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AUTHOR	Um, Eunkyoung; Dogan, Enis; Im, Seongah; Tatsuoka, Kimumi; Corter, James E.
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ABSTRACT

Diagnostic analyses were conducted on data from the Third International Mathematics and Science Study second population (TIMSS-R; 1999) from the United States, Korea, and the Czech Republic in terms of test item attributes (i.e., content, processing skills, and item format) and inferred students' knowledge. The Rule Space model (K. Tatsuoka, 1998) was used to infer student mastery of individual attributes. Korean, U.S., and Czech students ere compared in terms of patterns of attribute mastery. First, attribute mastery probabilities were related to their overall mathematics score (achievement level). Second, profiles of mean attribute mastery probabilities were compared between Czech, Korean, and U.S. students. Students of these three countries show relatively high achievement in integer arithmetic skills, using figures and graphs, evaluation/verification, proportional reasoning, translation, judgmental applications of knowledge in geometry, and computational applications of knowledge in geometry. These students are relatively low in statistics/data analysis, unit conversion, and applying and evaluating mathematical correctness. Finally, the effects of student characteristics on patterns of mathematics achievement were investigated in the United States, Korea, and the Czech Republic. Students' self-concept in mathematics and socioeconomic composition are significant predictors of student achievement in geometry, open-ended items, and logical reasoning in all three countries. An appendix lists knowledge and process skills related to achievement on TIMSS-R. (Contains 12 tables and 7 references.) (SLD)

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Comparing Eighth-Grade Diagnostic Test Results for Korean, Czech, and American Students

Eunkyoung Um
Enis Dogan
Seongah Im
Kikumi Tatsuoka
James E. Corter

Columbia University, Teachers College

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ABSTRACT

Diagnostic analyses were conducted of TIMSS-R data from the U.S., Korea, and the Czech Republic in terms of test item attributes (i.e., content; processing skills; and item format) and inferred students' knowledge. The Rule Space model (Tatsuoka, 1998) was used to infer student mastery of individual attributes. Korean, U.S., and Czech students were compared in terms of patterns of attribute mastery. First, attribute mastery probabilities were related to their overall math score (achievement level). Second, profiles of mean attribute mastery probabilities were compared between Czech, Korean, and U.S. students. Students of these three countries show relatively high achievement in integer arithmetic skills, using figures and graphs, evaluation/verification, proportional reasoning, translation, judgmental applications of knowledge in geometry, and computational applications of knowledge in geometry. These students are relatively low in statistics/data analysis, unit conversion, and applying and evaluating mathematical correctness. Finally, the effects of student characteristics on patterns of mathematics achievement were investigated in the U.S., Korea, and the Czech Republic. Students' self-concept in mathematics & socioeconomic composition are significant predictors of student achievement in geometry, open-ended item, and logical reasoning in the U.S., Korea, and the Czech Republic.

I. Overview

The Third International Math and Science Study, or TIMSS is a collaborative research project sponsored by the International Association for the Evaluation of Educational Achievement (IEA). A successor to the acclaimed 1995 TIMSS, the TIMSS 1999 focused on the mathematics and science achievement of eighth -grade students (Cozzens, 2001). Tatsuoka identified the knowledge and cognitive processing skills that are required to answer the mathematics items in the TIMSS 1999 test administered to eighth grade students in the United States (Tatsuoka, 2001, Appendix 1). The hypothesized skills were tested statistically via the Rule Space methodology[1] (Tatsuoka, 1998).

In this study, we analyzed the achievement test data from U.S., Korean, and Czech Republican segments of Population 2 of TIMSS in terms of attributes *(latent variables such as knowledge and cognitive processing skills),* knowledge states, and the structures of knowledge states. The primary underlying motivation for our research prompt the following inquiries: 1) "What similarities and differences emerge among students from the U.S., Korea, and the Czech Republic in terms of mastery probability attributes?" 2) "What are the effects of student background characteristics on the eighth grade mathematics achievement in the U.S., Korea, and the Czech Republic in the areas of content, process, and skill attributes?"

In order to address these questions, the outcome of the rule space analysis for each student was used for the first phase of research. First, attribute mastery probabilities were related to each student's overall math score. Second, profiles of mean attribute mastery probabilities were compared between U.S, Korean, and Czech Republic students.

The profiles (Figures 1-3) show that students of the three countries show relatively high achievement in integer arithmetic skills, using figures and graphs, evaluation/verification, proportional reasoning, translation, judgmental applications of knowledge in geometry. The profiles show that these students are low in statistics/data analysis, unit conversion, and applying and evaluating mathematical correctness. The largest differences between the U.S. and Korea are in geometry; data management, patterns, and open-ended item. The largest differences between the U.S. and the Czech Republic are in geometry, logical reasoning, and open-ended item.

[1] Rule Space methodology[1] estimates the probability of correctly applying each skill for each individual.

TIMSS items for the second phase of research were selected based on a student's ability to delineate proposed underlying constructs associated with his or her background. We used the outcome of the rule space analysis for each student to see if policy variables such as students' self-concept or socioeconomic composition are significant predictors of student achievement. Tree regression procedure with jackknife process was applied to reduce this set with 531 student background variables to a manageable size. Regression analyses were used to relate student background to student achievement in geometry, open-ended item, and logical reasoning. Students' self-concept in mathematics & socioeconomic composition are significant predictors of student achievement in geometry, open-ended item, and logical reasoning in the U.S., Korea, and the Czech Republic.

