12-1999

The Role of Student Attitudes and Beliefs About Mathematics and Science Learning in Academic Achievement: Evidence From TIMSS for Six Nations

Erling E. Boe
University of Pennsylvania, boe@gse.upenn.edu

Herbert M. Turner III
University of Pennsylvania

Henry May
University of Pennsylvania

Christine S Leow
University of Pennsylvania

Gema Barkanic
University of Pennsylvania

The Role of Student Attitudes and Beliefs About Mathematics and Science Learning in Academic Achievement: Evidence From TIMSS for Six Nations

Abstract
In view of the prevalent belief among parents, educators, and policy makers that positive student attitudes and beliefs about mathematics learning are associated with higher academic achievement, Turner and Boe (1999) recently examined this association using data from the Third International Mathematics and Science Study (TIMSS) for seventh- and eighth-grade students in the United States. In light of the substantial support found by Turner and Boe for such attitude-achievement relationships under statistically controlled conditions, the research reported here was designed to expand upon the prior study by quantifying the strength of these relationships in both mathematics and science and to extend the analysis to other nations. To examine cross-national similarities and differences in attitude-achievement relationships, Singapore, Korea, and Hong Kong (representing the Peoples' Republic of China 1) were selected from the East, and Switzerland, Germany, and the United States were selected from the West.

Disciplines
Education

THE ROLE OF STUDENT ATTITUDES AND BELIEFS ABOUT MATHEMATICS AND SCIENCE LEARNING IN ACADEMIC ACHIEVEMENT: EVIDENCE FROM TIMSS FOR SIX NATIONS[1]

Data Analysis Report No. 1999-DAR3

Erling E. Boe, Ph.D.
Professor of Education
Graduate School of Education

Herbert M. Turner, III, M.P.A.
Fontaine Fellow
Graduate School of Education

Henry May, B.S.
Research Assistant
Graduate School of Education

Christine S. Leow, M.Ed.
Research Assistant
Graduate School of Education

and

Gema Barkanic, B.A.
Research Specialist
Center for Research and Evaluation

Center for Research and Evaluation in Social Policy
Graduate School of Education
University of Pennsylvania
3700 Walnut Street
Philadelphia, PA 19104

December 30, 1999

---

[1]Support for this research was provided by a grant (Award Number R215U980021) from the Fund for Improvement in Education (CFDA Number: 84-215U), Office of Reform Assistance and Dissemination, Office of Educational Research and Improvement, U.S. Department of Education; by a grant (Grant Number REC-9815112) from the Research on Education, Policy, and Practice Program (NSF 96-138), Division of Research, Evaluation, and Communication, Directorate for Education and Human Resources, National Science Foundation; and by the Center for Research and Evaluation in Social Policy, the Graduate School of Education of the University of Pennsylvania.

DATA ANALYSIS REPORTS

Data Analysis Reports are a means for rapid dissemination of the results of data analyses in tabular and graphical form with minimal description and discussion. These results may later be used as the basis for fully-developed research reports, policy briefs, journal articles, and/or other modes of dissemination.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

In view of the prevalent belief among parents, educators, and policy makers that positive student attitudes and beliefs about mathematics learning are associated with higher academic achievement, Turner and Boe (1999) recently examined this association using data from the Third International Mathematics and Science Study (TIMSS) for seventh- and eighth-grade students in the United States. In light of the substantial support found by Turner and Boe for such attitude-achievement relationships under statistically controlled conditions, the research reported here was designed to expand upon the prior study by quantifying the strength of these relationships in both mathematics and science and to extend the analysis to other nations. To examine cross-national similarities and differences in attitude-achievement relationships, Singapore, Korea, and Hong Kong (representing the Peoples' Republic of China[1]) were selected from the East, and Switzerland, Germany, and the United States were selected from the West.

The association of student attitudes and beliefs with academic achievement has been of interest to educators because the cultivation of positive attitudes about learning might contribute to higher achievement (e.g., liking mathematics may lead to a higher level of mathematics achievement). Conversely, it is also possible that success in learning mathematics may lead to more positive attitudes about mathematics. The analyses of TIMSS data reported here address this complexity in the relationship between attitudes and achievement.

Furthermore, the development of positive student attitudes and beliefs about mathematics learning is entailed in the Curriculum and Evaluation Standards for School Mathematics, a set of recommendations prepared by the National Council of Teachers of Mathematics (NCTM) (1989). Among NCTM's goals for students are (a) to learn to reason mathematically, (b) to value the mathematical enterprise, and (c) to understand the role of mathematics in human affairs. The first of these goals was stated most directly in

[1]Unfortunately, the People's Republic of China (PRC) did not participate in TIMSS. Although Hong Kong (HK) can be regarded as "representing" the PRC, by no means is HK "representative of" the PRC or any of its parts (other than HK). Therefore, no generalizations from HK to PRC are warranted, and none are made in this report.

NCTM's The Professional Standards of Teaching Mathematics as a need to shift "toward mathematical reasoning--away from merely memorizing procedures" (NCTM, 1991, p. 3). In addition, the teaching standards advocated "connecting mathematics, its ideas, and its applications" (NCTM, 1991, p. 3). The analyses reported here assess student attitudes and beliefs related to these NCTM goals, and the relationship of these attitudes and beliefs to mathematics learning.

As in mathematics, major national organizations such as the American Association for the Advancement of Science (AAAS) and the National Research Council (NRC) have promulgated curriculum and teaching standards in science that emphasize understanding and minimize memorization (AAAS, 1990; NRC, 1995). For example, a teaching principle advocated by the AAAS is to "Deemphasize the memorization of technical vocabulary" in favor of promoting student understanding of the scientific process and scientific knowledge. The analyses reported here assess student beliefs about the role of memorization in science learning and the association of such beliefs with science learning.

Nationally representative data from the TIMSS Student Questionnaire at the seventh- and eighth-grade levels was used in this research to measure individual student attitudes, beliefs, and perceptions about mathematics and science learning. Likewise, TIMSS provided the mathematics and science achievement scores for each student. The data source, the student samples, and data analysis procedures are described in the Appendix.

Based on their relevance to mathematics and science curriculum and teaching standards and the preliminary analyses reported by Turner and Boe (1999), three questionnaire items tapping into student attitudes and beliefs about mathematics and science were selected for intensive analysis. These three items are related to the three NCTM goals enumerated above, as follows:

- Item related to reasoning mathematically and away from memorization: How strongly a student agrees or disagrees with the proposition that, to do well in mathematics, one needs to memorize the textbook or notes. A parallel item about memorization in science learning was also analyzed.

- Item related to valuing mathematics: How strongly a student likes or dislikes mathematics. A parallel item about liking science was also analyzed.

- Item related to the role of mathematics in human affairs and connecting mathematics to applications: How strongly a student would like a job that involved using mathematics. A parallel item about liking a job using science was also analyzed.

In conjunction with these attitude and belief variables, the following three control variables were selected:

- Grade level (seventh vs. eighth grade)
- Sex (boys vs. girls)
- Number of books in the home (a family background variable)

The bivariate relationship of each of the three attitude and belief variables, and each of the three control variables, with mathematics achievement scores were first computed across the student sample within each of the six nations separately (see Figures 3 and 4). Next, all six predictor variables were included in a multivariate model for each of the six nations separately (see Figures 5 through 11). This approach made it possible to examine both the bivariate relationships between attitude/belief variables and achievement scores, and the adjusted relationships under statistically controlled conditions.

The same type of analysis was then applied to attitudes and beliefs about science learning and science achievement scores (see Figures 14 through 22). Finally, the multivariate models for mathematics achievement and science achievement were compared (see Figures 23 through 28).

Summary Results

Descriptions of the data source, student samples, variables, and data analysis procedures used for this research are described in the Appendix. All findings discussed and interpreted in the results described below are statistically significant at the .05 level or less. The standard errors and probability level of many comparisons are reported in the tables of results presented in this report.

Mathematics Achievement in Six Nations

The mean and standard deviation of mathematics achievement scores at the eighth grade level are shown in Figure 1 for each of six nations. The mean scores for all three nations from the East [(Singapore (SNG), Korea (KOR), and Hong Kong (HK)] were all significantly higher than the means scores for the three nations from the West [Switzerland (SWZ), Germany (GER), and the United States (US)]. According to Beaton, Mullis, et al. (1996, Figure 1.1), the following differences between the mean scores of these six nations were statistically significant at the .05 level (as adjusted for multiple comparisons):

SNG: > KOR, HK, SWZ, GER, US
KOR: > SWZ, GER, US; < SNG
HK: > SWZ, GER, US; < SNG
SWZ: > GER, US; < SNG, KOR, HK
GER: < SNG, KOR, HK, SWZ
US: < SNG, KOR, HK, SWZ

Of all the 41 nations that completed mathematics achievement testing at the eighth grade level, Singapore's mean score was significantly higher than all others, while the US mean score was slightly (but significantly) below the mean of the 41 nations.

Though there was considerable variability in mathematics mean achievement scores among the six nations included in this research, these differences were not the focus of this study. Instead, the focus was on factors (i.e., three attitude/belief variables and three control variables) that were associated with variability in individual student mathematics achievement scores within each nation.

Predictors of Mathematics Achievement: Bivariate Relationships

1. Mathematics Achievement: Seventh vs. Eighth Grade Differences: TIMSS provides independent national probability samples of seventh grade and eighth grade students within each nation studied. As shown in Figure 2, it is therefore possible to compute the difference between the mean mathematics scores of seventh grade students and eighth grade students. These differences provide a quantitative index of the educational value for mathematics learning of one year of school from the seventh to the eighth grade. For instance, there was a difference of 42 score points from seventh to eighth grade in SNG, but only 24 score points in the US. Such national differences are discussed in paragraph 2.a. below. The one-year grade level difference can also be used as a reference point to interpret the magnitude of achievement score differences produced by other variables. For example, the mean score difference between boys and girls in the US might be only one-tenth of the seventh-eighth grade difference, while the mean score difference attributable to a family background variable (i.e., number of books in the home) might be twice the seventh-eighth grade difference.
2. Grade Level, Sex, and Books in the Home: Bivariate Relationships: The bivariate associations of the three control variables with mathematics achievement are shown in Figure 3, while the distributions of these variables are shown in Table 1.
   (a) Grade Level:The seventh to eighth grade difference scores in mathematics achievement for each of six nations (as shown in Figure 2) have been reproduced as a bar graph in the top panel of Figure 3. In addition, 95% confidence intervals have been added for each national difference score. Inspection reveals that the confidence intervals for all six nations overlap, thereby indicating that these differences among the nations in mathematics achievement scores are not statistically significant. Over the six nations, the mean mathematics achievement score difference between seventh and eighth grade was 32 points.
   (b) Sex: By comparison with the 32 point average difference for grade level, the mathematics achievement score differences between boys and girls was quite modest. The average across the six nations was only about 9 points in favor of boys, as shown in the middle panel of Figure 3.
   (c) Books in Home: The number of "Books in Home" variable, at its extreme limits of "10 or less" vs. "200 or more," was strongly associated with mathematics

achievement scores (see the lower panel of Figure 3). This variable accounted for about 112 mathematics achievement score points in KOR, a number that is significantly higher than all other nations except GER. In KOR and the three nations from the WEST (SWZ, GER, and US), the "Books in Home" variable accounted for well over twice the number of achievement score points as the seventh to eighth grade level. Of the three control variables, family background (as represented by number of books in the home) was most strongly associated with mathematics achievement scores.

(d) Distribution of Control Variables: The distribution of the three control variables across their respective levels for the six nations is shown in Table 1. The national estimates of the number of students in the seventh and eighth grades were close to 50/50 for all six nations, as were the numbers of boys and girls in these grades. However, the distribution of number of "Books in Home" varied considerably among nations. In particular, the distributions of this variable for the three nations from the West (SWZ, GER, and US) were very similar, and all differed from KOR which had a much smaller percentage of students with over 200 books in the home and a much larger percentage of students with only 0 - 10 books in the home.

3. Student Attitudes and Beliefs: Bivariate Relationships: The bivariate associations of the three attitude and belief variables with mathematics achievement are shown in Figure 4, while the distributions of these variables are shown in Table 2.

