Journal of the Korea Society of Mathematical Education Series D: Research in Mathematical Education
Vol. 7, No. 2, December 2003, 247–270

韓國數學敎育學會誌 시리즈 D: <數學敎育硏究>
제 7 권 제 4 호 2003 년 12 월, 247–270

Using Structural Equation Modeling to Fit a Model of Student Background, Teacher Background, Home Environment, and a School Characteristic to Mathematics Achievement on the TIMSS

Cho, Gyu-Pan
Department of Education, Dong-A University, 840 Hadan2-dong, Saha-gu, Busan 604-714, Korea
Email: gyupancho@hotmail.com

(Received November 27, 2003 and, in revised form, December 15, 2003)

The purpose of this study is to build a model that explains the relationship between and among five variables that are student background, teacher background, home environment, school characteristic, and student mathematics achievement, using structural equation modeling. Another purpose of this study is to compare the relationships of these variables between the United States and Korea in 7th and 8th grades mathematics. Student, teacher, and school background files from population 2 in the TIMSS were selected for this study. The result of the study provides practical information for teachers, parents, school principals, and other people who are interested in improving student achievement, and also provides the information that may explain differences and similarities between the US and Korea in mathematics achievement.

Keywords: Structural Equation Modeling (SEM), student and teacher, home and school.
ZDM classification: C73
MSC2000 classification: 97D60

I. INTRODUCTION AND LITERATURE REVIEW

A primary goal in education is to improve student academic achievement. In order to improve student academic achievement, it is necessary to study the factors that affect it. In the past several decades, a number of efforts have produced a variety of proposals for improving student learning and academic achievement. Researchers have tried to find the factors that affect student academic achievement, including student background, teacher background, teaching practices, curricula, class-room climates, home environment, and school environments.

The International Association for the Evaluation of Educational Achievement (IEA) has conducted a number of multinational studies on educational achievement. The most recent set of studies, by the IEA, is the Third International Mathematics and Science Study (TIMSS), which is the largest and most ambitious international comparative study of student achievement to date (Martin 1996). The TIMSS was designed to investigate students' learning of mathematics and the sciences internationally in forty-five countries.

A major focus of the TIMSS is comparing what students have learned in terms of their performance on the TIMSS achievement tests. However, beyond such comparisons the data can be used to investigate other factors associated with student learning (Schmidt & Cogan 1996). In order to obtain information about the contexts of learning in the environment in mathematics and science, the TIMSS researchers included questionnaires for the students, their mathematics and science teachers, and the principals of their schools. The students, their teachers, and the principals of their schools were asked to respond to questionnaires about their backgrounds, attitudes, experiences, and teaching practices (Martin & Kelly 1997). Descriptions of the content for the three questionnaires, which represent students' context, are as follows.

> *The student questionnaire* addresses students' attitudes towards mathematics and science, parental expectations, and out-of-school activities. Students also were asked about their classroom activities in mathematics and the sciences, and about the courses they had taken. A special version of the student questionnaire was prepared for countries where physics, chemistry, and biology are taught as separate subjects. Although not strictly related to the question of what students have learned in mathematics or science, characteristics of pupils can be important correlates for understanding educational processes and attainments. Therefore, students also provided general home and demographic information.
> *The teacher questionnaires* consist of two sections. The first section covered general background information about preparation, training, and experience, and about how teachers spend their time in school. Teachers were also asked about the amount of support and resources they received in fulfilling their teaching duties. The second part of the questionnaire related to instructional practices in the classrooms selected for TIMSS testing.
> *The school questionnaire* was designed to provide information about overall organization and resources. It asked about staffing, facilities, staff development, enrollment, course offerings, and the amount of school time for students, primarily in relation to mathematics and science instruction. School principals also were asked about the functions that schools perform in maintaining relationships with the community and students' families (*cf.* Martin 1996, pp. 1–13).

Factors effecting student academic achievement are: (1) student background (Aksoy & Link 2000; de Jong, Westerhof & Creemers 2000; Farrow, Tymms & Henderson 1999; Gallagher & DeLisi 1994; Gilson 1999; Hock, Pulvers, Deshler & Schumaker 2001; Hodges & White 2001; Kim & Hocevar 1998; Ma 1997; Odell & Schumacher 1998; Rheinheimer & Mann 2000; Shastri & Mohite 1997; Simich-Dudgeon 1996; Thorndike-Christ 1991; Weinberg 1995); (2) teacher practices and background (Betts & Morell

1999; Fetler 2001; Larson 2000; Ngwudike 2000); (3) home environment including parent background (Al-Samarrai & Peasgood 1998; Jones & White 2000; Kaplan, Liu & Kaplan 2001; Leffert & Jackson 1998; Schreiber 2000; Subrahmanyam, Kraut, Greenfield & Cross 2000; Tomoff, Thompson & Behrens 2000); and (4) school environment (Berner 1993; Erbe 2000; Gronna & Chin-Chance 1999; Luyten 1994; Nye, Hedges & Konstantopoulos 2001a, 2001b; Papanastasiou 2000; Pong & Pallas 2001; Sweetland & Hoy 2000).

Student background factors that appear to have on effect on student academic achievement include (1) tutoring (Hock et al. 2001; Hodges & White 2001; Rheinheimer & Mann 2000); (2) television viewing (Aksoy & Link 2000; Shastri & Mohite 1997); (3) homework (Aksoy & Link 2000; de Jong et al. 2000; Farrow et al. 1999); and (4) attitudes towards mathematics (Gallagher & DeLisi 1994; Gilson 1999; Kim & Hocevar 1998; Ma 1997; Odell & Schumacher 1998; Simich-Dudgeon 1996; Thorndike-Christ 1991; Weinberg 1995). While Hock et al. (2001) and Rheinheimer and Mann (2000) reported that there is positive relationship between tutoring and student academic achievement, Hodges and White (2001) found that there is no significant group differences in mean semester GPA between attendees and those who did not attend tutoring. Aksoy and Link (2000) and Shastri and Mohite (1997) studied the effect of hours of television viewing, and found that an extra hour of television viewing negatively effects on mathematics scores (Aksoy & Link 2000) or light viewers performed significantly better on oral reading (Shastri & Mohite 1997). While Aksoy and Link (2000) and de Jong et al. (2000) found that hours spent on homework increase student performance, Farrow et al. (1999) reported that there is negative relationship between these two variables. Many previous studies found that the attitude towards mathematics affects mathematics achievement (Odell & Schumacher 1998; Simich-Dudgeon 1996; Thorndike-Christ 1991). Several researchers reported that there were positive or reciprocal relationships between the attitude towards mathematics and mathematics achievement (Gallagher & DeLisi 1994; Kim & Hocevar 1998; Ma 1997; Weinberg 1995). A few researchers reported that there is no relationship between these two variables (Gilson 1999).