We believe this study can be beneficial in improving the quality of classroom instruction in the U.S., Korea, and the Czech Republic and help in the areas of accountability and policymaking. Our hope is that this study can add valuable insights into the influence of educational policy on mathematics achievement in the U.S., Korea, and the Czech Republic.

II. Introduction and Background

The Third International Math and Science Study, or TIMSS is a collaborative research project sponsored by the International Association for the Evaluation of Educational Achievement (Cozzens, 2001). TIMSS assessed the mathematic and science performance of U.S. students in comparison to their peers in other nations at three different grade levels in 1995 and at one grade level in 1999 (Cozzens, 2001). A successor to the acclaimed 1995 TIMSS, the TIMSS 1999 focused on the mathematics and science achievement of eighth -grade students (Cozzens, 2001). TIMSS 1999 included 38 countries. The 1999 assessment collected extensive information from students, teachers, and school principals about mathematics and science curricula, instruction, home contexts, and school characteristics and policies (Cozzens, 2001). Of the 38 participating countries, 26 of them also participated in the 1995 TIMSS assessment, which enabled these countries to look for trends in their children's mathematic and science achievement over the course of several years (Cozzens, 2001).

In 1999, U.S. eighth-graders' average scores were higher than the international average in math among the 38 participating nations (Cozzens, 2001). U.S. eighth-graders exceeded the international average and, performed similarly to students in six other nations. Among the top performing nations in 1999 were five Asian industrialized countries – Singapore, Korea, Chinese Taipei, Hong Kong SAR, and Japan (Cozzens, 2001).

Nine percent of U.S eighth-graders scored 616 or higher, placing them among the top 10 percent of all eighth-graders in the 38 nations participating in 1999 (Cozzens, 2001). U.S. eighth-graders' average scores were higher than the international average in three of the five mathematics content areas assessed in 1999: fractions and number sense, data representation, analysis, and probability and algebra (Cozzens, 2001).

In contrast to traditional psychometric approaches, Tatsuoka (1998) has developed a new model and methodology (the Rule Space method) to explain the proficiency of students on large-scale assessments, and she has applied the method to several tests. The Rule Space method (RSM) enables us to relate traditional scale scores to the underlying knowledge states (Tatsuoka, 1998). Tatsuoka identified knowledge and cognitive processing skills that are required to answer the mathematics items in the TIMSS 1999 test administered to eighth grade student in the United States (Tatsuoka, 2001, Appendix 1). The hypothesized skills that were represented in a "Q" matrix[2] were tested statistically via the RSM (Tatsuoka, 1998).

The RSM deals with any latent variables such as knowledge and cognitive processing skills (Tatsuoka, 2001). These latent variables are called "attributes" (Tatsuoka, 2001, Appendix 1). RSM is a statistical tool for hypothesis testing of such generated attributes. If the hypotheses are right, RSM will confirm the importance of the attributes and mastery of the attributes for individual students (Tatsuoka, 1998).

The primary underlying motivation and driver for our research prompted the following inquiries: 1) "What similarities and differences emerge among students from the U.S., Korea, and the Czech Republic in the content, process, and skill attributes?" 2) "What are the effects of student background characteristics on eighth grade mathematics achievement in the U.S., Korea, and the Czech Republic in the content, process, and skill attributes?"

[2] Q matrix: qjk = 1 if item j involves skill k, else qjk = 0

III. Method

In order to address these questions, the outcome of the rule space analysis for each student was used for the study. The proposed samples, one classroom of eighth grade students per school and associated mathematics teachers and administrators, were drawn from U.S., Korean, and Czech Republican segments of Population 2 of TIMSS (Mullis, 1999).

Goal I.

To classify the knowledge states of U.S., Korean, and Czech Republican eighth-grade students

First, attribute mastery probabilities were related to overall math scores (achievement level). Second, profiles of mean attribute mastery probabilities were compared between U.S., Korean, and Czech Republican students.

Goal II.

To evaluate the effects of student background characteristics on the eighth grade mathematics achievement in the U.S, Korea, and the Czech Republic in the attributes

We used the outcome of the rule space analysis for each student to see if policy variables such as students' self-concept or socioeconomic composition are significant predictors of student achievement. Tree regression procedure with jackknife process was applied to reduce this set with 531 student background variables to a manageable size. This process provides a regression model that would predict attribute mastery probabilities estimated in the rule space analysis by using student background variables as predictors. After tree analyses with jackknife process, the number of times that a predictor is selected as a significant variable in whole process is counted as an index to measure its importance on predicting the achievement of each attribute. In the study, if the number of selections as a significant predictor is more 90 percent of the time, the predictor is selected as a strong predictor.

The resulting set of variables for the U.S., Korea, and the Czech Republic was more manageable compared to the set with 531 variables. Below is a table that summarizes how many variables were found to be significant predictors of achievement scores across the U.S., Korea, and the Czech Republic for three specific attributes that we focus more on in the following sections.

Table 1. Number of significant predictors of achievement

	Geometry	Open-ended Item	Logical Reasoning
US	20	65	55
Korea	33	43	47
Czech	11	41	38

These results served as a starting point for the further analyses to make comparisons among U.S., Korean, and Czech students.