(a) Like Math: As shown in Table 2, the six nations differed greatly in the extent to which students reported liking mathematics. For example, about 25% of students from GER and the US reported liking mathematics a lot, while only 14% of students from KOR did so. Conversely, 23% of German students reported disliking mathematics a lot, while only 4% of students from SNG did so. The extent to which extreme differences in attitude toward mathematics[2] were associated with differences in mathematics achievement is shown in the top panel of Figure 4. Here it is seen that students who reported liking mathematics a lot performed at a considerably higher level than students who reported disliking it a lot. This difference is most striking in KOR, where this attitude variable

[2]That is, students in each nation who have a very positive attitude about mathematics (i.e., like it a lot) versus students who have a very negative attitude about it (i.e., dislike it a lot).

accounted for 121 achievement score points--a number four times higher than the 30 points accounted for by the seventh versus eighth grade difference (see Figure 3). By contrast, the association of the "like math" attitude variable with mathematics achievement was least striking for GER were it accounted for only 28 achievemnt points--a number equivalent to the 25 points accounted for by the seventh versus eighth grade difference (see Figure 3). Also significant is the fact that liking mathematics was related more strongly to mathematics achievement in nations from the East (SNG, KOR, and HR) than it is in nations from the West (SWZ, GER, and US). Taken as a whole for the six nations, the results show that a positive attitude toward mathematics was strongly associated with mathematics achievement.

(b) Math Job: In comparison, differences among students in their interest in wanting a job using mathematics were associated to a much lesser extent with mathematics achievement (see the middle panel of Figure 4) than were differences in liking mathematics. More particularly, the "Math Job" variable was more strongly associated with mathematics achievement in SNG and HK than it was in SWZ or GER. The distributions of the "Math Job" variable differed greatly among the nations. For example, 15% of students from SNG were strongly interested in a job using mathematics, while only 5% of students from KOR were strongly interested. Conversely, 39% of students from GER were strongly disinterested in a job using mathematics, while only 8% of students from SNG were strongly disinterested.

(c) Not Memorize: Students were asked how strongly they agreed or disagreed with the belief that, to do well in mathematics, one needs to memorize the textbook or notes. Responses to this question were coded so that a high score indicated strong disagreement with this statement, while a low score indicated strong agreement. This coding defines the "Not Mem." variable. As shown in Table 2, student beliefs about the importance of memorization in mathematics learning varied widely among the six nations studied. About 20% of students in SNG, SWZ, and GER strongly disagreed with this belief, while only 3% of students from KOR strongly disagreed. Similarly, only 8% students from SNG strongly agreed with this belief, while over 26% in KOR and HK strongly agreed. The lower panel of Figure 4 shows that the difference between strongly disagreeing versus strongly agreeing with this belief was highly related to mathematics achievement in SNG and KOR, even though these two nations differed greatly in the pervalence of this belief (as shown in Table 2). This means that in both nations, those students who believed that memorizing was not the way to do well in mathematics actually achieved at a much higher level than students who believed that memorizing the textbook and notes was important to doing well.

Predictors of Mathematics Achievement: Multivariate Analyses by Nation

In this section, the results of the bivariate analyses for the six predictor variables (three control variables and three attitude and belief variables) of mathematics achievement, as shown in Figures 4 and 5, are assembled in one bar graph for each of the six nations and compared with a parallel bar graph showing the results of a multivariate model based on the same six variables. Only the associations of predictor variables with mathematics achievement that are statistically significant at the .05 level are shown in these comparisons. In addition, the national multivariate models are shown in more detail in Table 3.

4. Singapore: Bivariate vs. Multivariate Analyses: As seen in Figure 5 For SNG, the bivariate relationships of "Not Mem." and "Like Math" with mathematics achievement were the strongest, though "Like Math" was not significantly more related than was number of "Books in Home." The multivariate model did not substantially change the relative predictive validity of each variable, though the size of associations with mathematics achievement were slightly reduced. The adjusted R^2 of .21 indicates that these six variables alone accounted for a considerable component of variability in mathematics achievement scores in SNG.
5. Korea: Bivariate vs. Multivariate Analyses: As seen in Figure 6 for KOR, remarkably strong bivariate relationships with mathematics achievement were produced by "Books in Home" and "Like Math," with "Not Mem." also strong (of an order of magnitude seen in SNG). The predictive power of these three variables was only modestly reduced in the multivariate model, while "Math Job" was no longer statistically significant. The adjusted R^2 of .25 indicates that these six variables alone accounted for a considerable component of variability in mathematics achievement scores in KOR.
6. Hong Kong: Bivariate vs. Multivariate Analyses: As seen in Figure 7 for HK, the strongest bivariate relationships with mathematics achievement was produced by "Like Math" (of an order of magnitude seen in SNG). The predictive power of all the

variables was modestly reduced in the multivariate model, while "sex" was no longer statistically significant. The adjusted R^2 of .13 for HK was the lowest seen in the six nations studied.

7. Switzerland: Bivariate vs. Multivariate Analyses: As seen in Figure 8 for SWZ, the strongest bivariate relationships with mathematics achievement was produced by "Books in Home" (of an order of magnitude seen in GER and the US). The association of sex differences was small. The predictive power of all six variables was only slightly changed in the multivariate model. The adjusted R^2 of .21 indicates that these six variables alone accounted for a considerable component of variability in mathematics achievement scores in SNG.
8. Germany: Bivariate vs. Multivariate Analyses: As seen in Figure 9 for GER, the strongest bivariate relationships with mathematics achievement was also produced by "Books in Home" (of an order of magnitude seen in SWZ and the US). The association of sex differences was not significant. The predictive power of all six variables was only slightly changed in the multivariate model. The adjusted R^2 of .21 indicates that these six variables alone accounted for a considerable component of variability in mathematics achievement scores in GER, with "Books in Home" providing most of the predictive validity.
9. United States: Bivariate vs. Multivariate Analyses: As seen in Figure 10 for the US, the strongest bivariate relationships with mathematics achievement was also produced by "Books in Home" (of an order of magnitude seen in SWZ and GER). The three attitude/belief variables were equivalent at a modest level in their association with mathematics achievement. The predictive power of all six variables were little changed in the multivariate model. The adjusted R^2 of .18 indicates that these six variables accounted for a modest component of variability in mathematics achievement scores in the US, with "Books in Home" being represented most prominently.
10. Multivariate Models for Six Nations Compared: The multivariate models of mathematics achievement for each of the six nations as shown in the lower half of Figures 5 through 10 are reproduced in Figure 11, with the nations from the East in the left column and the nations from the West in the right. While there are many similarities, a few differences stand out. In all three nations from the West (SWZ, GER, US), the family background variable of number of books in the home was the single strongest predictor of mathematics achievement. This variable was also a strong predictor in SNG and KOR, but in these two nations from the East, liking mathematics was an

equivalently strong predicator. For all three nations from the East, "Like Math" was a stronger predicator of achievement than it was for any of the three nations from the West. And for SNG (the nation scoring significantly higher in mathematics than all nations as reported by Beaton, Mullis, et al., 1996), "Not Mem." was a strong predicator, and stronger there than in any of the other five nations. As a broad generalization, it appears that the control variables (and especially "Books in Home) were a stronger set of predictors than attitude/belief variables in the West, while attitude/belief variables (especially "Like Math" and "Not Mem.") were a stronger set of predictors than the control variables in the East.

Student Perceptions of Mathematics Performance: Multivariate Analyses

Students were asked to report their agreement/disagreement with the statement "I usually do well in math" (i.e., the "Do Well Math" variable). As seen in Table 2, only a modest percentage of students from Eastern nations strongly agreed with this statement (e.g., 6% of Korean students) while a much higher percentage of students from Western nations strongly agreed (e.g., 38% of German students). In terms of national mean mathematics achievement scores as shown in Figure 1, the three nations from the East (with relatively high scores) had the lowest percentage of students who perceived themselves as doing well in mathematics, while the three nations from the West (with lower scores) had the highest percentage of students who perceived themselves as doing well in mathematics. These perceptions, no doubt, reflect the educational experience of each student within his/her respective national school culture. Since the student perceptions about doing well were opposite of what would be expected on the basis of their relative international performance, it is likely that students from the East were being held to a much higher standard than students from the West. Otherwise, one might expect a much higher percentage to have perceived themselves as doing very well in mathematics.

Just how well students actually performed on the mathematics achievement test is shown by nation in Figure 12 for students who perceived their performance[3] as "very good" versus "very poor." As can be seen, there was enormous variability across nations in the performance differences between students with perceptions of performing "very good" and "very poor." At the extremes, the average scores for students with perceptions

[3]In response to the statement "I usually do very well in math," students who reported they strongly agreed are labeled here as students who perceived their performance to be "very good," while students who reported they strongly disagreed are labeled "very poor."

of "very poor" versus "very good" performance differed by 164 points in KOR, but only 54 points in GER.

Likewise, there were enormous national differences in the mean mathematics achievement scores corresponding to student perceptions of performaing "very poor" versus "very good." In the GER and the US, for example, the average mathematics achievement scores of students who perceived that they performed "very good" in mathematics were actually below the average achievement scores of SNG students who perceived that they performed "very poor." As would be expected, this is further evidence that student perceptions were a function of national performance norms instead of international norms.

Finally, the "Do Well Math" variable was entered as a seventh predictor variable in the multivariate models of mathematics achievement shown in Figure 11. These models, with "Do Well Math" included, are shown in Figure 13. In comparing the multivariate models excluding and including this variable (i.e., the models of Figures 11 vs. 13), it is first apparent that the addition of "Do Well Math" did not change appreciably the associations of the three control variables with mathematics achievement for any of the six nations. However, for the three nations from the West (SWZ, GER, and US), the addition of "Do Well Math" to the models (as seen in the right panel of Figure 13) eliminated "Like Math", but barely influenced the other two attitude/belief variables. Thus, for these three nations, it appears that liking mathematics was secondary to perceptions of doing well in mathematics. In other words, it seems as though liking math followed more from doing well in mathematics, than doing well followed from liking math, in the three nations from the West. In all three Western nations, the addition of "Do Well Math" to the multivariate models resulted in higher predictive validity of the models (R^2s), even though the associations of "Like Math" with achievement were not statistically significant.

In the three nation from the East (SNG, KOR, and HK), the addition of "Do Well Math" (as seen in left panel of Figure 13) to the multivariate models of mathematics achievement of Figure 11 reduced substantially the predictive power of "Like Math," but did not eliminate it. The predictive power of "Do Well Math" for these nations was generally greater than "Like Math," also suggesting that liking mathematics is secondary to perceptions of doing well in mathematics instead of vice versa.

Predictors of Science Achievement: Bivariate Relationships

Science achievement for the <u>same sample</u> of seventh and eighth grade students for the same six nations were analyzed in parallel with the bivariate and multivariate analyses reported above for mathematics achievement. The results of analyzing science achievement as a function of three control and three attitude/belief variables are described in the following sections.

11. Grade Level, Sex, and Books in the Home: Bivariate Relationships: The bivariate associations of the three control variables with science achievement are shown in Figure 14, while the distributions of these variables were shown in Table 1, and discussed above in paragraph 2.(d).

   (a) Grade Level: As seen in the top panel of Figure 14 and in Table 4, eighth grade students in SNG scored 61 points higher than seventh grade students, a grade difference that exceeded that of the other five nations studied. Inspection reveals that the grade difference for the other five nations did not differ significantly (i.e., had overlapping confidence intervals) and averaged about 32 points, or roughly half of the SNG difference.

   (b) Sex: In comparison with sex differences in mathematics (see the middle panel of Figure 3), science achievement score differences between boys and girls was larger for each of the six nations, though none of these six differences were statistically significant. Thus, there is reason to suspect that, on the whole, sex differences in achievement might be greater in science than in mathematics. For the five nations other than SNG, the average magnitude of the achievement difference between boys and girls was well over half the difference between the 7th and 8th grade levels (18 points for sex, 32 points for one grade level).

   (c) Books in Home: As for mathematics achievement scores, "Books in Home" was strongly associated with science achievement scores (see the lower panel of Figure 14). This variable accounted for about 103 science achievement score points in GER, a number that was significantly higher than all other nations except the US. Of the three control variables, family background (as represented by number of books in the home) was most strongly associated with science achievement scores.

12. Student Attitudes and Beliefs: Bivariate Relationships: The bivariate associations of the three attitude and belief variables with science achievement are shown in Figure 15, while the distributions of these variables are shown in Table 4.