Teacher background factors that effect student academic achievement include (1) teacher education level (Betts & Morell 1999; Larson 2000) and (2) teacher experience (Betts & Morell 1999; Fetler 2001; Ngwudike 2000). While Larson (2000) found that teachers' education levels have an effect on student performance, Betts and Morell (1999) reported that there is no relationship between these two variables. Many previous studies indicate that teacher experience or preparation has effects on student achievement (Betts & Morell 1999; Fetler 2001; Ngwudike 2000).

Home environment factors that effect student academic achievement include (1) parent education level (Al-Samarrai & Peasgood 1998; Jones & White 2000; Kaplan et al. 2001; Tomoff et al. 2000); (2) the number of books at home (Leffert & Jackson 1998); and (3) the possession of a computer (Subrahmanyam et al. 2000). Many previous studies examining the relationship between parent education level and student achievement found that parent education levels are significantly associated with student achievement (Al-Samarrai & Peasgood 1998; Jones & White 2000; Kaplan et al. 2001; Schreiber 2000; Tomoff et al. 2000). Leffert and Jackson (1998) examined the contribution of the home environment to the reading achievement and found that the number of books at home is the only variable affecting student reading achievement. Subrahmanyam et al. (2000) studied the effects of home computer use on children's development, and reported that home computer use slightly increases academic performance.

School environment factors that effect student academic achievement include (1) school climate (Gronna & Chin-Chance 1999; Papanastasiou 2000; Sweetland & Hoy 2000) and (2) class size (Luyten 1994; Nye et al. 2001a, 2001b; Pong & Pallas 2001). Gronna and Chin-Chance (1999) examined effects of school safety and school characteristics, and reported that schools with lower levels of school violence provide better learning environments for students in middle-level school.

Papanastasiou (2000) examined internal and external factors affecting mathematics achievement using the TIMSS data and found socioeconomic level, educational background, school climate, and students' attitudes toward mathematics effect mathematics achievement. Sweetland and Hoy (2000) suggested that school climate makes a difference in the learning environments of schools and in the achievement of students. Reducing class size to increase academic achievement is a policy option currently of great interest. Many researchers suggested that small class sizes have statistically significant positive effects on student achievement (Luyten 1994; Nye et al. 2001a, 2001b; Pong & Pallas 2001).

Based on these previous studies, a purposed theoretical model (Figure 1) has been developed as part of this study. The theoretical model includes two environmental variables, home and school. There are many environmental variables that effect student mathematics achievement; however, based on a literature review, it is obvious that home and school environmental variables are the variables most effecting on student mathematics. The theoretical model also includes three human variables, the student, the parent, and the teacher. Of course other human variables, like peer group and other family members, effect students' mathematics achievement; however, student, parent, and teacher are three human variables that have most influence on student mathematics achievement.

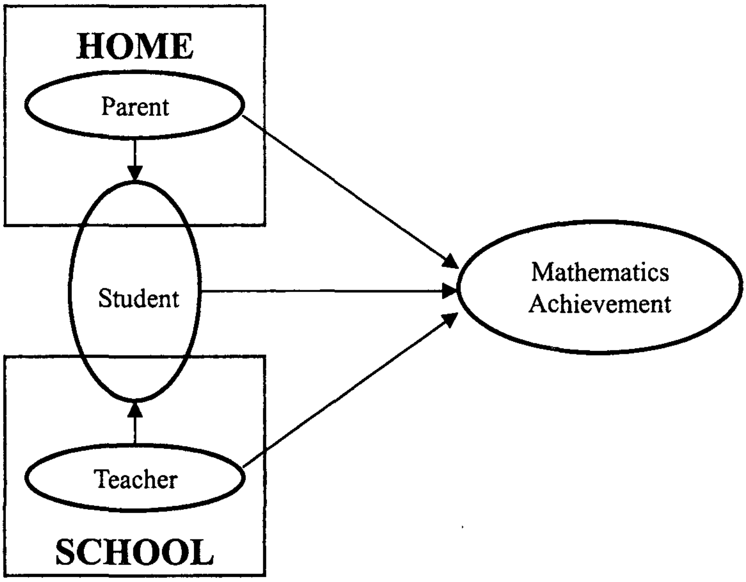

*Figure*1. Theoretical model

1. Purpose of the Study

As was stated in the introduction, the primary goal in education is to improve student academic achievement. To do this, it is necessary to study what variables effect student it. Based on this theoretical model and previous studies, the most important variables that effect student academic achievement are student, parents, teachers, home, and school. The purpose of this study is to build a model that explains the relationship between and among five variables, student background, teacher background, home environment, school characteristic, and student mathematics achievement. This study will also include a comparison of the relationships of these variables between the United States and Korea in 7th and 8th grades mathematics.

2. Significance of the Study

This study examines how student background, teacher background, home environment, and school characteristic variables effect student achievement in mathematics. Since formal education is the process of interaction between teachers and students using curricula, these variables are critical to student achievement in mathematics. The result of the study will provide practical information for teachers, parents, school principals, and other people who are interested in improving student achievement. The comparison of the relationships among these five variables between the United States and Korea will provide information that may explain differences and similarities in mathematics achievement in those countries.

II. METHOD

1. Participants

Student, teacher, and school background files from population 2 in the Third International Mathematics and Science Study (TIMSS) have been selected for this study. The basic sample design used in the TIMSS was a two-stage stratified cluster design. Schools were sampled using a probability proportional to size (PPS) systematic method, and then mathematics classrooms where sampled with equal probabilities (Foy 1997). As a rule, one classroom per target grade per school was sampled.

One hundred and eighty three middle schools were sampled from 27,330 middle schools in the United States. Three hundred and sixty two mathematics classrooms (179 seventh grade and 183 eighth grade classrooms) were sampled from 183 middle schools. Ten thousand nine hundred seventy three students (3,886 seventh grade and 7,087 eight grade students) have been sampled from the 183 sampled middle schools for the TIMSS.

One hundred fifty middle schools have been sampled from 2,338 middle schools in Korea. Three hundred mathematics classrooms (150 seventh grade and 150 eighthgrade classrooms) were sampled from 150 schools. Five thousand eight hundred twenty seven students (2,907 seventh grade and 2,920 eight grade students) have been sampled from the 150 sampled middle schools for the TIMSS.

Students who were sampled, their teachers, and the principals of their schools were asked to respond to questionnaires about their backgrounds and their attitudes, experiences, and practices in the teaching. Subjects who included missing values on the questionnaires used for this study were deleted. Table 1 shows the final samples used in the analyzes.

Table 1. Sample Description for the US and Korea

Country	Subjects		
	Students	Teachers	Principals
United States	5,885	320	121
Korea	5,179	275	146
Total	11,064	595	267

2. Variable Delineation

Items were selected for structural equation modeling to fit a model from three questionnaires from the TIMSS based on the literature. Items for the home environment and student background variables were selected from the student questionnaire. Items for the teacher background variable were selected from the teacher questionnaire. Item for the school characteristic variable was selected from the school questionnaire. Each item used a different categorical Likert-type scale based upon item format.