When attribute mastery profiles of the U.S., Korea, and the Czech Republic are compared, there are big differences in average probabilities of the attributes. As seen from figures the largest differences across three countries are selected, attribute C4 (basic concepts and properties of two-dimensional geometry) of content domain, S10 (logical reasoning) of skill domain, and P5 (open-ended questions) of process domain.

A three-step procedure was performed. Firstly, the set of predictors from tree regression for each country was combined in order to determine the set of student background variables that are strong predictors of attribute mastery probabilities for any of these three countries. As a second step, after determining this set of variables, linear regressions on three attributes C4, S10, and P5 are employed for each country separately with the combined predictors. Selected are the common significant predictors of the U.S. and Korea, and of the U.S. and Czech Republic. As a last step, Hostelling procedures were used to identify if there were significant differences in common predictors between U.S and Korean and between U.S. and Czech Republic.

IV. Validation of the Attributes

Rule space analysis was performed on nine different countries including the U.S., Korea, and the Czech Republic by using the content, process, and skill attributes.

Results of the rule space analysis are as follows: using a $D^2 < 4.5$ criterion for classifying a respondent's item response pattern into the nearest knowledge state, an average 99.9% classification rate across nine countries. In other words, almost all observed item response patterns could be classified into one of the logically derived knowledge states. This demonstrated that the set of attributes listed above could explain students' underlying performances on TIMSS items for eighth graders very well.

In an additional attempt to validate the attributes we also performed regression analysis using attributes as predictors of students' total scores. The results were quite strong. Table 2 below shows the resulting R-square values for the U.S., Korea and the Czech Republic.

Table 2. The R-square values for the U.S., Korea and the Czech Republic in the regression equations of predicting total scores by attribute mastery probabilities.

	USA	Korea	Czech
R^2-values	.97	.98	.98
SD.E	.04	.02	.03

As a result both the RSM classification rates and the high R-square values obtained from the regression analysis described above served as a validation for the attributes we used for the analysis.

V. Rule Space Knowledge Profiles

Profiles of mean attribute mastery probabilities were compared for Korean, U.S., and Czech Republic students (Table 3). This analysis was performed on the data pooled across all booklets for comparing the total scores. For each country, estimated attribute mastery profiles were computed.

ATTRIBUTES	MASTERY PROBABILITY (Czech Republic)	MASTERY PROBABILITY (U.S.)	MASTERY PROBABILITY (KOREA)
C1: Basic concepts in Integers	0.93*	0.95*	0.93*
C2: Basic concepts in fraction	0.86	0.98	0.97
C3: Basic concepts in algebra	0.76	0.84	0.75
C4: Basic concepts of Geometry	0.68	0.98	0.94
C5: Data and statistics	0.73	0.75	0.75
C6: Measurement	0.63	0.69	0.75
S1: Unit conversion	0.38	0.45	0.52
S2: Number sense/number line	0.78	0.82	0.81
S3: Using figures & graphs	0.95*	1.00*	0.99*
S4: Approximation/Estimation	0.88	0.82	0.88
S5: Evaluate/Verify/Check Options	0.97*	1.00*	1.00*
S6: Patterns & relationships	0.46	0.71	0.66
S7: Using proportional reasoning	0.91*	0.97*	0.90*
S8: Solving Novel/Unfamiliar problems	0.87	0.91	0.95
S10: Open-ended item	0.60	0.85	0.82
S11: Word Problem	0.88	0.96	0.96
P1: Translate/formulate equations	0.95*	0.97*	0.98*
P2: Computational applications of knowledge in geometry	0.92*	0.98*	0.96*
P3: Judgmental applications of knowledge in arithmetic and geometry	0.85*	0.97*	0.91*
P4: Applying rules in algebra	0.59	0.76	0.65
P5: Logical reasoning	0.65	0.84	0.82
P6: Problem Search	0.83	0.93	0.92
P7: Generating Figures	0.77	0.93	0.94
P8: Applying & Evaluating mathematical correctness	0.57	0.59	0.55
P9: Management of Data & Procedures	0.68	0.95	0.81
P10: Quantitative & Logical Reading	0.87	0.88	0.82

*High achievement

Table 3. Mean Attribute Mastery Probabilities

These group profiles are plotted in Figures 1 (Content attributes), 2 (Skill), and 3 (Process).

The content profiles (Figure 1) show that all three students show relatively high achievement in integer arithmetic skills. The profiles show that these students are low in statistics/data analysis. The profiles show that the largest difference between the U.S. and Korea is in the content area of geometry. Profiles show that the largest difference between the U.S. and the Czech Republic students is in the content area of geometry. This probably reflects the fact that achievement in these topics is more a function of opportunity to learn, rather than of student ability (Tatsuoka, 1998). In interpreting these results, it is important to consider the math content areas and topics that students have likely encountered in the years leading up to and including eighth grade (Cozzens, 2001).