   (a) Like Sci.: As shown in Table 4, the six nations differ greatly in the extent to which students reported liking science (Like Sci.). The percentage of students "liking science a lot" varied greatly from 32% for SNG to 12% for KOR. Conversely, only 1% of students from SNG reported disliking science a lot, while 11% of US students disliked science a lot. The extent to which extreme differences in attitude toward sciences[4] were associated with differences in science achievement is shown in the top panel of Figure 15. Here it is seen that, except for SWZ, students who reported liking science a lot performed at a much higher level than students who reported disliking it a lot.

(b) Sci. Job: Except for GER, differences among students in their interest in wanting a job using science (Sci. Job) were associated to a comparable extent with science achievement as were differences in liking science (see the middle panel of Figure 15). The distributions of "Sci. Job" also differed greatly among the nations. For example, only 4% of students from GER were strongly interested in a job using science, while 20% of students from the US were. Conversely, 48% of students from GER were strongly disinterested in a job using science, while only 7% of students from SNG were strongly disinterested.

(c) Not Mem.: Students were asked how strongly they agreed or disagreed with the belief that, to do well in science, one needs to memorize the textbook or notes. This question was coded so that a high score indicated strong disagreement with this statement (Not Mem.), while a low score indicated strong agreement. As shown in Table 4, student beliefs about the importance of memorization in science learning varied widely among the six nations studied. About 14% of students in SWZ strongly disagreed with this belief, while only 1% of students from KOR strongly disagreed. Similarly, a considerably larger percentage of students from the Eastern nations strongly agreed with this belief (over 40%) than did students from the Western nations. Nonetheless, a substantial majority of students from all six nations agreed, or strongly agreed, with the statement that to do well in science, one needs to memorize the textbook or notes. The lower panel of Figure 15 shows that, except for SNG, the difference between strongly disagreeing versus strongly agreeing with this belief was unrelated, or weekly related, to science achievement. Only in SNG did those students who strongly disagreed that memorization was important to doing well in science attain much higher science achievement scores. Insofar as data from six nations

---

[4]That is, students in each nation who have a very positive attitude about science (i.e., like it a lot) versus students who have a very negative attitude about it (i.e., dislike it a lot).

suggest, "Not Mem." revealed a major difference in mathematics and science achievement. This variable was much more predicative of achievement in mathematics than in science (see Figures 4 and 15) even though more students from all six nations regarded memorization as important to doing well in science than to doing well in mathematics (see Tables 2 and 4).

Predictors of Science Achievement: Multivariate Analyses by Nation

In this section, the results of the bivariate analyses for six predictor variables (three control variables and three attitude and belief variables) for science achievement, as shown in Figures 14 and 15, are assembled in one bar graph for each of the six nations and compared with a parallel bar graph showing the results of a multivariate model based on the same six variables. Only the associations of predictor variables with science achievement that were statistically significant are shown in these comparisons. In addition, the national multivariate models are shown in more detail in Table 5.

13. Singapore: Bivariate vs. Multivariate Analyses: As seen in Figure 16 For SNG, the bivariate relationships of all predictor variables (except sex) with science achievement were of comparable magnitude (60 - 80 point range) and not significantly different. There was no significant difference in science achievement between boys and girls. The predictive power of the attitude/belief variables was generally lower in the multivariate model than were the bivariate relationships, while the predictive power of the grade level and number of books in the home variables did not change. The adjusted R^2 of .20 indicates that these six variables accounted for a considerable component of variability in science achievement scores in SNG.
14. Korea: Bivariate vs. Multivariate Analyses: As seen in Figure 17 for KOR, strong bivariate relationships with science achievement were produced by "Books in Home" and "Like Sci.", while "Not Mem." was not related to achievement. The predictive power of the other five variables was only modestly reduced in the multivariate model. The adjusted R^2 of .15 indicates that these five variables accounted for a modest component of variability in science achievement scores in KOR.
15. Hong Kong: Bivariate vs. Multivariate Analyses: As seen in Figure 18 for HK, the strongest bivariate relationship with science achievement was produced by "Like Sci.", while "Not Mem." was not significantly associated with achievement. The predictive power of four variables was slightly reduced in the multivariate model, while

"Sci. Job" was no longer statistically significant. The adjusted R^2 of .08 for science achievement in HK was low--the lowest seen in the six nations studied.

16. Switzerland: Bivariate vs. Multivariate Analyses: As seen in Figure 19 for SWZ, the strongest bivariate relationships with science achievement was found with "Books in Home" (of an order of magnitude seen in GER and the US). The size of the associations of attitude/belief variables with achievement were only about half the grade level difference. The predictive power of all six variables was only slightly changed in the multivariate model. The adjusted R^2 of .16 indicates that these six variables accounted for a modest component of variability in science achievement scores in SWZ.
17. Germany: Bivariate vs. Multivariate Analyses: As seen in Figure 20 for GER, the strongest bivariate relationship with science achievement was also found with "Books in Home" (of an order of magnitude seen in SWZ and the US). The association of "Like Sc." was a strong second. The predictive power of the three control variables was barely changed in the multivariate model, while the predictive power of "Like Sci." was reduced by half. The adjusted R^2 of .17 indicates that these six variables accounted for a modest component of variability in science achievement scores in GER, with number of books in the home accounting for the largest share.
18. United States: Bivariate vs. Multivariate Analyses: As seen in Figure 21 for the US, the strongest bivariate relationships with science achievement was also found with "Books in Home" (of an order of magnitude seen in SWZ and GER). The associations of two attitude/belief variables ("Like Sci." and "Sci. Job") with achievement were about half that of "Books in Home." The predictive power of these two attitude/belief variables was substantially reduced in the multivariate model. The adjusted R^2 of .16 indicates that these six variables accounted for a modest component of variability in science achievement scores in the US, with "Books in Home" being represented most prominently.
19. Multivariate Models for Six Nations Compared: The multivariate models of science achievement for each of six nations as shown in the lower half of Figures 16 through 21 are reproduced in Figure 22, with the nations from the East in the left column and the nations from the West in the right. In all three nations from the West (SWZ, GER, US) the family background variable of number of books in the home was the single strongest predictor of science achievement, while the attitude/belief variables were relatively weak predictors. By contrast, the attitude/belief variables were much stronger predictors of achievement in SNG. For all three nations from the East, "Like

Sci." was a stronger predicator than for any of the three nations from the West. And for SNG (the nation scoring significantly higher in science at the eighth grade level than all nations as reported by Beaton, Martin, et al., 1996), "Not Mem." was a strong predicator, and stronger in SNG than in any of the other five nations. As a broad generalization, it appears that the control variables, and especially "Books in Home", were a stronger set of predictors of science achievement than attitude/belief variables in all nations but HK.

Mathematics and Science Achievement: Multivariate Models Compared

The multivariate models for predicting mathematics and science achievement from three student attitude/belief variables, along with three control variables, are reproduced by nation in Figures 23 through 28, and are discussed in the following paragraphs. These figures reproduce the multivariate models for mathematics achievement shown by nation in Figures 5 through 10 and for science achievement shown by nation in Figures 17 through 21.

20. Singapore: Mathematics vs. Science Multivariate Analyses: As shown in Figure 23, the multivariate models for mathematics and science achievement in SNG are very similar and have equivalent adjusted R^2s. Insofar as the variables included in these models are concerned, both student attitude/belief variables and the family background variable (number of books in the home) are related to achievement in both fields. Coincidentally, SNG produced the highest achievement scores internationally in both fields at the eighth grade level.

21. Korea: Mathematics vs. Science Multivariate Analyses: The multivariate models for mathematics and science achievement in KOR were very similar for the three control variables, but differed with respect to attitude/belief variables (see Figure 24). Liking science was much less predictive of achievement than liking mathematics, and "Not Mem." was a significant component of the mathematics model, but was not significant in the science model. Consequently, the predictive power of the science model was much less than that of the mathematics model (respective adjusted R^2s of .25 and .15).

22. Hong Kong: Mathematics vs. Science Multivariate Analyses: As seen in Figure 25, the multivariate models for mathematics and science achievement in HK are similar in that, among all the predictor variables, the "Like Math" and "Like Sci." attitude variables were most strongly related to achievement. A sex difference, in favor of

boys, was included in the science model (but not in the mathematics model) at a level not significantly different than the other two control variables (the grade 7 to 8 difference and "Books in Home"). Overall, however, both models accounted for little variability in achievement in HK (adjusted R^2s of .13 for mathematics and .08 for science).

23. Switzerland: Mathematics vs. Science Multivariate Analyses: The association of the three control variables with achievement in mathematics and science in SWZ were equivalent, while the associations of "Like Math/Sci." and "Not Mem." were lower in science than in mathematics (see Figure 26). "Books in Home" was clearly the strongest in both models.

24. Germany: Mathematics vs. Science Multivariate Analyses: In GER, the multivariate models for mathematics and science were similar, the dominant features of which were the large associations of "Books in Home" with achievement in both models (see Figure 27). As in HK, a sex difference in favor of boys was included in the science model, but not in the mathematics model. The predictive validity of the science model (adjusted R^2 of .17) was somewhat less than that of the mathematics model (adjusted R^2 of .21).

25. United States: Mathematics vs. Science Multivariate Analyses: Finally as seen in Figure 28, the variable profiles and predictive validities of the multivariate models for mathematics and science in the US were very similar. The distinctive feature of both models was the dominant position of "Books in Home".

26. Mathematics vs. Science Multivariate Models: Similarities and Differences
Overall, the multivariate models for predicting mathematics achievement and science achievement were more similar than different. In particular, "Books in Home" was consistently the strongest predictor of both mathematics and science in the three Western nations (SWZ, GER, US). This contrasts with the models for the three Eastern nations (SNG, KOR, HK) where "Like Math." and "Like Sci." were as strong predictors as "Books in Home" in their respective models. Some similarity of the models for mathematics and science achievement should be expected because of the substantial correlation within each nation between mathematics and science scores across the national samples of students. However, these correlations were not so high as to preclude the possibility of major differences appearing between the mathematics and science achievement models. The math/science achievement score correlations were:

SNG: r = .49	SWZ: r = .56
KOR: r = .57	GER: r = .62
HK: r = .56	US: r = .62

Of greater interest, perhaps, than the similarities of the multivariate models for mathematics achievement and science achievement were two noteworthy differences. First, the advantage of boys over girls in achievement was greater in science than in mathematics in HK, SWZ, GER. Second, the association of "Not Mem." with science achievement was significantly lower than with mathematics achievement in all six nations, thereby suggesting that memorizing as a learning strategy was less detrimental to achievement in science than in mathematics.

Conclusions

Several important conclusions can be drawn from the results of the analyses of student attitudes, beliefs, and perceptions about mathematics and science achievement, most of which are directly relevant to national curriculum and teaching standards in mathematics and science. These conclusions are organized in terms of the following four facets of this research:

National Differences in Student Attitudes, Beliefs, and Perceptions

1. Memorizing mathematics and science: In keeping with NCTM standards prescribing the learning of mathematical reasoning and understanding and away from merely memorizing procedures, more than 59% of seventh- and eighth-grade students from SNG (the nation leading the world in mathematics achievement), SWZ, and GER rejected the view that memorization is necessary to do well in mathematics, a percentage higher than that of students from the other three nations. By contrast, 78% of students from KOR (another high performing nation) accepted the view that memorization is necessary to do well in mathematics. Furthermore, students from all six nations agreed that memorization was much more important in learning science than mathematics. Contrary to AAAS standards for science learning, a substantial majority of students from each nation studied agreed that memorization was important to do well in science. Obviously, much remains to be accomplished in implementing NCTM and AAAS standards that deemphasize memorization in mathematics and science learning in the US and other nations that might be interested in implementing such standards.

2. Liking mathematics and science: Of the six nations studied, a higher percentage of seventh- and eighth-grade students from SNG liked mathematics a lot (29%) than from any of the other nations, and a lower percentage disliked it a lot (4%). Likewise, a higher percentage of such students from SNG (the nation also leading the world in science achievement) liked science a lot (32%) than from any of the other nations, and a lower percentage disliked it a lot (1%). Overall, more that 50% of students in all six nations liked mathematics, a finding consistent with the NCTM's goal of valuing mathematics.

