characteristics: they are Asian countries; they exhibit high mathematics performance; and they present a low level of affective domains (confidence in and enjoyment of mathematics). The target students of this study are those in fourth and eighth grades. The sampled students took the mathematics and science tests for two hours after being allocated to one of fourteen test booklets by matrix sampling.

The educational contextual variables were selected from the questionnaire for school principals, teachers, and students in order to analyze the intended curriculum of each country. Using the mathematics achievement score as an indicator of an attained curriculum, this study attempts to model school effectiveness and examines which factors affect mathematics achievement the most.



[Figure 1] The school effectiveness model

For the student background variables, Number of Books at Home, Home Educational Resources, Parents' Educational Expectations, and Attitudes toward School were selected. For the student characteristics, variables from the student questionnaire were selected, such as Like Learning Math, Value Math Studies, Confident in Math, and Students Engaged in Math. School level variables were selected from the teacher questionnaire as well as the school questionnaire. For the school background model, variables from the school questionnaire were selected, such as School Composition by Student Economic Background and School Emphasis on Academic Success. School policy variables were also selected, such as Teacher Career Satisfaction, Collaboration to Improve Teaching, Mathematics Instructional Activities, and Resources Teachers Use for Teaching Math.

Data

The TIMSS 2011 data were used for the HLM analysis. The numbers of students and math teachers in each country are summarized in Table 1 for the fourth grades and in Table 2 for the eighth grades.

<Table 1> Data for Grade 4

Country	Country Code	Math achievement	SD	N of Students
Korea	410	605	68	4494
Singapore	702	606	78	6687
Finland	246	545	68	4917

<Table 2> Data for Grade 8

Country	Country Code	Math achievement	SD	N of Students
Korea	410	613	90	5315
Singapore	702	611	84	6314
Finland	246	514	65	4549

Analysis method and procedure

With respect to the analytical method applied to the structural and hierarchical characteristics of the data, a 2-level model of student and school was analyzed, utilizing the statistics program HLM 6.0 (Hierarchical Linear Modeling)(Raudenbush et al., 2006). The two-level model that was analyzed first included data from the students, and then data from the teachers and schools at the second level.

The first step in the analysis estimates the proportion of student-level variance (σ^2) to school-level variance (τ_{00}) among the variances of total mathematics achievement by setting the base model without any explanatory variables. This makes it possible to identify variance size caused by gaps among schools in students' mathematics achievement. The multilevel model with the explanatory variables is as follows:

[Level 1 model: students]

$$Y_{ij} = \beta_{0j} + \beta_{1j} X_{1ij} + \ldots\ldots + \beta_{qj} X_{qij} + r_{ij} \qquad r_{ij} \sim N(0, \sigma^2)$$

The Level 2 model is the school level, and γ_{00} is the total mean of all samples. $u_{0j} - N(0,\tau)$ represents the difference between the total mean and jth schools' mean, which explains the school effect. β_{qj} is assumed to be unaffected by school level variables.

[Level 2 model: School]

$$\beta_{0j} = \gamma_{00} + \gamma_{01}Z_{01} + \cdots + \gamma_{0j}Z_{0j} + u_{0j},\ \ u_{0j} - N(0,\tau),\ \ \beta_{qj} = \gamma_{q0}$$

Then, using the Random Intercept Model (Bryk & Raudenbush, 1992; Kreft & de Leeuw, 1998), we can set a four-step research model by putting student, teacher, and school level variables in consecutive order. By putting the explanatory variables of each level into the model sequentially, the extent to which input variables explain variances at each level can be identified through the ratio of the additional explanatory variances. In addition, the variables that affect mathematics achievement can be examined and compared across the three countries.

The HLM model of this research is explained in Table 3. According to the hypothesis, a baseline model without the explanatory variables was set up and the total variance of mathematics variance was divided into school level and student level. The intra-class correlation (ICC) - that is, the school level variance among the total variance - was calculated. After testing the baseline model, in Step 1, the student background variables were included in the baseline model. Model 2 was then set up by including the students' characteristics variables for Step 2. In Step 3, school backgrounds that explain school environments were added to Model 2. In the last step, school policy variables were included that explain school characteristics as well as school decisions. To test the school effects of each country, according to the model, the explanatory variables were added sequentially. Using Model 4 (the final model), the effects of each explanatory variable and its significance were reported.