Figure 1. Content Attribute Mastery Probabilities

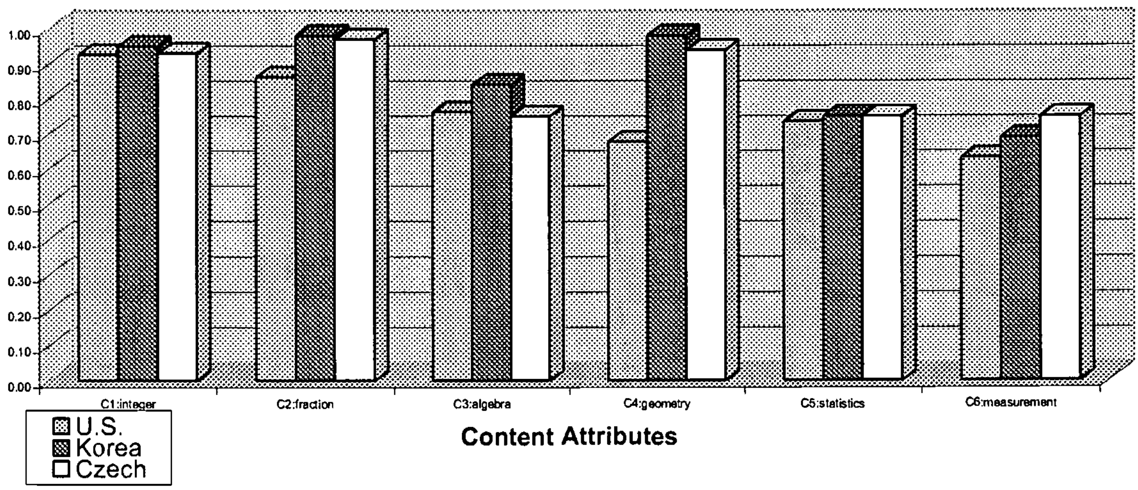

Table 4. Content Attribute Mastery Probabilities

Attribute	U.S.	Korea	Czech	Korea-U.S.	Czech-U.S.
C1: Basic concepts in Integers	0.93*	0.95*	0.93*	0.02	0.00
C2: Basic concepts in fraction	0.86	0.98	0.97	0.12	0.11
C3: Basic concepts in algebra	0.76	0.84	0.75	0.08	-0.01
C4: Basic concepts of Geometry	0.68	0.98	0.94	0.30	0.26
C5: Data and statistics	0.73	0.75	0.75	0.02	0.02
C6: Measurement	0.63	0.69	0.75	0.06	0.12

*High achievement

The skill profiles (Table 5; Figure 2) show that students of all three countries show high achievement in using figures, tables, charts, and graphs, evaluation/verification, and using proportional reasoning. The profiles show that these students are low in unit conversion. The profiles show that the largest differences between the U.S. and Korean students are in recognizing patterns and open-ended item. Profiles show that the largest difference between the U.S. and the Czech Republic students is in open-ended item. These item types may tap more abstract thinking skills, rather than rote performance (Tatsuoka, 1998).