3. Job using mathematics or science: A much higher percentage of seventh- and eighth-grade students from GER (a nation that performed close to the international average in mathematics achievement) was strongly disinterested in a job using mathematics (39%) and using science (48%) than any of the other five nations. By contrast, 62% of students from SNG agreed that they would like a job using mathematics.

4. Achievement standards: Seventh- and eighth-grade students from the three Eastern nations (SNG, KOR, HK) were much less likely to perceive themselves as doing well in mathematics and in science than were students from the three Western nations (SWZ, GER, US). Nonetheless, these students from the Eastern nations generally performed at a much higher level on the international academic achievement tests in mathematics and science than did students from the Western nations. Thus, it appears as though students from the Eastern nations have been held to a higher achievement standard than the students from the Western nations. If so, this evidence is supportive of standards-based educational reform in the US which holds that higher academic standards will lead to improved student achievement.

Multivariate Relationships of Student Attitudes, Beliefs, and Perceptions with Achievement

5. Predictors of mathematics achievement: A family background variable (number of books in the home) was the strongest predictor of mathematics achievement in the three Western nations (SWZ, GER, US), while the three attitude and belief variables ("Like Math.," "Math. Job," and "Not Mem.") were secondary. By contrast, two attitude and belief variables ("Like Math." and "Not Mem.") were the strongest predictors of mathematics achievement in the three Eastern nations (SNG, KOR, HK).

6. Liking mathematics as a product of doing well in mathematics: The addition of "Do Well Math" (i.e., student perceptions of how well they perform in mathematics) to the standard six variable multivariate models of mathematics achievement eliminated the "Like Math." variable in the models for the three Western nations and reduced the predictive validity of "Like Math." in the models for the three Eastern nations. Thus, it appears that liking mathematics is more a function of doing well in mathematics than vice versa.

Comparison of Multivariate Models for Mathematics and Science Achievement

7. Sex differences: Boys excelled girls more in science achievement than they did in mathematics achievement in three nations (HK, SWZ, GER).

8. Control vs. attitude/belief variables: Except for HK, the control variables (and especially the number of books in the home) were a stronger set of predictors of science achievement than attitude/belief variables. By contrast, the three attitude and belief variables collectively were the strongest predictors of mathematics achievement for the three Eastern nations (SNG, KOR, HK).

9. Memorization as a predictor of mathematics vs. science achievement: The association of "Not Mem." with science achievement was significantly lower than with mathematics achievement in all six nations studied, thereby suggesting that memorizing as a learning strategy was less detrimental to achievement in science than in mathematics. The strength of the relationship of "Not Mem." with science achievement ranged widely by nation from strong (SNG) to negligible (KOR). Therefore, little can be concluded from these findings about the importance for achievement of the AAAS standard deemphasizing memorization.

Student Attitudes, Beliefs, and Perceptions in the United States

10. Memorizing mathematics: In keeping with the NCTM standard prescribing the learning of mathematical reasoning and understanding and away from merely memorizing procedures, 41% of seventh and eighth grade students in the US disagreed with the proposition that one needs to memorize the textbook or notes to do well in mathematics. However, this percentage was much less than found for SNG, SWZ, and GER, but considerably greater than for students from KOR and HK. With only 41% of US students disagreeing with the idea that memorization is important, it appears this NCTM standard is far from attained in the US.

11. Memorizing science: With respect to the AAAS standard deemphasizing memorization in learning science, only 34% of seventh and eighth grade students in the US disagreed with the proposition that one needs to memorize the textbook or notes to do well in science. However, this percentage was much greater than found for the Eastern nations (SNG, KOR, HK), but considerably less than for students from SWZ. With but only 34% of US students disagreeing with the idea that memorization is important, it appears that this AAAS standard is far from attained.

12. Liking mathematics: As related to the NCTM standard about valuing mathematics, a remarkably high 71% of seventh and eighth grade students in the US reporting liking mathematics. Only SNG students were higher (at 84%) in this respect.

13. Liking science: A remarkably high 73% of seventh and eighth grade students in the US reporting liking science, a percentage equivalent to that for liking mathematics. Only SNG students were higher (at 90%) in this respect.

14. Job using mathematics: About 40% of US seventh and eighth grade students indicated that they would like a job using mathematics, a level about average among the group of nations studied.

15. Job using science: About 59% of US seventh and eighth grade students indicated that they would like a job using sciences, a level considerably higher than for mathematics. In this respect, US students were much more interested in a job using science than students in the other nations studied except SNG.

16. Achievement standards in mathematics: A surprising 86% of seventh- and eight-grade students in the US agreed with the statement that they usually did well in mathematics, the highest level among the nations studied by a considerable margin. In comparison with other nations, it is possible that such a high percentage of US students believe they are doing well because academic standards are relatively low. Eaton (1999) has suggested that US schools have focused on developing self-esteem at the expense of academic rigor.

17. Relationship between attitudes and achievement in mathematics and science: Considered separately, student attitudes and beliefs in the US are only modestly related to mathematics and science achievement under the statistically controlled conditions of the multivariate models used in this study. To put this in perspective, each of the three attitude and belief variables studied is associated, on the average, with mathematics and science achievement scores by about 23 points. By comparison, this is

equivalent to the difference in achievement points between seventh- and eighth-grade students in the US (about 23 score points in both mathematics and science). However, taken as a group of three predictor variables, a student who consistently held strongly positive attitudes and beliefs, as envisioned by NCTM standards, would be predicted to score about 70 points higher on either the mathematics or science achievement exam than a student who consistently held strongly negative attitudes and beliefs. Thus, it appears that strongly positive attitudes and beliefs can make a substantial difference in learning mathematics and science.

Table 1. *Student Grade Level, Sex, and Number-of-Books-in-Home Variables: Percentage Distributions for Six Nations for Seventh and Eighth Grade Students Combined*

		Eastern Nations			Western Nations		
Control Variable	Statistic[a]	Singapore	Korea	Hong Kong	Switzerland	Germany	United States
	National Estimate	72,719	1,608,813	177,164	136,414	1,468,434	6,345,144
Grade:							
Eighth	Col% / SE%	50.3% / 0.8%	50.4% / 0.3%	50.0% / 0.4%	51.1% / 0.7%	49.5% / 0.8%	50.3% / 0.4%
Seventh	Col% / SE%	49.8% / 0.8%	49.6% / 0.3%	50.0% / 0.4%	48.9% / 0.7%	50.6% / 0.8%	49.8% / 0.4%
	Total%	100%	100%	100%	100%	100%	100%
	Response n	8,285 / 100%	5,827 / 100%	6,752 / 100%	8,940 / 100%	5,763 / 100%	10,973 / 100%
	Non-Response n	0 / 0%	0 / 0%	0 / 0%	0 / 0%	0 / 0%	0 / 0%
Sex:							
Boys	Col% / SE%	50.8% / 2.4%	56.2% / 3.3%	55.1% / 2.8%	50.9% / 0.7%	49.2% / 1.3%	50.2% / 0.8%
Girls	Col% / SE%	49.2% / 2.4%	43.8% / 3.3%	44.9% / 2.8%	49.1% / 0.7%	50.8% / 1.3%	49.8% / 0.8%
	Total%	100%	100%	100%	100%	100%	100%
	Response n	8,238 / 99.4%	5,822 / 99.9%	6,719 / 99.5%	8,864 / 99.1%	5,685 / 98.6%	10,823 / 98.6%
	Non-Response n	47 / 0.6%	5 0.1%	33 / 0.5%	76 / 0.9%	78 / 1.4%	150 / 1.4%
Books in Home:							
Over 200	Col% / SE%	12.0% / 0.8%	8.8% / 0.5%	20.8% / 1.0%	26.1% / 0.8%	31.5% / 1.4%	30.6% / 1.6%
101 - 200	Col% / SE%	14.5% / 0.6%	10.9% / 0.5%	28.1% / 0.7%	21.1% / 0.6%	18.6% / 0.6%	21.0% / 0.6%
26 - 100	Col% / SE%	40.8% / 0.7%	33.5% / 0.7%	30.1% / 0.7%	30.8% / 0.6%	27.8% / 0.8%	27.9% / 0.8%
11 - 25	Col% / SE%	21.9% / 0.8%	24.0% / 0.5%	10.3% / 0.5%	15.3% / 0.6%	14.1% / 0.8%	12.4% / 0.7%
0 - 10	Col% / SE%	10.8% / 0.6%	22.8% / 0.8%	10.7% / 0.9%	6.7% / 0.6%	7.9% / 0.7%	8.1% / 0.8%
	Total%	100%	100%	100%	100%	100%	100%
	Response n	8,224 / 99.0%	5,811 / 99.7%	6,618 / 98.0%	8,781 / 98.2%	5,647 / 98.0%	10,723 / 97.7%
	Non-Response n	61 / 1.0%	16 / 0.3%	134 / 2.0%	159 / 1.8%	116 / 2.0%	250 / 2.3%

Note. Data from the Third International Mathematics and Science Study (TIMSS).

[a]The number of nationally weighted students (National Estimate) at the 7th and 8th grades combined; nationally weighted percentages (Col%) of the nationally estimated number of students; standard errors (SE%) of the nationally weighted percentages; item sample size (Response n / %); item non-response sample size (Non-Response n / %). Column percentages may not sum to 100% due to rounding.

9/16/99 fn: c:\boefiles\bbb-w70\bbb2\table1.doc; c:\timss\pop2\300s\301lst.sas

Table 2. *Student Attitude, Belief, and Perception Variables about Mathematics: Percentage Distributions for Six Nations for Seventh and Eighth Grade Students Combined*

Mathematics Predictor Variable	Statistic	Eastern Nations			Western Nations		
		Singapore	Korea	Hong Kong	Switzerland	Germany	United States
	National Estimate	72,719	1,608,813	177,164	136,414	1,468,434	6,345,144
Like Mathematics:							
Like a lot	Col% / SE%	29.4% / 0.8%	13.6% / 0.6%	18.2% / 0.7%	21.1% / 0.5%	25.5% / 0.8%	24.7% / 0.8%
Like	Col% / SE%	54.4% / 0.6%	44.9% / 1.0%	48.8% / 0.9%	47.9% / 0.7%	30.7% / 0.9%	46.9% / 0.8%
Dislike	Col% / SE%	12.6% / 0.5%	35.2% / 0.8%	22.4% / 0.7%	21.8% / 0.7%	21.0% / 0.8%	16.6% / 0.7%
Dislike a lot	Col% / SE%	3.7% / 0.3%	6.3% / 0.3%	10.7% / 0.7%	9.2% / 0.4%	22.9% / 0.8%	11.8% / 0.5%
	Total%	100%	100%	100%	100%	100%	100%
	Response n	8,229 / 99.3%	5,810 / 99.7%	6,591 / 97.6%	8,728 / 97.6%	5,659 / 98.2%	10,675 / 97.3%
	Non-Response n	56 / 0.7%	17 / 0.3%	161 / 2.4%	212 / 2.4%	104 / 1.8%	298 / 2.7%
Like Job Using Math:							
Strongly Agree	Col% / SE%	15.0% / 0.5%	4.7% / 0.3%	9.6% / 0.4%	12.9% / 0.5%	13.4% / 0.5%	12.5% / 0.3%
Agree	Col% / SE%	46.9% / 0.7%	15.0% / 0.5%	33.8% / 0.9%	26.8% / 0.7%	16.8% / 0.7%	27.9% / 0.5%
Disagree	Col% / SE%	30.3% / 0.7%	59.9% / 0.8%	44.0% / 0.8%	36.6% / 0.8%	31.4% / 0.9%	36.4% / 0.5%
Strongly Disagree	Col% / SE%	7.8% / 0.4%	20.4% / 0.5%	12.7% / 0.6%	23.7% / 0.7%	38.5% / 0.9%	23.2% / 0.5%
	Total%	100%	100%	100%	100%	100%	100%
	Response n	8,198 / 98.9%	5,792 / 99.4%	6,576 / 97.4%	8,657 / 96.8%	5,582 / 96.9%	10,572 / 96.3%
	Non-Response n	87 / 1.1%	35 / 0.6%	176 / 2.6%	283 / 3.2%	181 / 3.1%	401 / 3.7%
To Do Well in Math, Need to Memorize:							
Strongly Disagree	Col% / SE%	17.8% / 1.1%	3.4% / 0.3%	5.8% / 0.4%	20.7% / 0.7%	20.5% / 0.8%	10.0% / 0.5%
Disagree	Col% / SE%	44.5% / 1.0%	19.0% / 0.6%	24.0% / 0.9%	42.4% / 0.7%	28.6% / 0.9%	31.4% / 0.9%
Agree	Col% / SE%	29.8% / 1.2%	51.2% / 0.7%	42.7% / 0.7%	25.8% / 0.7%	28.0% / 0.8%	38.2% / 0.7%
Strongly Agree	Col% / SE%	7.9% / 0.6%	26.4% / 0.7%	27.6% / 0.8%	11.1% / 0.6%	22.9% / 1.1%	20.4% / 0.7%
	Total%	100%	100%	100%	100%	100%	100%
	Response n	8,179 / 98.7%	5,810 / 99.7%	6,589 / 97.6%	8,765 / 98.0%	5,611 / 97.4%	10,643 / 97.0%
	Non-Response n	106 / 1.3%	17 / 0.3%	163 / 2.4%	175 / 2.0%	152 / 2.6%	330 / 3.0%
I Usually Do Well in Math:							
Strongly Agree	Col% / SE%	11.6% / 0.5%	6.2% / 0.4%	6.1% / 0.4%	30.2% / 0.7%	37.6% / 0.9%	35.6% / 0.6%
Agree	Col% / SE%	48.8% / 0.9%	34.2% / 1.1%	32.6% / 0.8%	46.1% / 0.8%	33.3% / 0.8%	50.9% / 0.8%
Disagree	Col% / SE%	35.3% /0.9%	50.2% / 0.9%	54.0% / 0.9%	20.7% / 0.6%	22.7% / 0.8%	11.1% / 0.6%
Strongly Disagree	Col% / SE%	4.3% / 0.3%	9.4% / 0.7%	7.3% / 0.4%	3.0% / 0.2%	6.5% / 0.4%	2.4% / 0.2%
	Total%	100%	100%	100%	100%	100%	100%
	Response n	8,216 / 99.2%	5,819 / 99.8%	6,580 / 97.5%	8,757 / 98.0%	5,651 / 98.1%	10,679 / 97.3%
	Non-Response n	69 / 0.8%	8 / 0.2%	172 / 2.5%	183 / 2.0%	112 / 1.9%	294 / 2.7%

