Factors Affecting Mathematics Achievement: International Comparisons of PISA 2003 in Korea, Japan, and Finland

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Abstract: This study investigates the factors affecting the mathematics performance of 15-year-old students in the Program for International Student Assessment (PISA) 2003 data across different cultural settings using hierarchical linear modeling. Three high ranked countries in the PISA 2003 data were selected for a comparison of cultural differences: Korea, Japan, and Finland. Although all three countries' student performances were similarly high, significant differences existed in factors affecting students' performance. The factors studied were student-, teacher-, and school-related variables. In Korea and Japan, 40% of the variance in mathematics achievement was explained by school differences, in contrast to only 4% in Finland. All three countries showed that the student's motivation and negative class atmosphere significantly affected achievement. Positive teacher-student relations did not affect achievement in Korea and Japan, and affected negatively in Finland. Although the effect of a family's socio-economic background on national achievement was less than the OECD average, it still had a significant effect on student achievement in Korea and Finland. This study examined how all of these variables affected mathematics achievement. These findings were discussed with reference to cultural contexts.
Keywords: math achievement, cultural differences, motivation, international comparison

Introduction

Academic achievement is one of the key indicators for measuring the outcome of education. As countries strive to improve their students' academic performance, the need for comparative research has emerged. The most representative research within international comparison research is the Program for International Students Assessment (PISA) launched by the Organization for Economic Cooperation and Development (OECD). PISA seeks to measure the academic performance of 15-year-old students in mathematics, reading, science and problem solving.

Korea showed high academic performance, ranking third in mathematics, and has been recognized as an exemplary example of succeeding both in educational excellence and equality by showing only small differences in performance among socio-economic statuses (OECD, 2004a). However, little research has investigated how Korea achieved this high performance or analyzed which factors affect achievements by comparing different countries. This study investigated the student-, and school-related variables influencing academic

achievement and compared how these variables differently affected the mathematics performances of three high-ranking countries in the PISA 2003: Korea, Japan, and Finland.

The social and cultural factors affecting academic performance have been explored. The factors affecting academic performance can be categorized into two: (1) individual- and family- related variables and; (2) school-related variables. The key variables for the individual- related variables mainly researched are motivation (Deci & Ryan, 1985), sense of belonging at school (Finn, 1989; Jenkins, 1995), and teacher-student relationship. Research also has shown that when parents' socio-economic status is higher (Davis-Kean, 2005; Hill, 2001; Halle, 1997), and when parents possess greater cultural assets (Devis-Kean, 2005; Feldman & Wentzel, 1990), student achievement is higher.

The literature also indicates some major findings involving the effect of school-related variables on students' achievement; for instance, significant and positive causal relations within productive school cultures, teachers' morale, and high expectations of students performance (Kim, Namgung & Kang, 2004; Levine & Lexotte, 1990; Smith & Purkey, 1983).

In the present study, three student level variables and three school level variables were considered as affecting student performance. The student level variables were composed of motivation, teacher-student relation, and parents' socio-economic status; the school level variables were composed of negative class atmosphere, teacher's morale, and school resources. Korea, Japan, and Finland were compared with regard to how the above variables affected student achievements, and social and cultural explanations of the differences between these countries were explored.

Research Method

Participants

In this study, the PISA 2003 data was analyzed to target 15-year-old middle school students' in Korea, Japan, and Finland. The PISA 2003 data included 5,444 students in Korea, 4,707 students in Japan, and 5,796 students in Finland. The sampling weights were applied to data analysis to get representative comparisons among the countries.

Measured Variables

The PISA data provided raw survey data as well as the variables itemized using Item Response Theory (IRT) scaling methods, and indexed values for the different sets of variables. The student level variables included in this study were the students' perceived teacher-student relationship and the parents' socio-economic status index, as well as motivational variables including interest in mathematics, instrumental motivation for mathematics, and the self-efficacy in mathematics (see Table 1).

Table 1: *Independent variables*

Level	Variables	Sub-variables: Code of variables used from PISA data	Explanation
Student level	Motivation in mathematics	INTMAT	Interest in mathematics
		INSTMOT	Instrumental Interest in mathematics
		MATHEFF	Self efficacy
	Teacher-student relation	STUREL	Students' perceived teacher-student relation
	Parents' socio, economic, cultural status index	ESCS	Parents occupation and education, resources related to academic activities
School level	Negative class atmosphere	MSTREL	Negative class atmosphere
	Teachers' endeavor	TCMORALE	Teacher's morale
		TCHCONS	The consent between teachers
		TCHPARTI	Participation in school decisions
	School resources	SCMATBUI	Principal's perceived quality of physical resources
		SCMATEDU	Principal's perceived quality of humane resources

For the school level variables, three variables were included: negative class atmosphere, mathematics teachers' levels of endeavor (composed of the teachers' morale and the consent between teachers and participation in school decisions), and the principals' perception about the quality of school physical and humane resources. The variables were factor scores between two or three sub-variables scores used in PISA data. In addition, all variables were converted to standardized z scores to interpret the results.

The independent variable was the math achievement score. A composite score of four sub-area performance scores using all five plausible values was used for analysis.

Research Model and Data Analysis

The Hierarchical Linear Model was used to analyze the multilevel PISA data. The Base Model (null model) was established to confirm the size of variance existing in each level, and the research model was established by entering independent variables into an equation for studying the research questions. The only constant had a random effect, and the other intercepts had a fixed effect in the school level model. The specific explanations concerning the models were as follows.