Figure 2. Skill Attribute Mastery Probabilities

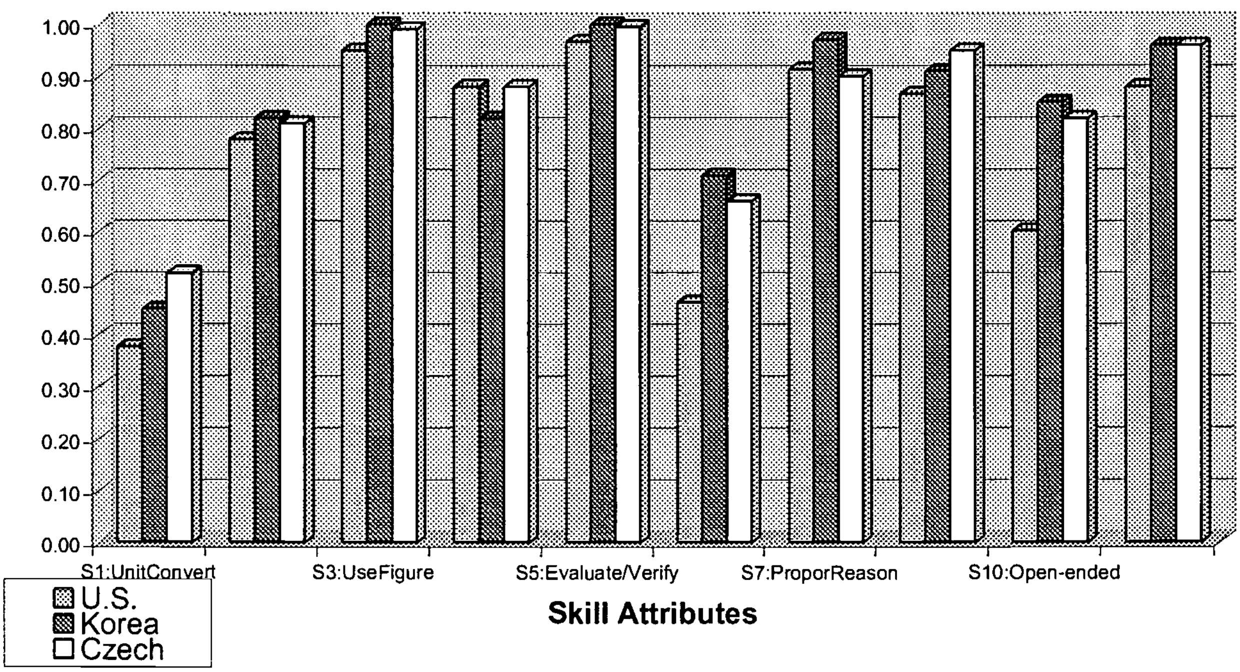

Table 5. Skill Attribute Mastery Probabilities

Attribute	Description	U.S.	Korea	Czech Republic	Korea-U.S.	Czech Republic -U.S.
S1_p	S1: Unit conversion	0.38	0.45	0.52	0.07	0.14
S2_p	S2: Number sense/number line	0.78	0.82	0.81	0.04	0.03
S3_p	S3: Using figures & graphs	0.95*	1.00*	0.99*	0.05	0.04
S4_p	S4: Approximation/Estimation	0.88	0.82	0.88	-0.06	0.00
S5_p	S5: Evaluate/Verify/Check Options	0.97*	1.00*	1.00*	0.03	0.03
S6_p	S6: Patterns & relationships	0.46	0.71	0.66	0.25	0.20
S7_p	S7: Using proportional reasoning	0.91*	0.97*	0.90*	0.06	0.01

S8_p	S8: Solving Novel/Unfamiliar problems	0.87	0.91	0.95	0.04	0.08
S10_p	S10: Open-ended item	0.60	0.85	0.82	0.25	0.22
S11_p	S11: Word Problem	0.88	0.96	0.96	0.08	0.08

*High achievement

The process profiles (Table 6; Figure 3) show that all three countries show high achievement in translation, computational applications of knowledge in geometry, and judgmental applications of knowledge in geometry. These students are low in applying and evaluating mathematical correctness. The profiles show that the largest differences between the U.S. and Korean eighth grade students are in logical reasoning and data management. The largest difference between the U.S. and the Czech Republic is in logical reasoning.

Figure 3. Process Attribute Mastery Probabilities

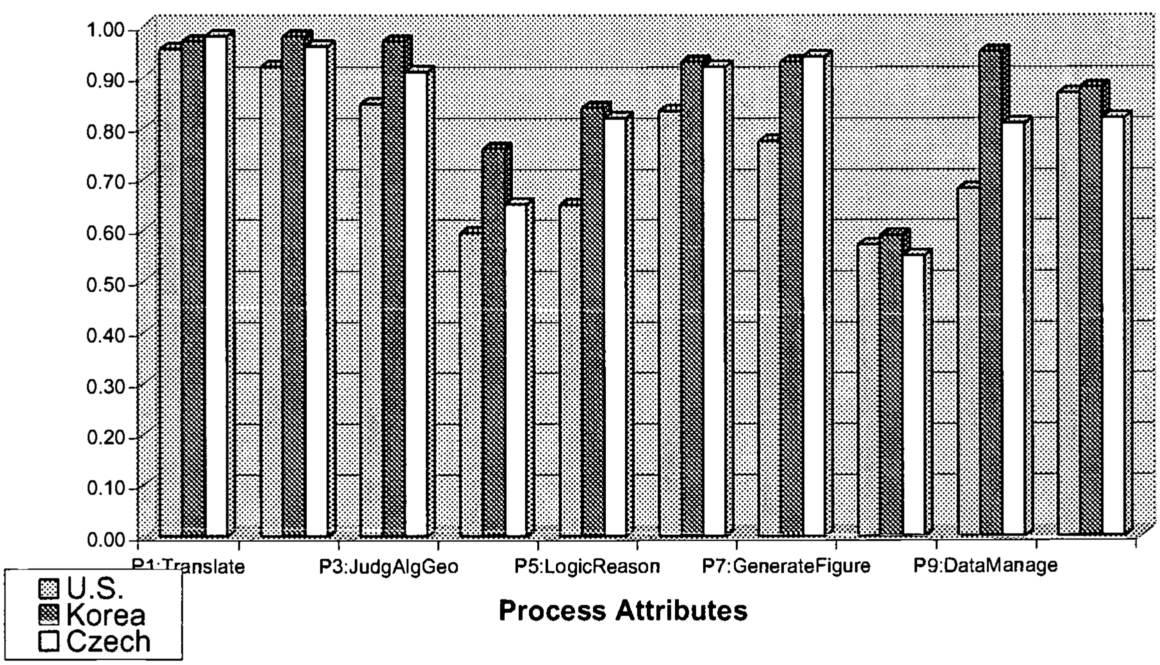

Table 6. Process Attributes Mastery Probabilities

Attribute	Description	U.S.	Korea	Czech Republic	Korea-U.S.	Czech Republic -U.S.
P1	P1: Translate/formulate equations	0.95*	0.97*	0.98*	0.02	0.03
P2	P2: Computational applications of knowledge in geometry	0.92*	0.98*	0.96*	0.06	0.04
P3	P3: Judgmental applications of knowledge in arithmetic and geometry	0.85*	0.97*	0.91*	0.12	0.06
P4	P4: Applying rules in algebra	0.59	0.76	0.65	0.17	0.06
P5	P5: Logical reasoning	0.65	0.84	0.82	0.19	0.17
P6	P6: Problem Search	0.83	0.93	0.92	0.10	0.09
P7	P7: Generating Figures	0.77	0.93	0.94	0.16	0.17
P8	P8: Applying & Evaluating mathematical correctness	0.57	0.59	0.55	0.02	0.02
P9	P9: Management of Data & Procedures	0.68	0.95	0.81	0.27	0.13
P10	P10: Quantitative & Logical Reading	0.87	0.88	0.82	0.01	0.05

*High achievement

VI. Results

U.S. vs. Korea

Content Attribute 'Geometry'

The common significant predictors are as follows: computer availability at home, how much time students spend outside school talking and playing with friends, students' self-concept in mathematics and number of books in home.