Note. Data from the Third International Mathematics and Science Study (TIMSS). See footnote [a] in Table 3 for definitions of terms in the Statistic column.

Table 3. *Mathematics Achievement as a Function of Attitudes and Beliefs of Seventh and Eighth Grade Students Combined: Reduced Multiple Regression Models for Six Nations*

Predictor Variables		Multiple Regression Parameter Estimates by Nation					
Name	Level	Singapore	Korea	Hong Kong	Switzerland	Germany	United States
Intercept		469.9	450.3	474.4	389.0	382.6	372.2
Grade	Eighth	38.9***	29.4***	28.1***	42.8**	20.1***	24.2***
	Seventh[a]						
Sex	Boys	0.4	13.9***	7.0	8.2	5.3	12.2***
	Girls[a]						
Books in the Home	More than 200	53.6***	96.1***	35.2***	76.9***	89.6***	77.2***
	101 - 200	44.6***	83.0***	29.5***	66.8***	75.7***	63.3***
	26 - 100	30.2***	55.8***	30.2***	47.1***	48.6***	38.9***
	11 - 25	6.2	20.0***	22.9***	21.0***	22.7***	11.1**
	0 - 10[a]						
Like Math	Like a lot	67.7***	102.2***	66.0***	38.4***	17.6***	27.1***
	Like	40.9***	62.8***	40.2***	23.0***	17.3***	18.1***
	Dislike	18.7*	20.7***	20.6**	17.9***	11.7***	14.8***
	Dislike a lot[a]						
Like a Job Using Math	Strongly Agree	14.0*	-14.2	22.1**	9.5*	1.7	28.0***
	Agree	16.7***	- 6.1	32.5***	17.2***	18.5***	24.9***
	Disagree	6.4	- 0.1	17.1***	9.9**	15.6***	13.6***
	Strongly Disagree[a]						
Memorize Notes	Strongly Disagree	77.3***	45.3***	33.2***	46.7***	42.2***	39.5***
	Disagree	61.3***	52.8***	35.6***	47.0***	43.1***	45.5***
	Agree	32.3***	23.8***	8.6**	26.3***	32.4***	24.6***
	Strongly Agree[a]						
Adjusted R^2		.21	.25	.13	.21	.21	.18

Note. Data from the Third International Mathematics and Science Study (TIMSS).

[a]The predictor variables were all treated as indicator variables with the lower level listed as the reference category coded as "0." The other (comparison) levels were each coded as "1." The level of statistical significance is indicated by asterisks: *$p<.05$, **$p<.01$, ***$p<.001$.

Table 4. *Student Attitude, Belief, and Perception Variables about* *__Science__*: *Percentage Distributions for Six Nations for Seventh and Eighth Grade Students Combined*

Science Predictor Variable	Statistic	Eastern Nations			Western Nations		
		Singapore	Korea	Hong Kong	Switzerland	Germany	United States
	National Estimate	72,719	1,608,813	177,164	136,414	1,468,434	6,345,144
__Like Science:__							
Like a lot	Col% / SE%	31.6% / 0.9%	11.9% / 0.5%	15.6% / 0.8%	22.6% / 0.6%	14.6% / 0.7%	26.1% / 1.0%
Like	Col% / SE%	58.5% / 0.7%	49.3% / 0.9%	52.7% / 0.9%	48.7% / 0.7%	43.1% / 0.7%	46.8% / 0.9%
Dislike	Col% / SE%	8.3% / 0.4%	33.5% / 1.0%	22.5% / 0.9%	20.3% / 0.6%	33.1% / 0.8%	16.2% / 0.9%
Dislike a lot	Col% / SE%	1.3% / 0.1%	5.4% / 0.3%	8.8% / 0.5%	8.5% / 0.6%	9.3% / 0.7%	10.8% / 0.5%
	Total%	100%	100%	100%	100%	100%	100%
	Response n	8,226 / 99.3%	5,807 / 99.7%	6,606 / 97.8%	8,718 / 97.5%	5,681 / 98.6%	10,644 / 97.0%
	Non-Response n	59 / 0.7%	20 / 0.3%	146 / 0.2%	222 / 2.5%	82 / 1.4%	329 / 3.0%
__Like Job Using Science:__							
Strongly Agree	Col% / SE%	17.2% / 0.7%	9.1% / 0.6%	8.6% / 0.5%	9.5% / 0.4%	4.2% / 0.4%	20.5% / 0.6%
Agree	Col% / SE%	40.7% / 0.9%	19.2% / 0.8%	28.1% / 0.6%	21.5% / 0.6%	10.8% / 0.5%	28.8% / 0.6%
Disagree	Col% / SE%	35.3% / 0.9%	53.8% / 0.9%	49.3% / 0.8%	40.0% / 0.7%	37.0% / 0.8%	31.1% / 0.7%
Strongly Disagree	Col% / SE%	6.9% / 0.4%	18.0% / 0.6%	14.0% / 0.7%	29.1% / 0.8%	48.0% / 1.1%	19.6% / 0.6%
	Total%	100%	100%	100%	100%	100%	100%
	Response n	8,195 / 98.9%	5,754 / 98.7%	6,553 / 97.1%	8,603 / 96.2%	5,418 / 94.0%	10,364 / 94.5%
	Non-Response n	90 / 1.1%	73 / 1.3%	199 / 2.9%	337 / 3.8%	345 / 6.0%	609 / 5.5%
To Do Well in Science, __Need to Memorize:__							
Strongly Disagree	Col% / SE%	3.3% / 0.4%	1.1% / 0.1%	3.5% / 0.3%	13.6% / 0.5%	11.9% / 0.6%	8.2% / 0.3%
Disagree	Col% / SE%	9.7% / 0.5%	5.3% / 0.3%	12.9% / 0.4%	31.2% / 0.7%	18.5% / 0.7%	26.1% / 0.8%
Agree	Col% / SE%	46.6% / 0.7%	46.2% / 0.7%	43.5% / 0.7%	34.9% / 0.7%	33.1% / 0.9%	39.9% / 0.6%
Strongly Agree	Col% / SE%	40.4% / 0.8%	47.4% / 0.8%	40.0% / 0.8%	20.3% / 0.7%	36.6% / 1.0%	25.8% / 0.8%
	Total%	100%	100%	100%	100%	100%	100%
	Response n	8,219 / 99.2%	5,808 / 99.7%	6,584 / 97.5%	8,737 / 97.7%	5,584 / 96.9%	10,633 / 96.9%
	Non-Response n	66 / 0.8%	19 / 0.3%	168 / 2.5%	203 / 2.3%	179 / 3.1%	340 / 3.1%
__I Usually Do Well in Science:__							
Strongly Agree	Col% / SE%	10.0% / 0.5%	4.4% / 0.3%	4.5% / 0.3%	23.1% / 0.7%	22.6% / 0.8%	34.7% / 1.0%
Agree	Col% / SE%	60.4% / 0.7%	31.0% / 0.8%	38.4% / 1.3%	55.2% / 0.7%	51.3% / 0.7%	52.3% / 0.8%
Disagree	Col% / SE%	28.2% / 0.8%	58.2% / 0.9%	50.4% / 1.2%	19.0% / 0.7%	23.5% / 0.7%	10.6% / 0.5%
Strongly Disagree	Col% / SE%	1.4% / 0.1%	6.5% /0.4%	6.7% / 0.5%	2.6% / 0.3%	2.6% / 0.3%	2.4% / 0.2%
	Total%	100%	100%	100%	100%	100%	100%
	Response n	8,218 / 99.2%	5,814 / 99.8%	6,578 / 97.4%	8,713 / 97.5%	5,681 / 98.6%	10,661 / 97.2%
	Non-Response n	67 / 0.8%	13 / 0.2%	174 / 2.6%	227 / 2.5%	82 / 1.4%	312 / 2.8%

__Note.__ Data from the Third International Mathematics and Science Study (TIMSS). See footnote [a] in Table 3 for definitions of terms in the Statistic column.

Table 5. *Science Achievement as a Function of Attitudes and Beliefs of Seventh and Eighth Grade Students Combined: Reduced Multiple Regression Models for Five Nations*

Predictor Variables		Multiple Regression Parameter Estimates by Nation					
Name	Level	Singapore	Korea	Hong Kong	Switzerland	Germany	United States
Intercept		435.4	456.8	456.1	413.4	410.6	407.4
Grade	Eighth	60.8***	35.1***	27.4***	42.1***	27.9***	25.9***
	Seventh[a]						
Sex	Boys	4.6	18.7***	18.4***	19.6***	17.1***	18.1***
	Girls[a]						
Books in the Home	More than 200	74.0***	79.1***	23.5***	82.2***	103.3***	93.8***
	101 - 200	66.9***	66.7***	22.2***	70.2***	88.5***	79.3***
	26 - 100	41.5***	49.0***	20.2***	52.0***	60.6***	56.2***
	11 - 25	9.7**	19.6***	17.3***	24.2***	32.7***	18.0***
	0 - 10[a]						
Like Science	Like a lot	48.2***	60.4***	50.7***	9.3*	30.1***	18.5**
	Like	36.5**	30.1***	33.9***	0.5	24.5***	7.8
	Dislike	26.6*	13.5**	21.6***	- 4.2	10.4**	3.8
	Dislike a lot[a]						
Like a Job Using Science	Strongly Agree	34.4***	13.9*	8.5	13.8**	-18.5*	34.4***
	Agree	36.1***	12.2*	8.0	16.7***	- 1.4	29.6***
	Disagree	18.6***	2.1	6.2	11.3***	5.9*	15.5***
	Strongly Disagree[a]						
Memorize Notes	Strongly Disgree	49.2***	-20.7	0.5	15.9**	8.3*	27.3***
	Disagree	19.8***	5.6	-5.9	17.2***	23.0***	36.6***
	Agree	12.9***	1.9	-6.1*	16.7***	20.7***	21.5***
	Strongly Agree[a]						
Adjusted R^2		.20	.15	.08	.16	.17	.16

Note. Data from the Third International Mathematics and Science Study (TIMSS).

[a]The predictor variables were all treated as indicator variables with the lower level listed as the reference category coded as "0." The other (comparison) levels were each coded as "1." The level of statistical significance is indicated by asterisks: *p<.05, **p <.01, ***p<.001.