<Table 3> Analysis model and Input Variables

Step	Model	Input variables
Baseline	Model 0	NA
Step 1	Model 1	Student Background
Step 2	Model 2	Student Background + Students Characteristics
Step 3	Model 3	Student Background + Students Characteristics +School Background
Step 4	Model 4	Student Background + Students Characteristics + School Background + School Policy

Results

Variance of Explained

In Table 4, the intra-class correlation (ICC) attributable to schools and the proportion of variances explained by the HLM models are summarized together with the model which showed the best fit. In general, the ICC was various for three countries. Table 4 includes the variance of the baseline model of fourth grades mathematics achievement.

<Table 4> Variance of Baseline Model of Mathematics Achievement for Grade 4

		Korea, Rep. of		Singapore		Finland	
		Variance	(%)	Variance	(%)	Variance	(%)
Model 0	Student Level	4230.1	(90.8)	4541.5	(76.0)	4033.2	(88.9)
	School Level	426.9	(9.2)	1435.0	(24.0)	504.2	(11.1)
	total	4657.0	(100.0)	5976.5	(100.0)	4537.4	(100.0)
ICC		0.092	(9.2)	0.240	(24.0)	0.111	(11.1)

The ICCs varied from 9.2 to 24.0. Korea has the least school variance with 9.2, while Singapore has the greatest ICC with 24.0. Compared to other countries, Korea has a very low level of school influence on math achievement.

<Table 5> Variance of Baseline Model of Mathematics Achievement for Grade 8

		Korea, Rep. of		Singapore		Finland	
		Variance	(%)	Variance	(%)	Variance	(%)
Model 0	Student Level	7093.2	(91.6)	3967.4	(57.5)	3661.6	(87.2)
	School Level	650.3	(8.4)	2936.1	(42.5)	538.6	(12.8)
	total	7743.5	(100.0)	6903.5	(100.0)	4200.2	(100.0)
ICC		0.084	(8.4)	0.425	(42.5)	0.128	(12.8)

The ICC of the three countries for Grade 8 also varied from 8.4 to 42.5. Korea has the least school variance with 8.4, and Singapore has the greatest ICC with 42.5. Finland has an ICC of 12.8, second lowest among the three countries. Compared to other countries, Korea has a very low level of school influence on math achievement.

As each explanatory variable is included in each model, the percentage of variance changes compared to the previous step is explained in Table 6.

<Table 6> Variance of each Model of Mathematics Achievement for Grade 4

		Korea, Rep. of		Singapore		Finland	
		Variance	(% of change)	Variance	(% of change)	Variance	(% of change)
Within School	Model 1	3730.2	(11.8)	4322.6	(4.8)	3746.6	(7.1)
	Model 2	2988.3	(29.4)	3561.7	(21.6)	2910.0	(27.8)
	Model 3	2988.0	(29.4)	3561.5	(21.6)	2914.4	(27.7)
	Model 4	2987.7	(29.4)	3561.4	(21.6)	2915.2	(27.7)
Between School	Model 1	212.5	(50.2)	1167.2	(18.7)	465.0	(7.8)
	Model 2	297.8	(30.2)	1218.7	(15.1)	536.9	(-6.5)
	Model 3	225.6	(47.2)	956.6	(33.3)	433.9	(13.9)
	Model 4	198.9	(53.4)	964.7	(32.8)	341.5	(32.3)

Table 6 summarizes the percentage of changing variance from the previous model after adding Model 1 to the explanatory variables sequentially from Model 1 to Model 4. For the Grade 4 data, based on Model 4 with all the variables added, Korea has an changed variance of 53.4 percent.

<Table 7> Variance of each Model of Mathematics Achievement for Grade 8

		Korea, Rep. of		Singapore		Finland	
		Variance	(% of change)	Variance	(% of change)	Variance	(% of change)
Within School	Model 1	6201.6	(12.6)	3818.2	(3.8)	3218.4	(12.1)
	Model 2	4130.2	(41.8)	3253.6	(18.0)	2041.1	(44.3)
	Model 3	4131.9	(41.7)	3253.4	(18.0)	2040.7	(44.3)
	Model 4	4128.0	(41.8)	3253.3	(18.0)	2040.5	(44.3)
Between School	Model 1	396.8	(39.0)	2738.1	(6.7)	478.8	(11.1)
	Model 2	581.5	(10.6)	2780.5	(5.3)	563.1	(-4.5)
	Model 3	342.5	(47.3)	2152.0	(26.7)	493.2	(8.4)
	Model 4	271.2	(58.3)	1989.7	(32.2)	487.2	(9.5)

For the Grade 8 data, based on Model 4 with all the variables added, Korea has an changed variance of 58.3 percent, Singapore 32.2 percent, and Finland 9.5 percent.