Although there is a clear positive association between computer availability at home and mathematics achievement internationally (Mullis, 1999), there is a negative association between computer availability at home and mathematics achievement in Korea. There is a positive association between computer availability at home and achievement in the U.S. It may be that Korean students spend less time with computers for studying; rather they use computers for purposes such as gaming and internet surfing. The computer availability in U.S. homes is significantly higher than that of Korea. Higher self-concept in mathematics predicts higher achievement in geometry in Korea and the U.S., which means students with high mastery probability in Geometry would do well in other areas. The average self-concept in mathematics of

U.S. students is higher, in other words, more positive than the average of Korean students. The number of books in home is positively associated with geometry in both countries. With a significant difference represented, the number of books in a Korean home is higher than that of the U.S. The last common predictor in geometry is how much time students spend outside talking and playing with friends, which is negatively related to mastery probability in geometry. The time for playing of Korean students is significantly higher than the playing time of U.S. students.

Table 7. Predictors of Achievement in Geometry

Common predictors of achievement in Geometry	**Association**	**Difference in Prediction**
Computer availability at home	Positive (U.S) Negative (Korea)	U.S. > Korea
Students' self-concept in math	Positive	U.S. > Korea
Number of books at home	Positive	Korea > U.S.
How much time students spend outside school playing with friends	Negative	Korea > U.S.

Skill Attribute 'Open-Ended Item'

These regression analyses suggested that six common variables are significant predictors of achievement in open-ended items across the U.S. and Korea. The variables are as follows: number of books at home, how frequently the student listens to popular music, number of people living in the home, the degree at which the student is good at memorizing note, number of books at home, the degree to which the student has time for fun, and students' self-concept in mathematics.

The number of books at home is a positive predictor as described above section. Students' self-concept in mathematics is positively related with the mastery probability of 'Open-ended items'. U.S. students have higher efficiency than Koreans. How frequently the student listens to popular music is a predictor for the U.S. and Korea. A predictor shows socio-cultural differences between the U.S. and Korea. There is a negative association between them in the U.S., but a positive association between them in Korea. The average frequency that U.S. students watch music shows is higher than the average of Korean with a significant difference. The number of people living in home is a negative predictor. In other words, it may be that students with more people in home have lower attribute mastery of Open-ended items. There are no significant difference of average number of people living at the home between U.S. and Korea. There is a negative association between the degree of playing with friends outside school and the mastery of open-ended items. The more playing time the lower mastery of open-ended items. There is a negative association between the degree to which the student has time for fun and the mastery probability of open-ended item. The average time of Korean students is higher than the average time of U.S. students. There is a clear negative association between the degree to which the student is good at memorizing note and achievement in mastery of open-ended items. Thus, memorizing notes would be considered a hindrance of open-ended items that need a thinking process. U.S students more firmly believe they are good at memorizing notes than Korean do.

Table 8. Predictors of Achievement in Open-ended Items

Common predictors of achievement in open-ended items	**Association**	**Difference in Prediction**
Degree at which the student agrees that he/she is good at memorizing note	Negative	U.S. > Korea
Number of books at home	Positive	Korea > U.S.
Number of people living at home	Negative	U.S. = Korea
How frequently the student listens to popular music	Positive (U.S.) Negative (Korea)	U.S. > Korea
How much time students spend outside school playing with friends	Negative	Korea > U.S.

<u>Process Attribute 'Logical Reasoning'</u>

Common predictors in Logical reasoning are as follows: number of books in home, students' self-concept in math, the degree to which students think math is more difficult for them than for others, preference for mathematics, and the highest education level of parents.

The number of books in home is a positive predictor of logical reasoning in both countries. The average of books at the home of Korea is significantly higher than the average of U.S. Self-concept in mathematics is a positive predictor in the U.S. and Korea. The students who think math is difficult have higher achievement on logical reasoning. U.S. students think that math is more difficult for them than for others when compared to Korean. Considering the achievement difference between both countries, lower mathematical self-concept would affect the accomplishment of logical reasoning. With a significant difference, the general efficiency of US students is higher than Korean's. The frequency of watching popular music video shows is again a common significant predictor of logical reasoning as well as open-ended items. The degree at which students believe they are good at memorizing predicts lower mastery of logical reasoning and open-ended items. As described above, U.S. student have higher average than Korean students. Preference for mathematics is positively related to the mastery probability of logical reasoning. High-performing Korea is the country with a less positive attitude than the U.S. It may be that the Korean students follow a demanding mathematics curriculum, one that leads to high achievement but little enthusiasm for mathematics (Mullis, 1999). There is a positive association with the highest education level of parents and student achievement in logical reasoning. The results suggest that the higher education level of parents predicts better achievement of their children. The average level of education in US parents is higher than that of Korean parents.