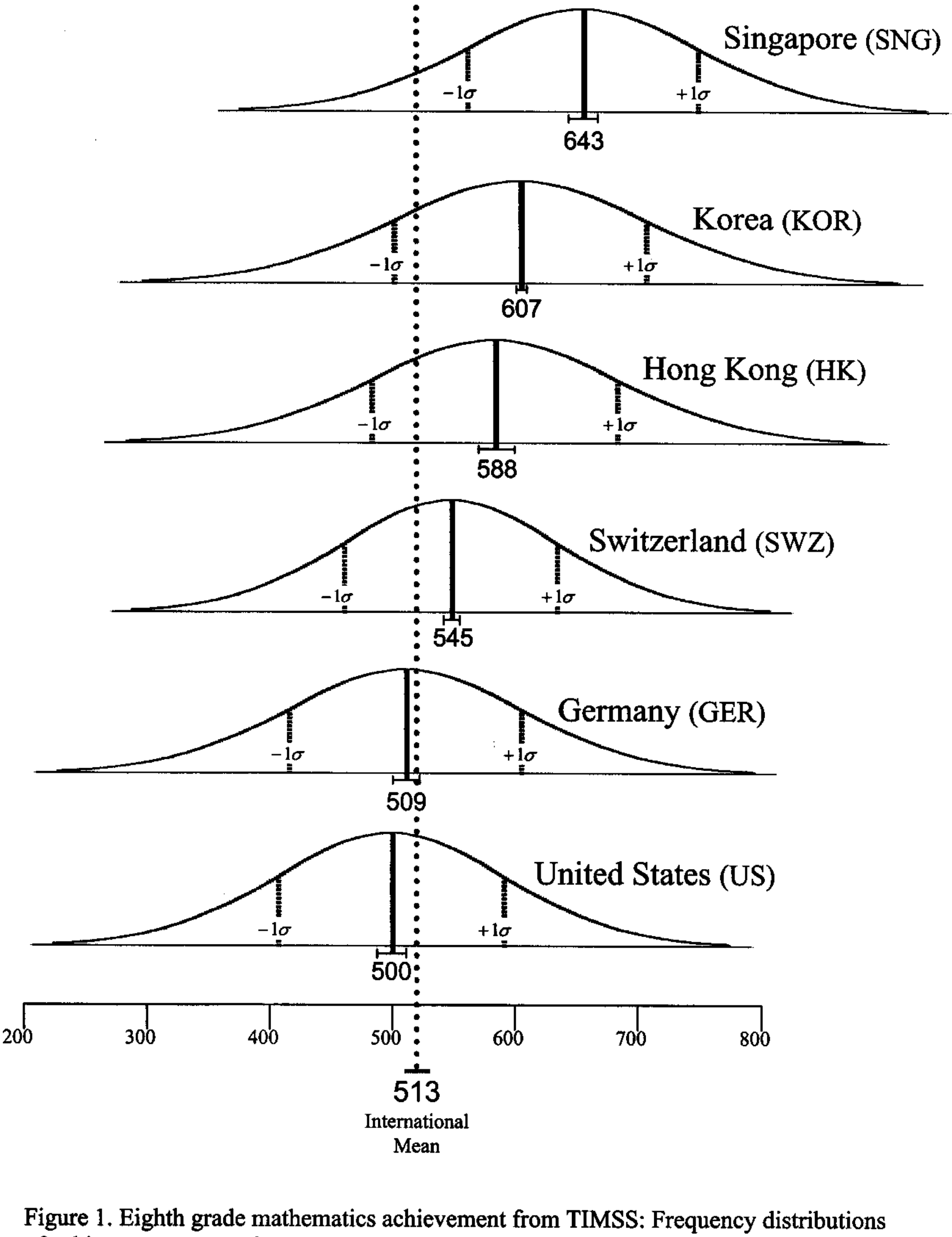


Figure 1. Eighth grade mathematics achievement from TIMSS: Frequency distributions of achievement scores for each of six nations with national mean scores and their 95% confidence intervals (|—|), all in comparison with the international mean score. Data Source: TIMSS .

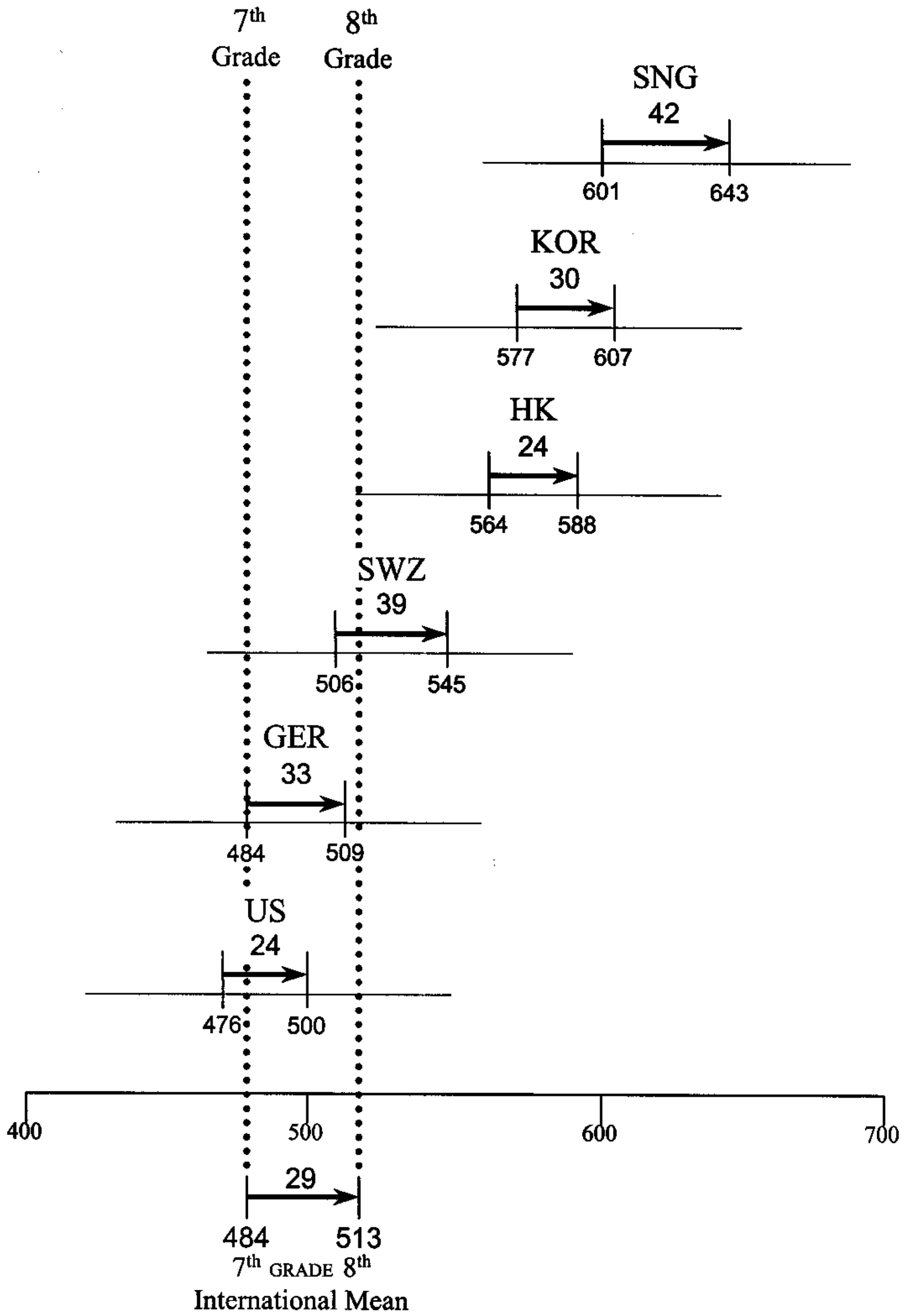


Figure 2. Mathematics achievement from TIMSS: Means for seventh and eighth grades, in comparison with the international means, and the difference between seventh and eighth grade means. Data are shown for Singapore (SNG), Korea (KOR), Hong Kong (HK), Switzerland (SWZ), Germany (GER), and United States (US). Data Source: TIMSS.

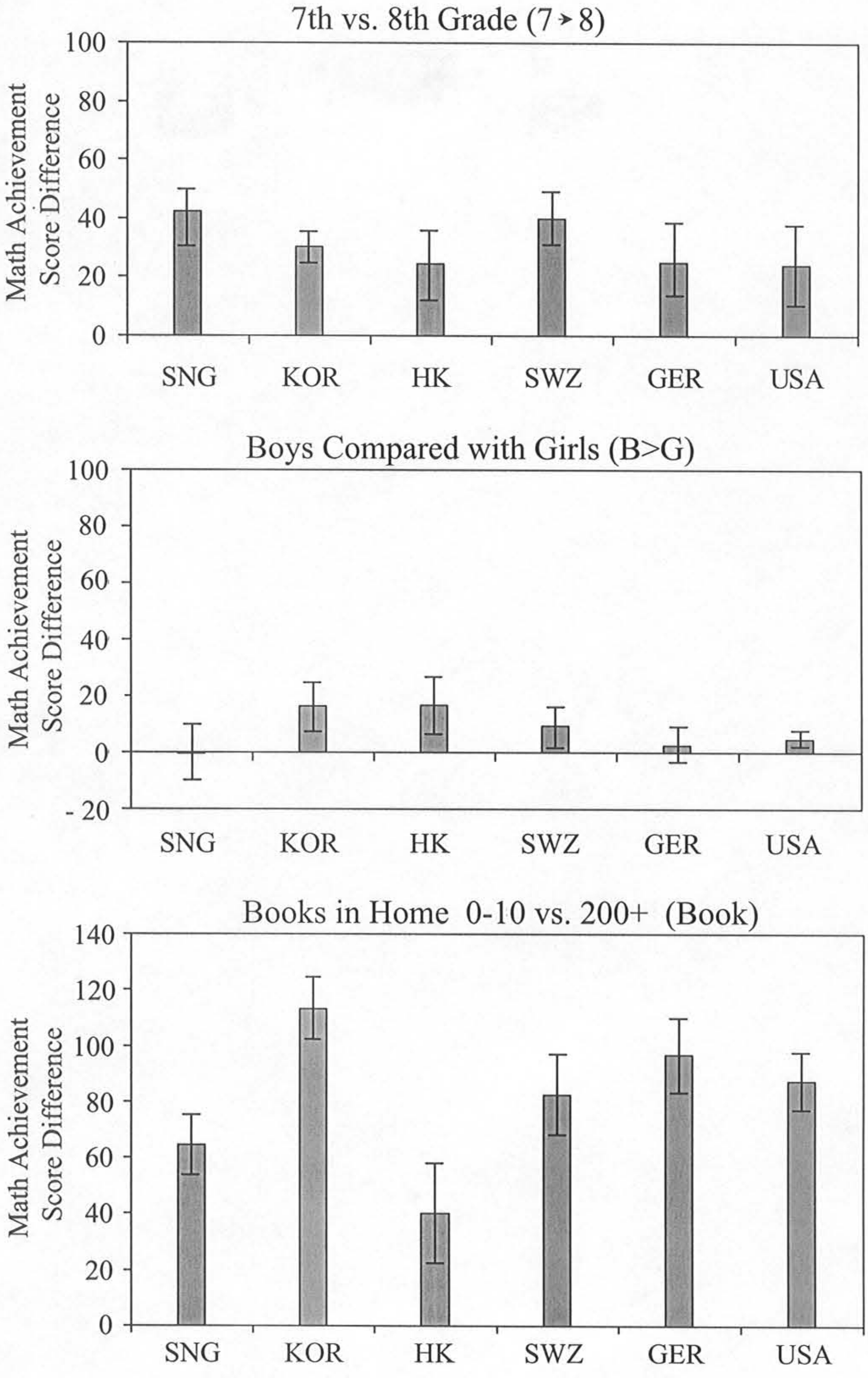


Figure 3. Bivariate analyses of mathematics achievement from TIMSS for seventh and eighth grades combined as a function of one-unit variation in each of three control variables. Achievement score differences with 95% confidence intervals (|—|) are shown for Singapore (SNG), Korea (KOR), Hong Kong (HK), Switzerland (SWZ), Germany (GER),and United States (USA). Data Source: TIMSS.