Five variables used for this study are as follows:

Student background (STUDBACK): Five items were selected from the student questionnaire in population 2, 13 year olds, to measure student backgrounds. The five items are hours taking extra math lesson, hours watching television or video, hours studying or doing mathematics homework, expectant education level, and interest in mathematics.

Teacher background (TEACBACK): Three items were *selected* from the teacher questionnaire in population 2 to measure teacher backgrounds. The three items are teacher's education level, importance of remembering formulas and procedures, and importance of thinking creatively.

Home environment (HOMEENVR): Five items were selected from the student questionnaire in population 2 to measure student home environment. The five items are the mother's education level, the father's education level, the number of books at home, the possession of a computer at home, and the possession of a study desk at home.

School characteristic (SCHOCHAR): Class size (number of students in a class) was selected from the school questionnaire in population 2 to measure a school characteristic.

Mathematics achievement (MATHACHI): The tests for student mathematics achievement are based on a matrix design whereby blocks of items were distributed across multiple test booklets and the booklets were distributed across students in a country. Each student completed only one test booklet. Test booklets for population 2 consist of eight booklets and each booklet consists of 31 multiple-choice items, 2 short answer items, and 4 extended response items. Because of the difficulty in making any comparisons across the test booklets using only the number of raw score points obtained on a set of items, raw scores were standardized by booklet to provide a simple score which could be used in comparisons across booklets in preliminary analyzes.

Since one of the purposes of this study is to compare the relationships of three variables (attitude toward mathematics, mathematics activity, and mathematics achievement) between the United States and Korea, students' standardized mathematics score was used as mathematics achievement in this study, which has a mean of 50 and a standard deviation of 10. The mathematics achievement has mean of 51.19 and standard deviation of 9.61 for the United States (n = 5,885) and mean of 50.35 and standard deviation of 9.80 for Korea (n = 5,179). The internal reliability of the mathematics achievement test is Cronbach's $\alpha = 0.91$ (7th grade) and 0.92 (8th grade) for Korean and Cronbach's $\alpha = 0.89$ (both 7th and 8th grades) for the United States.

3. Methodology

SPSS was used for the descriptive statistics and the correlation matrix for both countries. Structural equation modeling (LISREL 8.51) (Jöreskog & Sörbom 2001) was used to analyze the relationships among student background, teacher background, home environment, school characteristic, and student mathematics achievement for both countries. While multiple regressions is usually used for analyzing the relationships between observed variables and a latent variable, structural equation modeling is used for examining the relationships among latent variables.

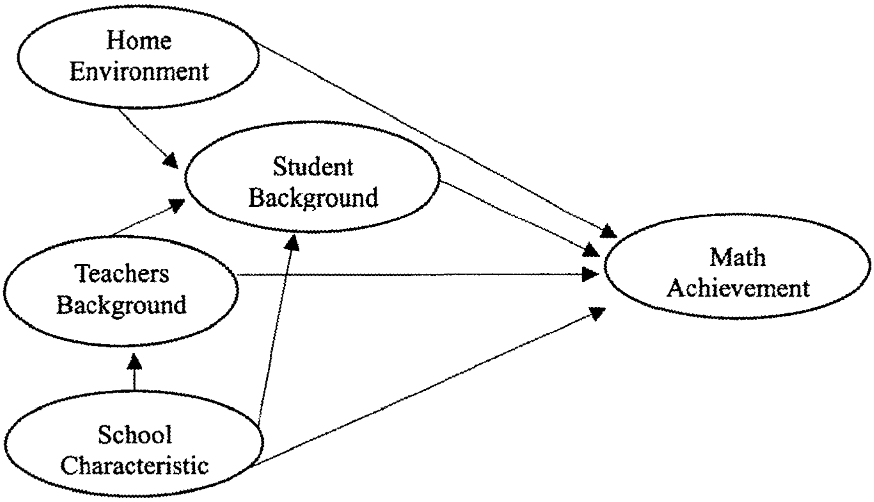

Figure 2. Expectant path diagram

Since the purpose of this study is examining the relationships among the five latent variables (STUDBACK, TEACBACK, HOMEENVR, SCHOCHAR, and MATHACHI), structural equation modeling is an appropriate method in this study. Figure 2 shows an expectant path diagram of the five latent variables.

III. RESULT

1. Preliminary Analysis

In order to run the structural equation modelling program, descriptive statistics (mean and standard deviation for each item) and correlation coefficients were computed first using SPSS. Five variables consist of one or more items. (1) The variable of student background includes five items; extra lessons, watching a television or video, study of mathematics, expectant education level, and liking of mathematics. (2) The variable of teacher background consists of three items; teacher education level, memorization of formulae, and thinking creatively. (3) The variable of home environment includes five items; mother education level, father education level, number of books at home, computer, and study desk. (4) The variable of school characteristic has one item that is a class size. (5) The variable of mathematics achievement has one item that is student mathematics score (standardized mathematics score). The mathematics achievement has mean of 51.19 and standard deviation of 9.61 for the United States (n = 5,885) and mean of 50.35 and standard deviation of 9.80 for Korea (n = 5,179). The mean of mathematics achievement for the United States is slightly larger than the mean of mathematics achievement for Korea. However, Korean students had larger mean

$$(Mean = 50.00, SD = 9.97, n = 5{,}827)$$

of mathematics achievement than the US students

$$(Mean = 49.42, SD = 10.15, n = 10{,}973)$$

before samples including missing value were deleted.

Descriptive statistics and correlation matrix for the United States and Korea are presented in Tables 3.2 and 3.3. The correlation coefficients between "standardized mathematics score" and all other items are significant at the 0.01 levels except. The item, "memorize formulas", for the United States. The item, "number of books at home", has the highest correlation coefficient with "standardized mathematics score". The items, "have computer", "expectant education level", "father education level", "mother education level", and "like mathematics" have relatively high correlation coefficients with "standardized mathematics score".

The item of "extra lesson", "watch television or video", and "class size" have negative correlation coefficients with "standardized mathematics score". The correlation coefficients between "standardized mathematics score" and all other items are significant at 0.01 or 0.05 level for Korea. The items "number of books at home" and "like mathematics" have the highest correlation coefficients with "standardized mathematics score". The items "extra lesson", "class size", "have computer", "study mathematics" and "expectant education level" have relatively high correlation coefficients with "standardized mathematics score".

The items "watch television or video" and "memorize formulas" have negative correlation coefficients with "standardized mathematics score" It means if a student watches more hours of television and video, or if a teacher thinks memorization of formulas is important, student mathematics score is decreased.