Table 9. Predictors of Achievement in Logical Reasoning

Common predictors of achievement in logical reasoning	**Association**	**Difference in Prediction**
Number of books at home	Positive	Korea > U.S.
Students' self-concept in math	Positive	U.S. > Korea
Frequency of watching popular music video shows	Negative (U.S.) Positive (Korea)	U.S. > Korea
Students' positive attitudes towards math	Positive	U.S. > Korea
Parents' education	Positive	U.S. > Korea

U.S. vs. Czech Republic

Content Attribute 'Geometry'

The results of these regression analyses suggested that four common variables appear to be significant predictors of attribute C4 mastery probabilities across the U.S. and the Czech Republic. These variables are as follows: computer availability at home, students' self-concept in math, student's access to internet at home, and how much time the student spends outside talking and playing with friends.

The first two variables are positively related to attribute mastery and the remaining two are negatively related to attribute mastery both in the U.S. and in the Czech Republic data set. These results are interesting in several ways. First thing to notice is that although computer availability is positively related to attribute mastery, internet access at home is negatively related to the same variable. It can be argued that while computer availability at home might be a reflection of one's socio-economic status, having internet access at home gives a clearer idea about how the student uses the computer and therefore how he or she uses time at home. It is quite intuitive to assume that if one has internet access at home one will spend more time on surfing the web. This may lead to less time spent studying and with other school-related activities. It is not a secret that many young students spend hours on the web chatting with each other. On the other hand one of the other variables also supports the expectation that less time studying has negative effects on achievement. As stated above, the more time the student spends outside playing and talking to friends, the weaker his attribute mastery. These two results are quite parallel. It seems that time allocated to non-academic activities (whether it is spending time on the web at home or talking and playing with friends outside) has a negative effect on a student's attribute mastery. The fourth variable, student's self-concept in mathematics, is positively related to attribute mastery. A lower score on this variable indicates that the student agrees more with the idea that he or she is not talented in math. This is also not surprising. A student's self-perception about math obviously has an effect on his or her achievement. This is another context where this fact is observed: The more the student thinks he or she is not talented in math the weaker his or her attribute mastery.

Table 10. Predictors of Achievement in Geometry

Common predictors of achievement in Geometry	Association	Difference in Prediction
Computer availability at home	Positive	U.S. = Czech Republic
Internet Access at home	Negative	Czech Republic > U.S.
Students' self-concept in math	Negative	Czech Republic > U.S.
How much time students spend outside school playing with friends	Negative	U.S. > Czech Republic

<u>Skill Attribute 'Open-Ended Item'</u>

The results of these regression analyses suggested that six common variables appear to be a significant predictor of attribute S10 mastery probabilities across the U.S. and Czech Republic These variables are as follows: number of books at home, watch popular music video shows, number of people living in the home, highest educational level of parents, the degree to which the student thinks he or she is not talented in math, and the degree at which the student agrees that he/she is good at memorizing notes.

The first of these variables, number of books at home, is positively related to attribute mastery. This implies that the more books the student has at home the stronger his or her attribute mastery. This result is not surprising in the sense that having more books at home might actually imply a couple of things which are all positively related to achievement: higher socio-economic status, a more academically-stimulating home environment, a parent with a higher educational level, or a parent who invests and appreciates education more. The second variable, watching popular music, is also positively related to attribute mastery. A higher score on this variable implies that the student watches less popular music shows on TV. Therefore it follows that the more the student watches popular music shows on TV, the weaker his or her attribute mastery. This result is also in line with several other factors discussed before. This variable-like some others- relates to how the student manages his or her time at home. It is argued above that the more the student has opportunity to access the internet, doing jobs, or talking and playing with friends outside the home, the weaker his or her attribute mastery. This last variable adds another aspect to the same topic: how the student manages his or her time –in and outside home- matters in determining his or her attribute mastery. The third variable, 'number of people living at home,' is negatively related to attribute mastery. That means that the more people there are at home the weaker the student's attribute mastery. This might be because of a couple of different reasons. More people at home might mean less private space for the student, which may, in turn, mean less quite and a less free environment to study. Or the fact that there are more people at home might mean the student has more siblings than others, which in turn might result in less parental support and surveillance on student's academic life. The fourth variable 'highest educational level of parents' is negatively related to attribute mastery. A lower score on this variable indicates a higher parental educational level. Therefore it follows that the higher the student's parental educational level the stronger his or her attribute mastery. This result is also an expected one. Higher parental education might actually mean a couple of different things: higher socio-economic status, parents that appreciate and emphasize education more. and who can provide better support to the students for her academic needs. The fifth significant variable is the degree to which the student thinks he is just not talented in math. This variable is positively related to attribute mastery in both countries and actually appeared as a significant predictor for attribute C4 as well. Remember that a lower score on this variable indicates that the student agrees more with the idea that he or she is not talented in math. Therefore the more the student thinks he or she is not talented in math the weaker his or her attribute mastery. The sixth and the last variable is the degree to which the student agrees that s/he does well in memorizing class notes. A lower score on this variable indicates more acceptance of the idea that the student does well in memorizing notes. This variable is positively related to attribute mastery. That means that the more the student thinks he or she does well memorizing notes the weaker his or her attribute mastery is. It is important at this point to remember that the attribute under investigation here is S10, which is an open-ended item type. Mastery of this attribute requires the students to be more successful in open-ended item types. And these items require more skills in reasoning, proof, and simple memorizing. Therefore it is not surprising to see that students who rely on their memory skills more have more difficulty in mastering this attribute and answering open-ended items.