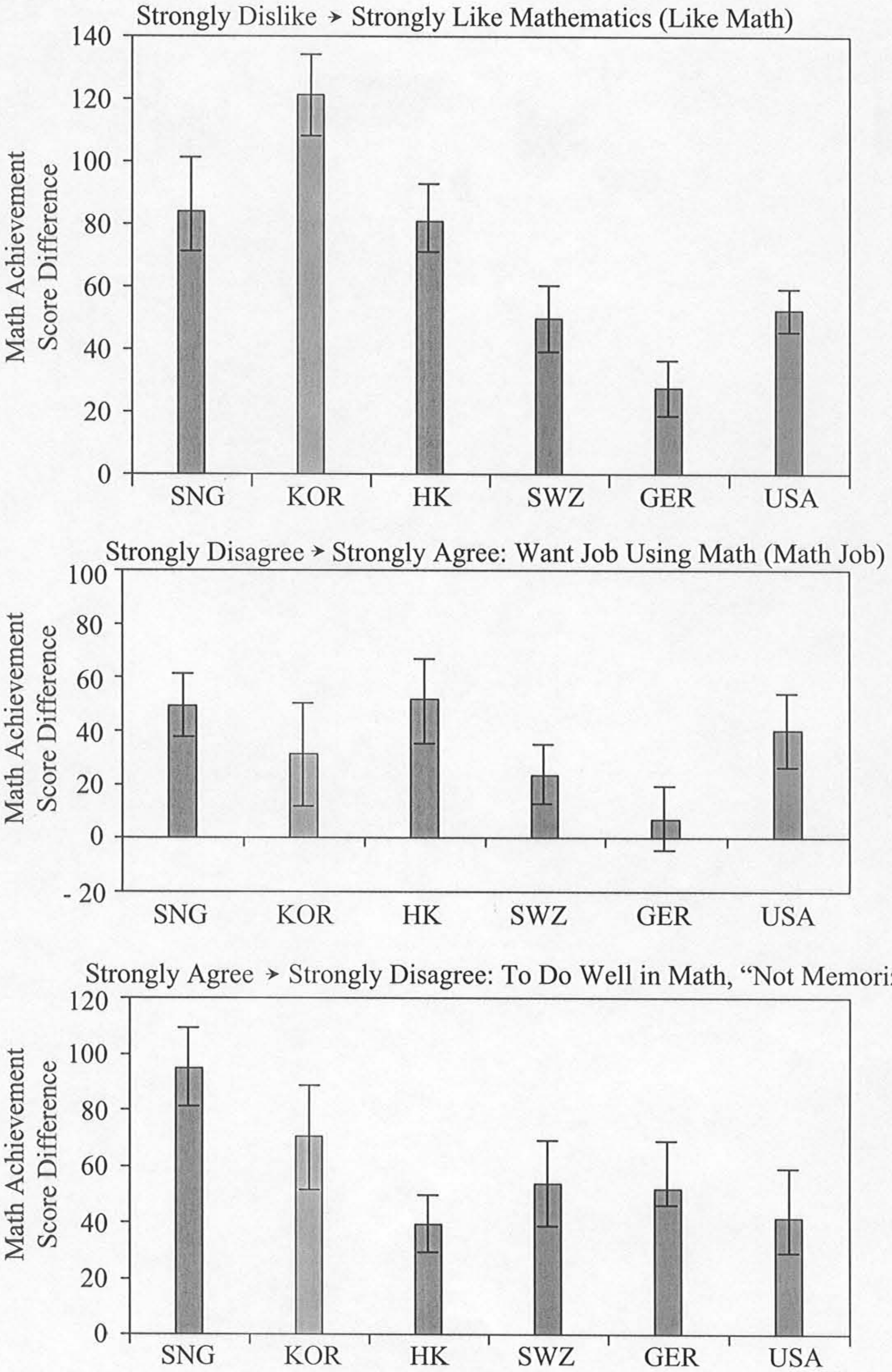


Figure 4. Bivariate analyses of mathematics achievement from TIMSS for seventh and eighth grades combined as a function of one-unit variation in each of three student attitude and belief variables. Achievement score differences with 95% confidence intervals (|—|) are shown for Singapore (SNG), Korea (KOR), Hong Kong (HK), Switzerland (SWZ), Germany (GER), and United States (USA). Data Source: TIMSS.

SINGAPORE

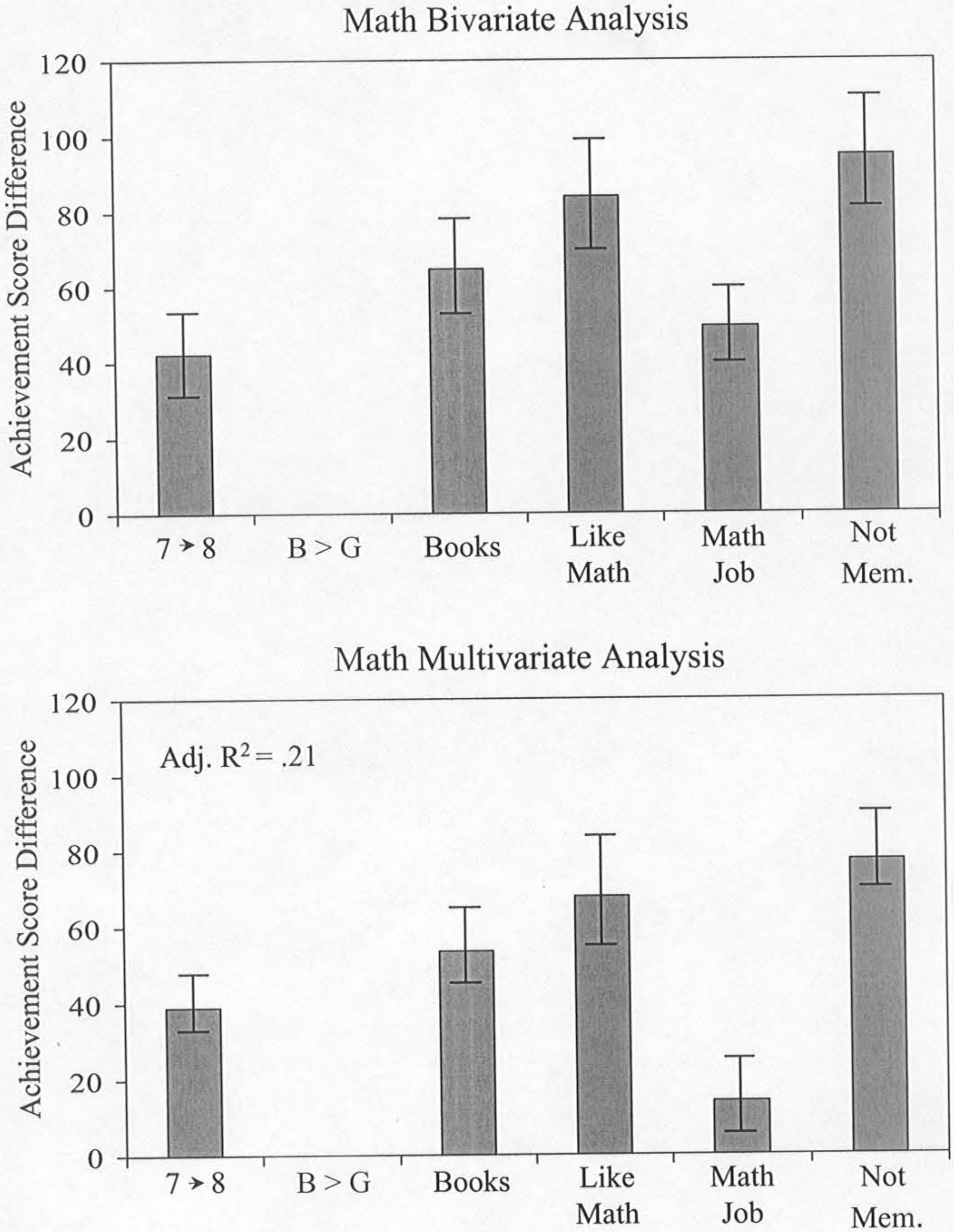


Figure 5. Bivariate and multivariate analyses of mathematics achievement in Singapore from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (|—|). Data Source: TIMSS.

KOREA

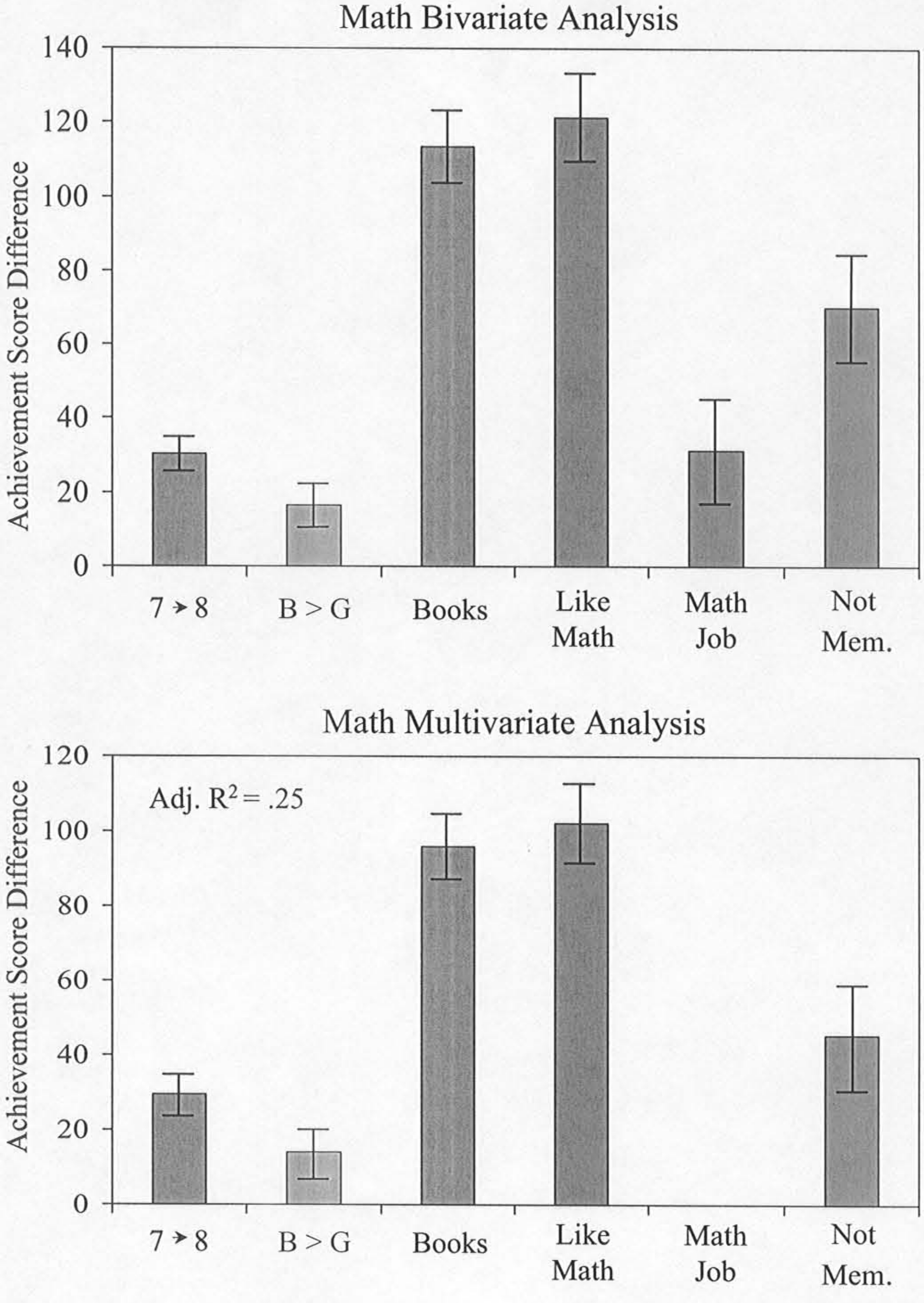
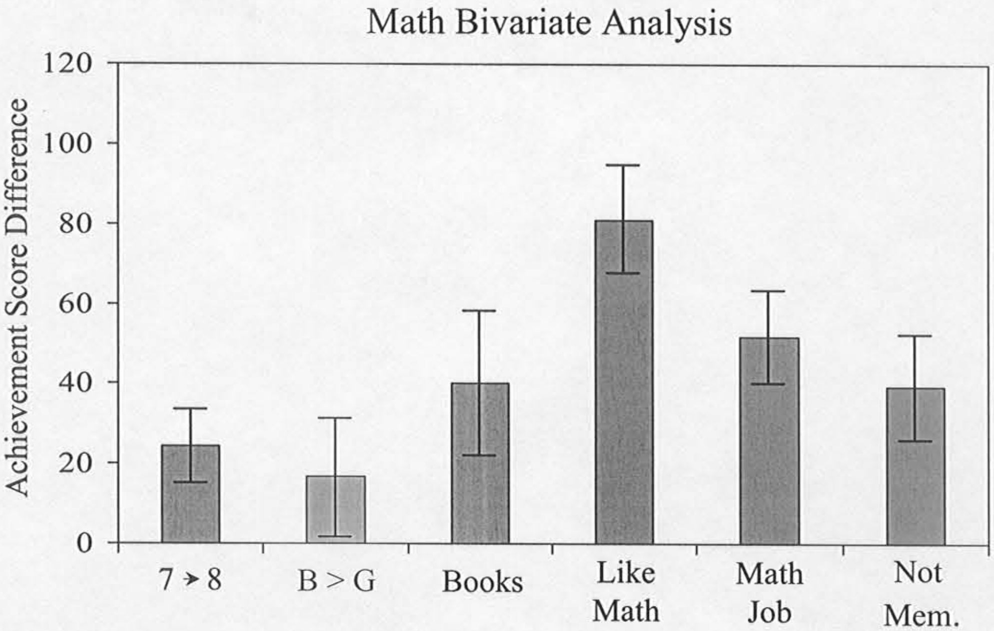