Table 2. Descriptive Statistics and Correlation Matrix for the US (n = 5,885)

Variable	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Student Background																	
1. Extra Lesson	1.41	0.69	1.00														
2. Watch TV & Video	3.27	1.02	-.03*	1.00													
3. Study Math	2.12	0.71	.30**	-.04**	1.00												
4. Expectant Education Level	4.68	2.06	-.01	-.04**	.09**	1.00											
5. Like Math	2.85	0.92	.06**	-.04**	.20**	.06**	1.00										
Home Environment																	
6. Mother Education Level	4.43	1.57	.03*	-.06**	.05**	.10**	.01	1.00									
7. Father Education Level	4.51	1.67	.03*	-.07**	.07**	.10**	.03	.57**	1.00								
8. Number of Books at Home	3.58	1.24	.04**	-.12**	.12**	.12**	.08**	.25**	.25**	1.00							
9. Have Computer	1.59	0.49	.01	-.09**	.05**	.09**	.01	.23**	.23**	.30**	1.00						
10. Have Study Desk	1.91	0.29	.03*	-.06**	.09**	.05**	.06**	.11**	.09**	.18**	.18**	1.00					
Teacher Background																	
11. Teacher Education Level	6.88	1.01	-.00	-.02	.08**	.05**	.02	.04**	.05**	.08**	05**	.04**	1.00				
12. Memorize Formulas	2.37	0.53	-.01	-.01	-.02	.01	-.01	.01	.01	-.00	-.01	.01	.08**	1.00			
13. Think Creatively	2.56	0.55	.01	-.05**	.02	.02	.04**	.01	.02	.04**	.04**	.01	.21**	.10**	1.00		
School Characteristic																	
14. Class Size	15.28	31.38	.02	.03*	-.04**	-.05**	-.01	-.03**	-.01	-.07**	-.06**	-.04**	-.11**	-.00	.02	1.00	
Mathematics Achievement																	
15. Standardized Math Score	51.19	9.61	-06**	-.13**	.09**	.21**	.16**	.18**	.19**	.30**	.24**	.09**	.12**	-.02	.08**	-.07**	1.00

Note. *$p < .05$, **$p < .01$

Table 3. Descriptive Statistics and Correlation Matrix for Korea ($n = 5{,}179$)

Variable	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Student Background																
1. Extra Lesson	2.09	1.27	1.00													
2. Watch TV & Video	2.84	1.07	-.12**	1.00												
3. Study Math	2.21	0.76	.19**	-.08**	1.00											
4. Expectant Education Level	5.57	1.44	.06**	-.02	.02	1.00										
5. Like Math	2.66	0.79	.22**	-.12**	.25**	.06**	1.00									
Home Environment																
6. Mother Education Level	3.26	1.80	.13**	-.07**	.06**	.00	.05**	1.00								
7. Father Education Level	3.74	1.84	.17**	-.08**	.08**	.02	.08**	.65**	1.00							
8. Number of Books at Home	3.43	1.20	.22**	-.08**	.17**	.12**	.18**	.12**	.23**	1.00						
9. Have Computer	1.39	0.50	.17**	-.08**	.06**	.05**	.10**	.12**	.17**	.21**	1.00					
10. Have Study Desk	1.95	0.21	.09**	-.02	.07**	.06**	.06**	.02	.06**	.15**	.08**	1.00				
Teacher Background																
11. Teacher Education Level	6.16	0.61	.07**	.00	.03*	.01	.00	.03*	.03*	.05**	.02	.03*	1.00			
12. Memorize Formulas	2.11	0.55	-.02	.00	-.02	-.02	-.00	-.00	-.05**	-.03*	-.04*	.00	-.04**	1.00		
13. Think Creatively	2.75	0.46	.07**	.00	-.00	-.03	.01	-.01	.03*	.03*	.01	-.00	.07**	-.14**	1.00	
School Characteristic																
14. Class Size	50.25	4.63	.23**	-.00	.05**	.02	.04**	.17**	.24**	.22**	.14**	.11**	.08**	-.07**	.05**	1.00
Mathematics Achievement																
15. Standardized Math Score	50.35	9.80	.29**	-.04*	.17**	.17**	.35**	.06**	.13**	.35**	.19**	.12**	.05**	-.04**	.05**	.21**

Note. $^{*}p < .05$, $^{**}p < .01$

While the items of "number of books at home", "have computer", "expectant education level" and "like mathematics" have relatively high positive correlation coefficients with "standardized mathematics score", item "watch television or video" has a negative correlation coefficient with "standardized mathematics score" in both countries. While items of "extra lesson" and "class size" have negative correlation coefficients with "standardized mathematics score" for the United States, those items have positive correlation coefficients for Korea.

2. Evaluation and Comparison of Structural Equation Models of the US and Korea

The structural equation model was used to analyze the relationships among the student background (STUDBACK), teacher background (TEACBACK), home environment (HOMEENVR), school characteristic (SCHOCHAR), and mathematics achievement (MATHACHI) for the United States and Korea.

The model fit determines the degree to which the structural equation model fits the sample data (Schumacker & Lomax 1996). Model fit criteria commonly used are chi-square (x^2), goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), and standardized root-mean-square residual (SRMR) (Jöreskog & Sörbom 1989). A significant chi-square (x^2) value relative to the degrees of freedom indicates that the observed and estimated matrices differ. Since the chi-square (x^2) value is easily distorted by large sample sizes (Fassinger 1987), it is considered as a minor model fit criteria in this study.

The adjusted goodness-of-fit index (AGFI) adjusts the GFI for degrees of freedom. The standardized root mean square residual (SRMR) is a standardized measure of the residuals resulting from the difference between the sample covariance matrix and the model-implied covariance matrix (Kenny, Lomax, Brabeck & Fife 1998). Goodness-of-fit index values, 0 (no fit) to 1 (perfect fit), above 0.90, AGFI values, 0 (no fit) to 1 (perfect fit), above 0.90, and SRMR values below 0.10 often are cited as criteria for acceptable fit (Kenny et al. 1998; Schumacker & Lomax 1996).

Structural equation modeling was conducted to analyze the relationships among STUDBACK, TEACBACK, HOMEENVR, SCHOCHAR, and MATHACHI for the United States and Korea. The theoretical model (Figure 1) was used to build a model. Table 4 shows the Maximum-Likelihood (ML) estimates of models for the United States and Korea.

Structural equation modeling consists of latent independent variables, latent dependent variables, and observed variables. A latent independent variable is any latent variable that is not influenced by any other latent variable in the model, which has variance estimates. A latent dependent variable is any latent variable that is influenced by some other latent variable in the model, which has an equation error variance that indicates the portion of the latent dependent variable that is not explained or predicted by the latent independent and dependent variables in that equation.

Observed variables (indicator variables) are variables that are directly observable or measured. Each observed variable has a factor loading estimate and an error variance. Factor loadings are the relationship between the observed variables and latent variables. Path coefficients (or structural coefficients) indicate the strength and direction of the relationships among the latent variables. Error covariance estimate indicates the correlation between the residuals of variables. All the estimates are statistically significant at 0.05 level except [b] marked.