Table 11. Predictors of Achievement in Open-ended Items

Common predictors of achievement in open-ended items	Association	Difference in Prediction
Degree at which the student agrees that he/she is good at memorizing note	Negative	U.S. > Czech Republic
Number of books at home	Positive	Czech Republic> U.S.
Parents' education	Positive	U.S. > Czech Republic
How frequently the student listens to popular music	Negative	U.S. > Czech Republic
Number of people living at home	Negative	U.S. > Czech Republic
Students' self-concept in math	Negative	Czech Republic > U.S.

Process Attribute 'Logical Reasoning'

These variables are as follows: students' self-concept in math, how much time the student spends doing jobs at home, and students' attitudes towards mathematics.

The first variable, the degree at which the student thinks math is more difficult for him or her than for others, is positively related to attribute mastery. On this variable a lower score indicates a greater acceptance of the afore-mentioned idea. Therefore the more the student agrees that math is more difficult for him or her than for others the weaker his or her attribute mastery. This result is another indication of the fact that students' achievement is related to a self-perception about math. The second variable- how much time the student spends doing jobs at home- is negatively related to attribute mastery in both countries. A lower score indicates less time spent doing jobs at home. Therefore the results can be interpreted as follows: the more time the student spends in doing jobs at home the weaker his or her attribute P5 mastery probability. This result is very much in line with what we found in analyzing attribute C5. In that analysis also we found that the more time students spend in non-academic activities (both at home and outside) the weaker their attribute masteries. Here again we found that spending more time on another non-academic activity at home also results in weaker attribute mastery. The third variable - how much the student reports he or she likes math- is also negatively related to attribute mastery in both countries. A lower score indicates a higher level of liking of math on this variable. Therefore the results suggest that the more the student reports he or she likes math the stronger his or her attribute P5 mastery.

Table 12. Predictors of Achievement in Logical Reasoning

Common predictors of achievement in logical reasoning	**Association**	**Difference in Prediction**
How much time the student spends doing jobs at home	Negative	Czech Republic = U.S.
Students' positive attitudes towards math	Positive	U.S. > Czech Republic
Degree at which the student thinks math is more difficult for him	Positive	Czech Republic > U.S.

VII. Conclusion

Diagnostic analyses were conducted of TIMSS-R data from the U.S., Korea, and the Czech Republic in terms of test item attributes (i.e., content, processing skills, and item format) and inferred knowledge states of students.

U.S, Korean, and Czech Republic students show relatively high achievement in integer arithmetic skills, using figures and graphs, evaluation/verification, proportional reasoning, translation, judgmental applications of knowledge in geometry. These students are low in statistics/data analysis, unit conversion, and applying and evaluating mathematical correctness. The largest differences between the U.S. and Korea are in geometry, data management, logical reasoning, patterns, and open-ended item. The largest differences between the U.S. and the Czech Republic are in geometry, logical reasoning, patterns, and open-ended items. Students' self-concept in mathematics & socioeconomic composition are significant predictors of student achievement in geometry, open-ended items, and logical reasoning in the U.S., Korea, and the Czech Republic.

We believe results of this study can be beneficial in improving the quality of classroom instruction in the U.S., Korea, and the Czech Republic and help in the areas of accountability and policymaking. Our hope is that this study can add valuable insights into the influence of educational and curricular policy on mathematics achievement in Korea, the U.S., and the Czech Republic.

Appendix 1. A list of knowledge, skill, and process attributes derived to explain performance on the TIMSS-R (1999) math items, Population 2 (8th graders) (Tatsuoka, 2001).

CONTENT ATTRIBUTES

C1	Basic concepts, properties and operations in whole numbers and integers
C2	Basic concepts, properties and operations in fractions and decimals
C3	Basic concepts, properties and operations in elementary algebra
C4	Basic concepts and properties of two-dimensional Geometry
C5	Data, probability, and basic statistics
C6	Using tools to measure (or estimating) length, time, angle, temperature

PROCESS ATTRIBUTES

P1	Translate/formulate equations and expressions to solve a problem
P2	Computational applications of knowledge in arithmetic and geometry
P3	Judgmental applications of knowledge in arithmetic and geometry
P4	Applying rules in algebra
P5	Logical reasoning—includes case reasoning, deductive thinking skills, if-then, necessary and sufficient, generalization skills
P6	Problem Search; Analytic Thinking, Problem Restructuring and Inductive Thinking
P7	Generating, visualizing and reading Figures and Graphs
P8	Applying and Evaluating Mathematical Correctness
P9	Management of Data and Procedures
P10	Quantitative and Logical Reading

SKILL (ITEM TYPE) ATTRIBUTES

S1	Unit conversion
S2	Apply number properties and relationships; number sense/number line
S3	Using figures, tables, charts and graphs
S4	Approximation/Estimation
S5	Evaluate/Verify/Check Options
S6	Patterns and relationships (be able to apply inductive thinking skills)
S7	Using proportional reasoning
S8	Solving novel or unfamiliar problems
S9	Comparison of two/or more entities (deleted because of low frequencies in each booklet)
S10	Open-ended item, in which an answer is not given
S11	Using words to communicate questions (word problem)

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