This study reviewed the variables affecting mathematics achievement with respect to variables related to student background and characteristics, as well as the school's characteristics. Considering the variables in student background, the number of books at home has a positive influence on math achievement for all three countries. Interestingly, parents' educational expectations have a negative influence on math achievement for all three countries. Only for Finland, where the attitudes toward schools are better, does academic achievement increase. In the case of home educational resources, only Singapore showed a significant influence on mathematics scores.

For the student characteristics variables, students' confidence in mathematics was a significant predictor of student achievement in mathematics for all three countries. Only for Korea and Singapore, there was a positive effect on mathematics scores for students' value of mathematics. For Finland only, students liking of math and students engagement in math negatively influenced math achievement.

Among school background variables, School Composition by Student Economic Background positively influenced math achievement for Korea and Singapore. Except for Korea, however, School Emphasis on Academic Success has a significant influence on mathematics scores. For school policy, only Korea has a negative influence on mathematics scores for homework. The number of Mathematics instructional activities negatively affects mathematics achievement in Finland only.

<Table 8> G4 HLM Analysis Summary

Variables		Korea, Rep. of		Singapore		Finland	
		Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error
	Intercept	536.06***	(17.54)	528.12***	(23.89)	513.31***	(10.88)
Level-1 Students							
Student Background	Number of books in the Home	13.89 ***	(1.66)	10.67 ***	(1.02)	11.50 ***	(1.43)
	Home Educational Resources	3.87	(2.44)	3.30 *	(1.49)	3.27	(2.99)
	Parents' Educational Expectations	-4.15 *	(1.93)	-3.85 **	(1.19)	-9.65 ***	(2.08)
	Attitudes Toward School	2.32	(4.60)	1.28	(1.52)	11.05 ***	(2.43)
Student Characteristics	Like Learning Math	-0.11	(1.57)	-0.16	(0.64)	-3.31 **	(1.02)
	Value Math	5.87 **	(1.99)	9.12 ***	(1.83)	-1.35	(1.94)
	Confident in Math	19.85 ***	(1.63)	13.40 ***	(0.61)	17.08 ***	(0.85)
	Students Engaged in Math	-1.27	(1.42)	0.05	(0.63)	-2.73 *	(1.16)
Level-2 Schools							
School Background	School Composition by Student Economic Background	12.08 **	(3.63)	19.35 ***	(3.79)	6.20	(3.79)
	School Emphasis on Academic Success	-1.19	(1.17)	4.11 **	(1.34)	5.58 **	(1.80)
School Policy	Teacher Career Satisfaction	-0.23	(1.41)	0.04	(2.06)	-2.57	(1.75)
	Collaboration to Improve Teaching	-0.27	(1.08)	-2.17	(2.30)	2.30	(1.99)
	Mathematics Instructional Activities	6.42	(5.76)	1.81	(6.80)	-20.95 *	(8.59)
	Resources Teachers that Use for Teaching Math	9.93	(8.46)	-8.05	(11.74)	25.57	(13.99)
	Homework	-6.52 *	(3.02)	7.12	(4.52)	2.26	(7.00)
Reliability		0.668		0.905		0.800	

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

Considering the variables in student background, the number of books at home has a positive influence on math achievement for Korea and Singapore. The home educational resources have a positive influence on math achievement for Singapore and Finland, but differing from educational resources, parents' educational expectations have a negative influence on math achievement for Singapore and Finland. For Korea and Finland, where the attitudes toward schools are better, academic achievement increases.

For the student characteristics variables, in common with the Grade 4 result, students' confidence in mathematics was a significant predictor of student achievement in mathematics for all three countries. Only for Korea and Finland, was there a positive effect from students' value of mathematics on mathematics scores. For Singapore only, students' liking for math positively influenced math achievement. Students' engagement in math negatively influenced math achievement in all but Korea.

Among the school background variables, School Composition by Student Economic Background positively influenced math achievement for Korea and Singapore. It is the same result as the Grade 4 students. Except for Korea, however, School Emphasis on Academic Success significantly influences mathematics scores. For school policy, only in Korea do Mathematics instructional activities have a positive influence on mathematics scores. In Singapore, Teacher career Satisfaction has a positive influence, but the Resources that Teachers Use for Teaching Math has a negative influence on math achievement. Only for Finland, as the number of homework increases, the math achievement score increases as well.