Goodness-of-fit indices of the model for the United States in Table 4 are GFI (0.96), AGFI (0.94), and SRMR (0.05), and x^2 (x^2 = 1902.19 with 83 degrees of freedom, p = 0.00). Goodness-of-fit indices of the model for Korea in Table 4 are GFI (0.95), AGFI (0.93), and SRMR (0.06), and x^2 (x^2 = 1887.55 with 83 degrees of freedom, p = 0.00). These goodness-of-fit indices for both countries are comparing well with model fit criteria. The models in Table 4 suggest that the structural equation modeling analyzes the relations among STUDBACK, TEACBACK, HOMEENVR, SCHOCHAR, and MATHACHI for both the United States and Korea. The Maximum-Likelihood (ML) estimates detailed in Table 4 are used in the structural equation modeling in Figure 3.

Figure 3 presents the Maximum-Likelihood (ML) solution for the structural equation model specifying the relation among student background (STUDBACK), teacher background (TEACBACK), home environment (HOMEENVR), school characteristic (SCHOCHAR), and mathematics achievement (MATHACHI) for the United States and Korea. The numbers of paths for the United States are outside of parentheses, and those for Korea are in parentheses.

To analyze the hypothesized structural model, goodness of fit statistics has been assessed. Analysis of the hypothesized structural model with the covariance matrix for the United States resulted in x^2 (df=83, n=5,885) of 1902.19 (p =0 .00), a goodness-of-fit index (GFI) of 0.96, an adjusted GFI (AGFI) of 0.94, and a standardized root mean square residual (SRMR) of 0.05. Analysis of the hypothesized structural model with the covariance matrix for Korea resulted in x^2 (df = 83, n = 5,179) of 1887.55 (p = 0.00), a goodness-of-fit index (GFI) of 0.95, an adjusted GFI (AGFI) of 0.93, and a standardized root mean square residual (SRMR) of 0.06. All the indices for both the United States and Korea indicate that data have a reasonable fit. This structural equation model is identical with expectant path diagram (Figure 2), which is constructed from theoretical model (Figure 1) and literature review.

Table 4. Maximum-Likelihood (ML) Estimates for the US and Korea

Estimates	Model for the US	Model for Korea
MOEDULE loading*	1.00	1.00
FAEDULE loading	1.07	1.32
NUBOOKHO loading	.45	.25
COMPUTER loading	.16	.08
STUDDESK loading	.05	.01
CLASSIZE loading*	1.00	1.00
XTRALESS loading*	1.00	1.00
WATCTVID loading	-.24	-.29
STUDMATH loading	2.44	.44
EXEDULE loading	1.01	.40
LIKEMATH loading	.91	.67
TEEDULE loading*	1.00	1.00
MEMOFORM loading	.09	-1.59
THICREAT loading	.22	1.44
STMATHSC loading*	1.00	1.00
TEACBACK → STUDBACK	.03	.47
HOMEENVR → STUDBACK	.03	.12
SCHOCHAR → STUDBACK	-.00[b]	.02
SCHOCHAR → TEACBACK	-.00	.01
STUDBACK → MATHACHI	2.18	9.24
TEACBACK → MATHACHI	1.67	3.44[b]
HOMEENVR → MATHACHI	2.59	-.23[b]
SCHOCHAR → MATHACHI	-.01	.16
HOMEENVR variance	1.28	1.62
SCHOCHAR variance	984.70	21.44
STUDBACK equation error variance	.06	.34
TEACBACK equation error variance	.53	.01
MATHACHI equation error variance	80.69	60.70
MOEDULE error variance	1.18	1.63
FAEDULE error variance	1.33	.59
NUBOOKHO error variance	1.27	1.34
COMPUTER error variance	.21	.24
STUDDESK error variance	.08	.04
CLASSIZE error variance	.00	.00
XTRALESS error variance	.42	1.23
WATCTVID error variance	1.04	1.11
STUDMATH error variance	.15	.50
EXEDULE error variance	4.18	2.01
LIKEMATH error variance	.80	.45
TEEDULE error variance	.48	.36
MEMOFORM error variance	.28	.27
THICREAT error variance	.28	.18
STMATHSC error variance	.00	.00
Goodness-of-fit indices:		
x^2	1902.19	1887.55
df	83	83
p value	.00	.00
GFI	.96	.95
AGFI	.94	.93
SRMR	.05	.06

Note. *Observed variables those are fixed. All the estimates are significantly different from zero ($p<.05$) except [b] marked.