Base Model

Student- level model (within school model)

$$Y_{ij}(math\_achive) = \beta_{0j} + \varepsilon_{ij} \quad , \qquad \varepsilon_{ij} \sim N(0, \sigma^2)$$

School-level model (between schools model)

$$\beta_{0j} = \gamma_{00} + u_{0j} \quad , \qquad u_{0j} \sim N(0, \tau)$$

Research Model

Student- level model (within school model)

$$Y_{ij}(math\_achive) = \beta_{0j} \cdot (motiv\_math) + \beta_{2j} \cdot (STUREL) + \beta_{3j} \cdot (ESCS) + \varepsilon_{ij} \ , \ \varepsilon_{ij} \sim N(0, \sigma^2)$$

School-level model (between schools model)

$$\beta_{0j} = \gamma_{00} + \gamma_{01} \cdot (MSTREL) + \gamma_{02} \cdot (teachers\_endeavor) + \gamma_{03} \cdot (school\_resaurce) + u_{0j} \ ,$$

$$u_{0j} \sim N(0, \tau)$$

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Research Results

Base Model

Table 2 illustrates how mathematics achievement scores were attributable to student differences. As shown in Table 2, 40% of the variance in mathematics achievement in Korea and Japan were explained by differences between schools. The fact that the Intraclass Correlation (ICC) exceeded 0.4 suggested the appropriateness of explaining mathematics achievement by considering both the student and school level factors. In the case of Finland, the ICC was 0.04, indicating that the variance of mathematics achievement score was substantially explained by student level variables rather than school level variables.

Table 2: *Base Model*

	Korea		Japan		Finland	
	Regression coefficient	Standard error	Regression coefficient	Standard error	Regression coefficient	Standard error
Mathematics mean score	541.37***	5.06	531.35***	6.34	544.72***	1.87
Variance						
Student level	4880.31 (57.8%)		4664.95 (46.7%)		6865.76 (95.8%)	
School level	3559.39 (42.2%)		5532.50 (53.3%)		304.54 (4.2%)	
Total	8439.7		10017.45		7170.3	

Research Model

Table 3 shows the result of entering independent variables into each student and school level equations in the base model. For Korea, students' motivation and family socio-economic backgrounds significantly affected mathematics achievement scores at the student level, whereas negative class atmosphere and school resources influenced the math score at the school level. For Japan, only motivation significantly affected math achievement at the student level, while negative class atmosphere and teacher's endeavor affected the average school mathematics score. For Finland, all three of the student level variables (motivation, teacher-student relationship, and family socio-economic background), significantly affected mathematics performance, whereas only negative class atmosphere among the school level variables affected the average school mathematics performance score.

Table 3: *Research Model*

	Korea		Japan		Finland	
	Regression coefficient	Standard error	Regression coefficient	Standard error	Regression coefficient	Standard error
Mathematics mean score	540.74***	3.53	530.62***	4.64	546.48***	1.59
Student level						
Motivation	30.61***	1.11	23.37***	1.28	35.69***	1.46
Teacher-student relation	-1.87	1.10	-2.49	1.54	-4.85***	1.24
Family background	8.74***	1.32	2.32	1.29	20.10***	1.18
School level						
Negative class atmosphere	-13.97**	3.85	-30.57***	4.48	-3.23*	1.40
Teachers' endeavor	2.86	4.47	15.97**	4.71	-0.50	2.19
School resources	9.47*	4.10	-3.96	4.74	0.40	1.60
Explained variance R^2						
Student level	0.157		0.089		0.264	
School level	0.510		0.457		0.316	
Total	0.306		0.285		0.266	

Discussion

In Korea and Japan, 40% of variance in mathematics achievement were explained by schools differences; in sharp contrast, only 4% of the variance in mathematics achievement is explained by school differences in Finland. The reason why Finland displayed small differences between school mathematics performances may be explained by its education policy, which emphasizes the support of low achievement students, minimizing the achievement difference between schools, and supporting public and private school equally (OECD, 2004b). On the other hand, Japan and Korea show large achievement differences between private and public schools (OECD, 2004a).

The data from all three countries illustrated that student motivation had a significant effect on mathematics performance. All those three countries stood out among the OECD countries because their average mathematics performance in high despite low motivation levels (OECD, 2004a). However, this present study suggested that motivation was actually

the most important explanatory factor in individual differences of mathematics achievement in Korea , Japan and Finland.

In contrast to the expectation, positive teacher-student relations did not affect achievement in Korea and Japan, and affected negatively in Finland. The teachers' support and strong interest might be interpreted as a psychological burden by the student in Finland, and therefore might have a negative effect. Thus, future research is needed to study how intermediate factors effect teacher-student relations and student achievement.

Although the overall effect of socio-economic background on national achievement was less than the OECD average, its effect on student achievement was also significant in Korea and Finland. Korea expends 2.88% of its GDP in providing private education, ranking at the top among the OECD countries (OECD, 2006**).** Finland's expenditure on private education is only 0.11 % of its GDP, a relatively low ratio. However, despite the fact the education expenditure is low in Finland, the effect of socio-economic background was significant. It is known that the competition to enter prestigious universities is also intense in Finland. This result may be interpreted as meaning that and a few Finnish families pursue private education and this may result in the difference of mathematics achievement among students in Finland.

For all three countries, a negative class atmosphere harmed achievement, especially in Japan. This result suggests that Japan's collective culture would be associated with students being strongly influenced by a negative atmosphere.

The teachers' level of endeavor only had a significant effect in Japan. This result may be due to differences in the teachers working in the different school types and locations in Japan (Yun & Lee, 2006).

The extent of the affluence of school resources as perceived by the principal significantly affected school mathematics achievement only in Korea. This finding may be due to the large differences in socio-economic status between schools according to school types and locations especially in Korea (OECD, 2004; Yun & Lee, 2006).

The fact that specific social, cultural factors were not included in 2003 PISA data limits its ability to enable the understanding of how different cultural and social differences affected students academic achievements; thus, further research would benefit from including consideration of educational and cultural factors.

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