<Table 9> G8 HLM Analysis Summary

Variables		Korea, Rep. of			Singapore			Finland		
		Coefficient		Standard Error	Coefficient		Standard Error	Coefficient		Standard Error
	Intercept	586.26***		(24.54)	609.44***		(37.34)	491.03***		(17.27)
Level-1 Students										
Student Background	Number of books in the Home	9.83	***	(2.66)	4.18	*	(1.49)	3.04		(1.54)
	Home Educational Resources	3.80		(2.85)	3.99	**	(1.18)	6.22	***	(1.15)
	Parents' Educational Expectations	-4.39		(3.37)	-5.50	**	(1.35)	-8.51	***	(1.12)
	Attitudes Toward School	6.48	*	(3.03)	3.51		(1.75)	5.80	***	(1.47)
Student Characteristics	Like Learning Math	1.84		(2.39)	3.10	***	(0.76)	1.11		(0.81)
	Value Math	6.81	***	(1.68)	0.07		(0.67)	1.67	*	(0.72)
	Confident in Math	24.75	***	(2.26)	10.82	***	(0.70)	16.66	***	(0.58)
	Students Engaged in Math	0.21		(1.32)	-3.60	***	(0.84)	-4.55	***	(0.91)
Level-2 Schools										
School Background	School Composition by Student Economic Background	18.42	***	(3.92)	25.21	***	(6.24)	7.48		(4.28)
	School Emphasis on Academic Success	1.44		(1.18)	6.67	***	(1.60)	5.70	**	(1.66)
School Policy	Teacher Career Satisfaction	3.56		(2.19)	7.23	**	(2.41)	-0.41		(1.41)
	Collaboration to Improve Teaching	1.36		(1.40)	1.01		(3.22)	-0.09		(1.77)
	Mathematics Instructional Activities	21.74	**	(8.15)	8.58		(14.84)	2.63		(8.21)
	Resources Teachers that Use for Teaching Math	-9.44		(14.33)	-55.07	*	(26.73)	-16.03		(11.14)
	Homework	-3.80		(2.84)	12.72		(7.23)	8.02	*	(3.76)
Reliability		0.721			0.956			0.857		

*: *p* < .05, **: *p* < .01, ***: *p* <.001

Summary and Conclusion

According to the process above, the mathematics achievement results of TIMSS 2011 in Korea, Singapore, and Finland were analyzed with the same method of data conversion and model. This study attempted to compare the structural relationships between students' achievement and the contextual variables among these high achieving countries. Through this study using multilevel models, we discovered whether it is possible to explain the cross-national differences in students' performance in mathematics. Both similarities and differences were found with regard to predictors at student and school level in student performance in mathematics.

Analyzing the trends that appeared in both Grades 4 and 8, among the student background, student characteristics, and school background, it was discovered that there were some similarities between the two grades. There were, however, no similarities in school policy variables for the three countries. In the case of Korea and Singapore, the Number of Books at Home had a positive effect on mathematics achievement for both Grades 4 and 8. This means that home with more study materials in Asian countries can affect their students' performance. For Finland, the Number of Books at Home had a positive effect for only Grade 4. Parents' Educational Expectations had a negative influence for Grade 4 in all three countries, while it did not significantly affect the performance of Grade 8 students in Korea. This is a peculiar result that parents' excessive expectations can have a bad influence on students. In Korea, the effect of Attitudes toward School for Grade 4 was also not significant, while it had a positive influence in the case of Grade 8.

Liking Learning Math had a negative influence for Grade 4 only in Finland, while it had a positive influence for Grade 8 only in Singapore. Valuing Math had a positive influence on both grades in Korea. Confidence in Math had a positive effect on achievement for both Grades 4 and 8 in all three countries, and the coefficient was the largest in Korea for both grades. More learning and teaching methods should be developed to improve students' confidence, so that this can affect students' mathematics achievement. One of the interesting results was that in Finland, Students Engaged in Math had a negative influence for both Grades 4 and 8. Further study is needed to examine these results.

School background showed the same pattern for Grade 4 and Grade 8 in all three countries. Economic Background positively affected achievement for both grades in Korea and Singapore, and so did School Emphasis on Academic Success in Singapore and Finland. Among the school policy variables, Mathematics Instructional Activities had a negative influence on Grade 4 only in Finland, while it had a positive influence on Grade 8 only in Korea. In contrast, Homework had a negative influence on Grade 4 only in Korea, while it had a positive influence on Grade 8 only in Finland.

These results could provide better opportunities for explaining differences among the countries in achievement. Moreover, this study could discover the educational contextual characteristics of high performance and some reasons why these countries outperformed other countries in spite of many involved factors, and the social and cultural differences among countries. This study also provided the difference in contextual effects between grade 4 and grade 8 for three countries, which presented another important information about how the contextual effects on mathematics achievement changed.

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