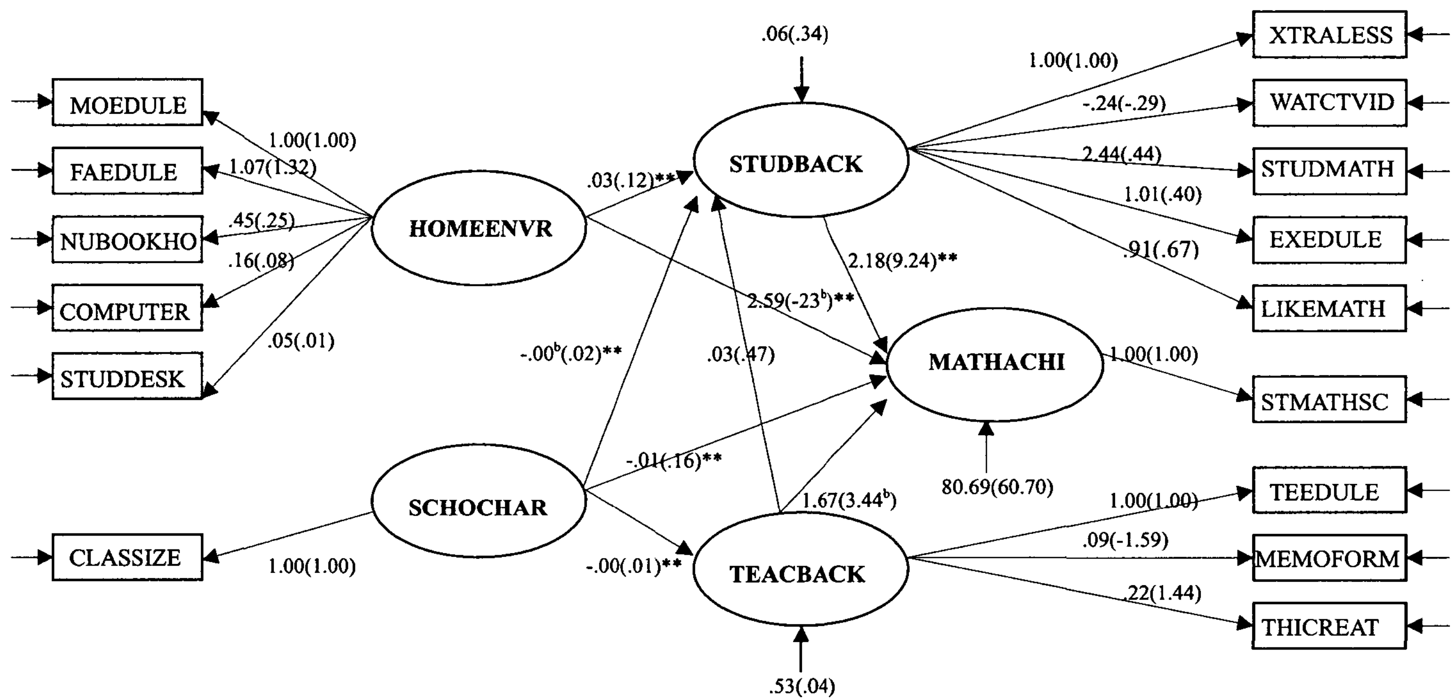

Figure 3. Structural Equation Model Assessing the Relations Among Student Background (STUDBACK), Teacher Background (TEACBACK), Home Environment (HOMEENVR), School Characteristic (SCHOCHAR), and Mathematics Achievement (MATHACHI) for the United States and Korea. United States = no parentheses, Korea = in parentheses; All paths and factor loadings are significant (p<0.05) except [b] marked. x^2= 1902.19 (1887.55) (p=0.000), df = 83 (83), GFI = 0.96 (0.95), AGFI = 0.94 (0.93), SRMR = 0.05 (0.06). GFI = goodness-of-fit index; AGFI = adjusted goodness-of-fit index; SRMR = standardized root mean square residual.
**Path coefficients differ by country at the 0.01 level.

The standardized coefficients in Figure 3 represent factor loadings between the indicators (observed variables) and the constructs (latent variables). All standardized coefficients of factor loadings are statistically significant ($p < 0.05$) for both the United States and Korea. Among five indicators of HOMEENVR, "father education level (FAEDULE)" has the highest factor loading in both countries. Among five indicators of student background, "watch television or video (WATCTVID)" has a negative factor loading in both countries.

It indicates hours watching television or videos have negative relationship with STUDBACK considering four other indicators in both countries. There are three indicators in TEACBACK, which are "teacher education level (TEEDULE)," "memorize formulas (MEMOFORM)," and "think creatively (THICREAT)". Among these three indicators, "memorize formulas (MEMOFORM)" has a positive factor loading for the United States and a negative factor loading for Korea. Teacher's positive attitude toward about memorization of formulas has a positive relationship with TEACBACK for the United States, but it has a negative relationship for Korea.

Only one path coefficient among eight path coefficients of five latent variables showing in Figure 3 is not statistically significant for the Untied States, which is the path linking SCHOCHAR with STUDBACK. Two path coefficients among eight paths are not statistically significant for Korea, which are the paths linking TEACBACK with MATHACHI and HOMEENVR with MATHACHI.

Multiple sample analyzes were conducted to determine whether difference between countries existed among path coefficients. Differences between countries are determined by using the confidence interval for the standard error of the two path coefficients (structural coefficients). Path coefficients from both countries are compared using the confidence interval for the path coefficients using the following equation.

$$CI_{95}\text{: Path Coefficient} \pm (1.96)\ (\text{Standard Error})$$
$$CI_{99}\text{: Path Coefficient} \pm (2.58)\ (\text{Standard Error})$$

When the confidence intervals of two path coefficients do not overlapped, it is obvious that there is a difference between countries. Such differences were found in six path coefficients among eight path coefficients result from examination of mean parameter differences across samples. Structured means multiple sample models revealed that (1) the path from HOMEENVR to STUDBACK was stronger for Korea than for the United States ($p < 0.01$); (2) the path from HOMEENVR to MATHACHI was stronger for the United States than for Korea ($p < 0.01$); (3) the path from SCHOCHAR to STUDBACK was stronger for Korea than for the United States ($p < 0.01$); (4) the path from SCHOCHAR to MATHACHI was stronger for Korea than for the United States ($p < 0.01$); (5) the path from SCHOCHAR to TEACBACK was stronger for Korea than for the

United States ($p < 0.01$); (6) the path from STUDBACK to MATHACHI was stronger for Korea than for the United States ($p < 0.01$); and (7) the other two path coefficients did not differ by country ($p > 0.01$).

IV. CONCLUSION AND DISCUSSION

This study examined the relationships among student background, teacher background, home environment, school characteristic, and student mathematics achievement for both the United States and Korea, and compared the relationships of these variables between two countries using structural equation modeling. The data used in the analysis came from the Third International Mathematics and Science Study (TIMSS), which is the largest and most ambitious international comparative study of student achievement. The population for this study is those students who were 13 years old and in the 7th or 8th grade (population 2 in the TIMSS) in 1995. Since 10,973 US students and 5,827 Korean students were randomly sampled from a population in each country, the results can be generalized to the population.

Five latent variables consist of one or more items taken from student, teacher, and school questionnaires. (1) The variable of student background (STUDBACK) includes five items: extra lesson, watch television or video, study mathematics, expectant education level, and likeness of mathematics. (2) The variable of teacher background (TEACBACK) consists of three items: teacher education level, memorization of formulas, and think creatively. (3) The variable of home environment (HOMEENVR) includes five items: mother education level, father education level, number of books at home, computer, and study desk. (4) The variable of school characteristic (SCHOCHAR) is a class size. (5) The variable of mathematics achievement (MATHACHI) is standardized mathematics score.

Correlation coefficients were computed to run the structural equation modeling program for both the United States and Korea. Items of "number of books at home", "have computer", "expectant education level" and "like mathematics" have relatively high positive correlation coefficients with "standardized mathematics score" in both countries. It means students who possess a computer and (or) more number of books at home will get high mathematics achievement (Leffert & Jackson 1998; Subrahmanyam et al. 2000). It also means students who have high expectation of educational level and (or) students who like mathematics will get high mathematics achievement (Gallagher & DeLisi 1994; Kim & Hocevar 1998; Ma 1997; Odell & Schumacher 1998; Simich-Dudgeon 1996; Thorndike-Christ 1991; Weinberg 1995). Item "watch television or video" has a negative correlation coefficient with "standardized mathematics score" in both countries. It is reasonable that if students watch more hours of television or videos, they study less hours, so that student mathematics score is decreased (Aksoy & Link 2000).

While items of "extra lesson" and "class size" have negative correlation coefficients with "standardized mathematics score" for the United States, those items have positive correlation coefficients in Korea. Even though the majority of previous studies supports that extra lessons including after-school tutoring increases student achievement (Hock et al. 2001; Rheinheimer & Mann 2000), some forms of tutoring may be more harmful than helpful. In fact, some students demonstrate little skill growth and become dependent on their tutors for success (Ceprano 1995; Keim, McWhirter & Bernstein 1996).

It is common that students who need supplemental study take extra lessons in the United States, so that those students taking extra lessons have relatively lower mathematics achievement. However, many students who are highly ranked in their class take extra lesson in Korea. That might be a reason why the item, 'extra lesson', has negative correlation coefficients with 'standardized mathematics score' for the United States and positive correlation coefficients for Korea. Many previous studies reported that small class size effects positively on student achievement (Luyten 1994; Nye et al. 2001a, 2001b; Pong & Pallas 2001). However, it is not the case for Korean students. Students in larger class sizes have relatively high mathematics achievement in Korea. In general, class size in urban schools is larger than class size in rural schools, and student achievement in urban schools is higher than it is in rural schools. It may be the reason why students in larger class sizes have relatively high mathematics achievement in Korea.

Structural equation modeling was used to analyze the relationships among STUDBACK, TEACBACK, HOMEENVR, SCHOCHAR, and MATHACHI for the United States and Korea. Structural equation modeling analysis with three basic indices, GFI, AGFI, and SRMR, indicates the data have a reasonable fit. Since the chi-square (x^2) value is easily distorted by large sample sizes (Fassinger 1987), it is considered as a minor fit index. This structural equation model is identical with the expectant path diagram (Figure 2) constructed from the theoretical model (Figure 1) and a literature review.

All factor loadings are statistically significant at 0.05 levels for both the United States and Korea. It means all indicators (observed variables) contribute to constructs (latent variables). Among five indicators of HOMEENVR, "father education level (FAEDULE)" has the highest factor loading in both countries. It indicates that the father education level contributes most to home environment. Among five indicators of student background, "watch television or video (WATCTVID)" has a negative factor loading in both countries. It indicates hours watching television or videos have negative relationship with student background considering four other indicators in both countries.

In other words, if a student watches more hours of television or videos, the student's mathematics score is decreased.

One path coefficient among eight paths is not statistically significant at .01 level for the United States, which are the paths linking SCHOCHAR with STUDBACK. Since there is only one observed variable in SCHOCHAR, that may be the reason that the path coefficient between SCHOCHAR and STUDBACK is not statistically significant. The other seven path coefficients are significant at .01 levels for the United States. All paths are positive except three paths from SCHOCHAR. The reason may be class size. A larger class size effects negatively on student background, teacher background, and mathematics achievement. Home environment is a variable that has relatively high path coefficient with mathematics achievement.

All path coefficients are significant at .01 levels for Korea except two path coefficients that are the paths linking TEACBACK with MATHACHI and HOMEENVR with MATHACHI. It indicates that teacher background and home environment do not have an effect statistically on mathematics achievement for Korea. The path coefficient between student background and mathematics achievement is the highest path coefficients among eight paths, which indicates that student background has the most effect on mathematics achievement.

All standardized coefficients of the paths were tested for differences and found statistically significant differences from six paths. These six paths are (1) the path between home environment and student background, (2) the path between home environment and mathematics achievement, (3) the path between school characteristic and student background, (4) the path between school characteristic and teacher background, (5) the path between school characteristic and mathematics achievement, and (6) path between student background and mathematics achievement. The US students have statistically higher path coefficient only between home environment and mathematics achievement. Korean students have statistically higher path coefficients in the other five paths. These results indicate (1) the relationship between home environment and student background is stronger for Korea than for the United States; (2) the relationship between home environment and mathematics achievement is stronger for the United States than for Korea; (3) the relationship between school characteristic and student background is stronger for Korea than for the United States; (4) the relationship between school characteristic and teacher background is stronger for Korea than for the United States; (5) the relationship between school characteristic and mathematics achievement is stronger for Korea than for the United States; and (6) the relationship between student background and mathematics achievement is stronger for Korea than for the United States.

Two methodological limitations should be considered to evaluate this study and to plan further studies. First, many subjects who included missing values were deleted to analyze the relationships among five latent variables. Since 5,088 US subjects among 10,973 and 648 Korean subjects among 5,827 were deleted, it may limit a generalization of the results. Second, this study examined the relationships among five variables (latent variables) and each variable includes one or more number of items (observable variables) as described above. Since some of the variables like school characteristic and teacher background, did not include enough items that represented each variable, there is a limitation of representation. Further studies need to include a greater number of represent able items to each variable.

Educational implications from the findings of this study are as follows. First, home environment is important for mathematics achievement. In particular, the items, "the number books at home" and "having computer at home", are the most effective factors on mathematics achievement among five factors of home environment in both countries. Second, student attitude towards mathematics ("like mathematics" and "expectant educational level") in student background is an important factor in explaining mathematics achievement in both countries. Third, hours watch television or video have negative effect on mathematics achievement in both countries. Regulating the number of hours watching television or videos may improve students' mathematics achievement. Fourth, extra lessons are one of factors that help students to increase their mathematics achievement in Korea; however, it negatively effects on mathematics achievement for the US students. This may be a cultural difference since the US students who are tutored are usually at the bottom of their class and Korean students are more likely to be at the head of their class. Fifth, small class size positively effects on mathematics achievement in the United States; however, students in larger class size have relatively high mathematics achievement in Korea. It may not be because of class size, but rather because of region. In general, class sizes in urban schools are larger than class sizes in rural schools, and academic achievement in urban schools is higher than it is in rural schools. Sixth, Korean students are stronger than US students in four relationships: (1) relationship between school characteristic and student background; (2) relationship between school characteristic and teacher background; (3) relationship between home environment and student background; and (4) relationship between student background and mathematics achievement.

REFERENCES

Aksoy, T. & Link, C. R. (2000): A panel analysis of student mathematics achievement in the US in the 1990s: Does increasing the amount of time in learning activities affect math achievement? *Economics of Education Review* **19(3)**, 261–277. MATHDI **2001c**.02611

Al-Samarrai, S. & Peasgood, T. (1998): Educational attainments and household characteristics in Tanzania. Economics of Education Review **17**, 395–417.

Berner, M. M. (1993): Building conditions, parental involvement, and student achievement in the District of Columbia public school system. *Urban Education* **28**, 6–29.

Betts, J. R. & Morell, D. (1999): The determinants of undergraduate grade point average. The relative importance of family background, high school resources, and peer group effects. *Journal of Human Resources* **34**, 268–293.

Ceprano, M. A. (1995): Strategies and practices of individuals who tutor adult illiterates voluntarily. *Journal of Adolescent and Adult Literacy* **39**, 56–64.

de Jong, R.; Westerhof, K. J. & Creemers, B. P. M. (2000): Homework and student math achievement in junior high schools. *Educational Research and Evaluation* **6(2)**, 130–157. MATHDI **2001d**.03614

Erbe, B. (2000): *Correlates of school achievement in Chicago elementary schools.* Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Farrow, S.; Tymms, P. & Henderson, B. (1999): Homework and attainment in primary schools. *British Education Research Journal* **25(3)**, 323–341. MATHDI **2001f**.05206

Fassinger, R. (1987): Use of structural equation modeling in counseling psychology research. *Journal of Counseling Psychology* **34**, 425–436.

Fetler, M. (2001): Student mathematics achievement test scores, dropout rates, and teacher characteristics. *Teacher Education Quarterly* **28(1)**, 151–168.

Foy, P. (1997): Implementation of the TIMSS sample design. In: M. O. Martin & D. L. Kelly (Eds.), *Third International Mathematics and Science Study (TIMSS). Technical Report, Volume II: Implementation and Analysis.* Chestnut Hill, MA: Boston College.

Gallagher, A. M. & DeLisi, R. (1994): Gender differences in scholastic aptitude test mathematics problem solving among high-ability students. *Journal of Educational Psychology* **86(2)**, 204–211. MATHDI **1995e**.03175

Gilson, J. E. (1999): *Single-gender education versus coeducation for girls: A study of mathematics achievement and attitudes toward mathematics of middle-school students.* Paper presented at the annual meeting of the American Educational Research Association, Montreal, Quebec.

Gronna, S. S. & Chin-Chance, S. A. (1999): *Effects of school safety and school characteristics on grade 8 achievement: A multilevel analysis.* Paper presented at the annual meeting of the American Educational Research Association, Montreal, Quebec, Canada.

Hock, M. F.; Pulvers, K. A.; Deshler, D. D. & Schumaker, J. B. (2001): The effects of an after-school tutoring program on the academic performance of at-risk students and students with LD. *Remedial and Special Education* **22**, 172–186.

Hodges, R. & White, W. G. (2001): Encouraging high-risk student participation in tutoring and supplemental instruction. *Journal of Developmental Education* **24**, 2–10.

Jones, I. & White, C. S. (2000): Family composition, parental involvement, and young children's academic achievement. *Early Child Development and Care* **161**, 71–82.

Jöreskog, K. G. & Sörbom, D. (1989): *LISREL 7 user's reference guide*. Mooresville, IN: Scientific Software, Inc.

_____ (2001): *LISREL 8.51*. Chicago: Scientific Software International, Inc.

Kaplan, D. S.; Liu, X. & Kaplan, H. B. (2001): Influence of parents' self-feelings and expectations on children's academic performance. *Journal of Educational Research* **94(6)**, 360–370. MATHDI **2001f.**05171

Keim, J.; McWhirter, J. J. & Bernstein, B. L. (1996): Academic success and university accommodation for learning disabilities: Is there a relationship? *Journal of College Student Development* **37**, 502–509.

Kenny, M. E.; Lomax, R.; Brabeck, M. & Fife, J. (1998): Longitudinal pathways linking adolescent reports of maternal and paternal attachments to psychological well-being. *Journal of Early Adolescence* **18**, 221–243.

Kim, S. & Hocevar, D. (1998): Racial differences in eighth grade mathematics: Achievement and opportunity to learn. *Clearing House* **71**, 175–178.

Larson, J. C. (2000): *The role of teacher background and preparation in students' algebra success (Research Report)*. Rockville, MD: Montgomery County Public Schools.

Leffert, S. W. & Jackson, R. M. (1998): The effect of the home environment on the reading achievement of children with low vision. *Journal of Visual Impairment & Blindness* **92**, 293–301.

Luyten, H. (1994): *School size effects on achievement in secondary education: Evidence from the Netherlands, Sweden and the USA*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Ma, X. (1997): Reciprocal relationships between attitude toward mathematics and achievement in mathematics. *Journal of Educational Research* **90(4)**, 221–228. MATHDI **1997e.**02928

Martin, M. O. (1996): Third international mathematics and science study: An overview. In: M. O. Martin and D. L. Kelly (Eds.), *Third International Mathematics and Science Study (TIMSS) Technical Report, Volume I: Design and Development*. Chestnut Hill, MA: Boston College.

Martin, M. O. & Kelly, D. L. (1997): Third international mathematics and science study: An overview. In: M. O. Martin & D. L. Kelly (Eds.), *Third International Mathematics and Science Study (TIMSS) Technical Report, Volume II: Implementation and Analysis*. Chestnut Hill, MA: Boston College.

Ngwudike, B. C. (2000). *Third International Mathematics and Science Study (TIMSS): Reforming teacher preparation program to improve student achievement*. Washington, DC: U. S. Department of Education.

Nye, B.; Hedges, L. V. & Konstantopoulos, S. (2001a): The long-term effects of small classes in early grades: Lasting benefits in mathematics achievement at grade 9. *Journal of Experimental Education* **69(3)**, 245–257. MATHDI **2002b.**01178

_____ (2001b): Are effects of small classes cumulative? Evidence from a Tennessee experiment. *Journal of Educational Research* **94(6)**, 336–345. MATHDI **2001f.**05172

Odell, P. M. & Schumacher, P. (1998): Attitudes toward mathematics and predictors of college mathematics grades: Gender differences in a 4-year business college. *Journal of Educational for Business* **74(1)**, 34–38. MATHDI **1999f.**03940

Papanastasiou, C. (2000): Internal and external factors affecting achievement in mathematics: Some findings from TIMSS. *Studies in Educational Evaluation* **26(1)**, 1–7. MATHDI **2001b.**01131

Pong, S. & Pallas, A. (2001): Class size and eighth-grade math achievement in the United States and abroad. *Educational Evaluation and Policy Analysis* **23**, 251–273.

Rheinheimer, D. C. & Mann, A. (2000). Gender matching, floor effects, and other tutoring outcomes. *Journal of Developmental Education* **24**, 10–28.

Schmidt, W. H. & Cogan, L. S. (1996): Development of the TIMSS context questionnaires. In: M. O. Martin and D. L. Kelly (Eds.), *Third International Mathematics and Science Study (TIMSS) Technical Report, Volume I: Design and Development.* Chestnut Hill, MA: Boston College.

Schreiber, J. B. (2000): *Scoring above the international average: A logistics regression model of the TIMSS advanced mathematics exam.* Paper presented at the annual meeting of the Mid-Western Educational Research Association, Chicago, IL.

Schumacker, R. E. & Lomax, R. (1996): *A beginner's guide to structural equation modeling.* Hillsdale, NJ: Lawrence Erlbaum.

Shastri, J. & Mohite, P. (1997): Television viewing pattern of primary school children and its relationship to academic performance and cognitive skills. *International Journal of Early Years Education* **5**, 153–160.

Simich-Dudgeon, C. (1996): *Ethnicity, gender, attitudes and mathematics achievement: The 1992 NAEP trial state assessment.* Paper presented at the annual meeting of the American Educational Research Association, New York, NY.

Subrahmanyam, K.; Kraut, R. E.; Greenfield, P. M. & Cross, E. F. (2000): The impact of home computer use on children's activities and development. *Future of Children* **10**, 123–144.

Sweetland, S. R. & Hoy, W. K. (2000): School characteristics and educational outcomes: Toward an organizational model of student achievement in middle schools. *Educational Administration Quarterly* **36(5)**, 703–729. MATHDI **2001e.**04067

Thorndike-Chirst, T. (1991): *Attitudes toward mathematics: relationships to mathematics achievement, gender, mathematics course-taking plans, and career interests.* (ERIC Document Reproduction Service No. ED 347066).

Tomoff, J.; Thompson, M. & Behrens, J. (2000): *Measuring NCTM-recommended practices and* *student achievement with TIMSS*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Weinberg, M. (1995): Gender difference in student attitude toward science: A meta-analysis of literature from 1970–1991. *Journal of Research in Science Teaching* **32**, 387–398.