Figure 6. Bivariate and multivariate analyses of mathematics achievement in Korea from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (|—|). Data Source: TIMSS.

HONG KONG



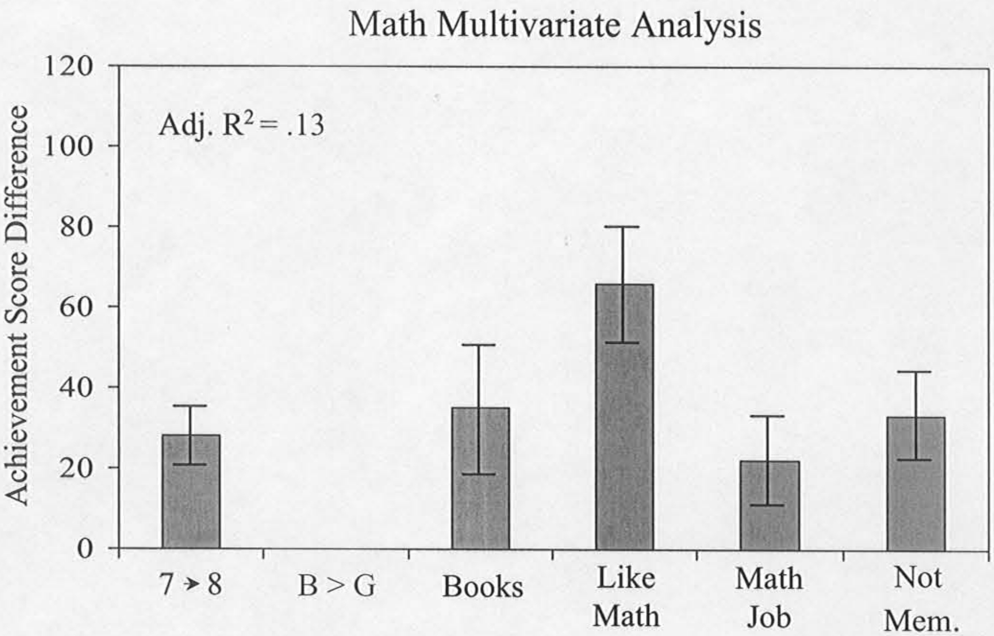
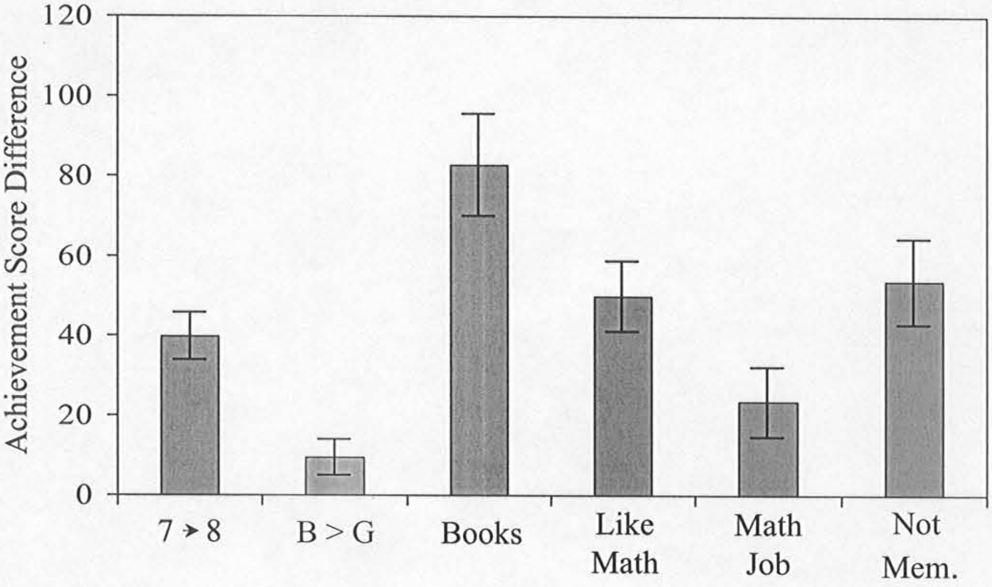


Figure 7. Bivariate and multivariate analyses of mathematics achievement in Hong Kong from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (|—|). Data Source: TIMSS.

SWITZERLAND

Math Bivariate Analysis



Math Multivariate Analysis

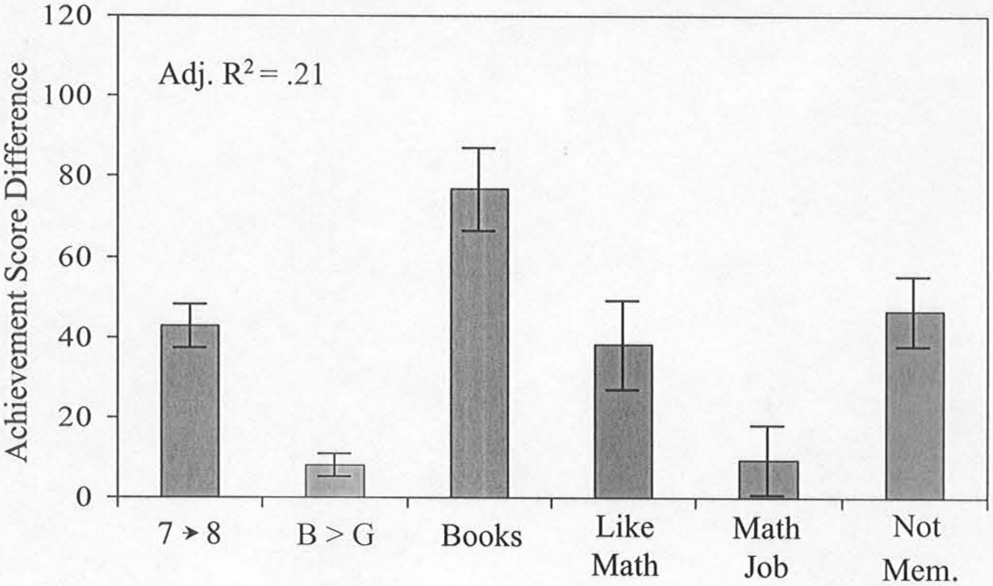
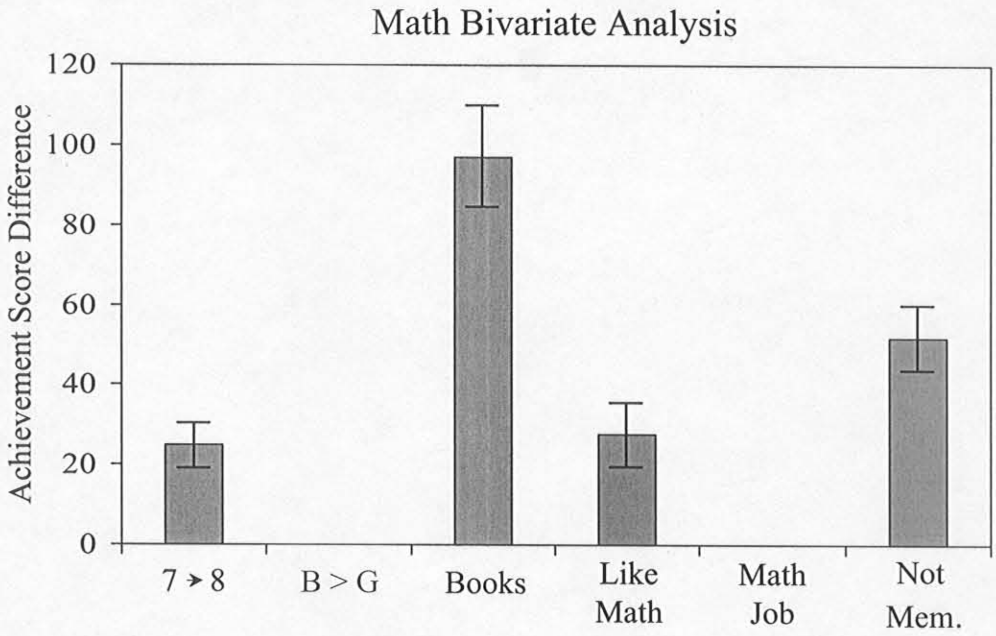


Figure 8. Bivariate and multivariate analyses of mathematics achievement in Switzerland from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (├─┤). Data Source: TIMSS.

GERMANY



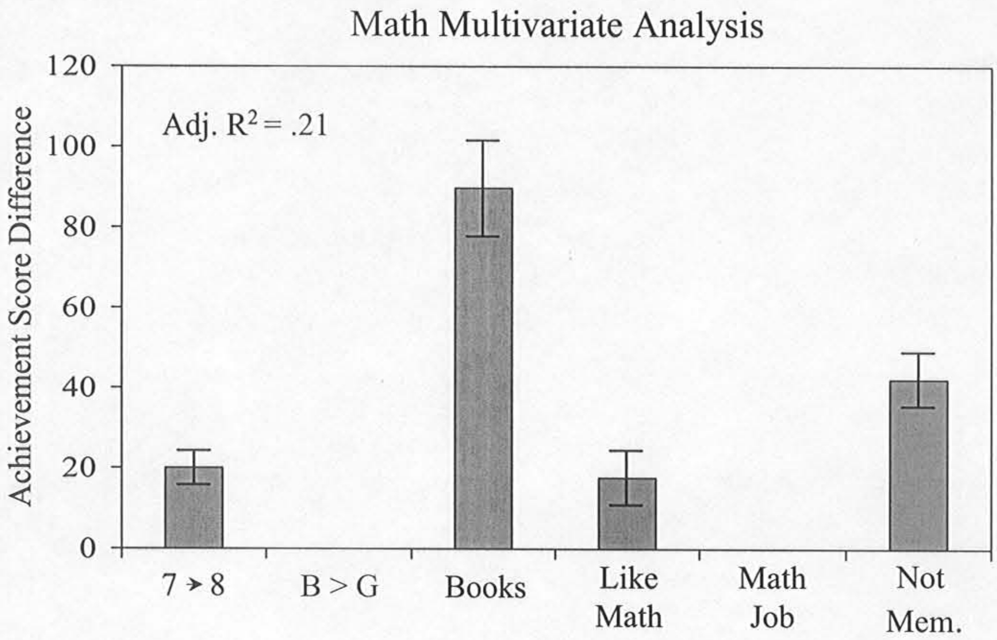


Figure 9. Bivariate and multivariate analyses of mathematics achievement in Germany from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (|—|). Data Source: TIMSS.

UNITED STATES

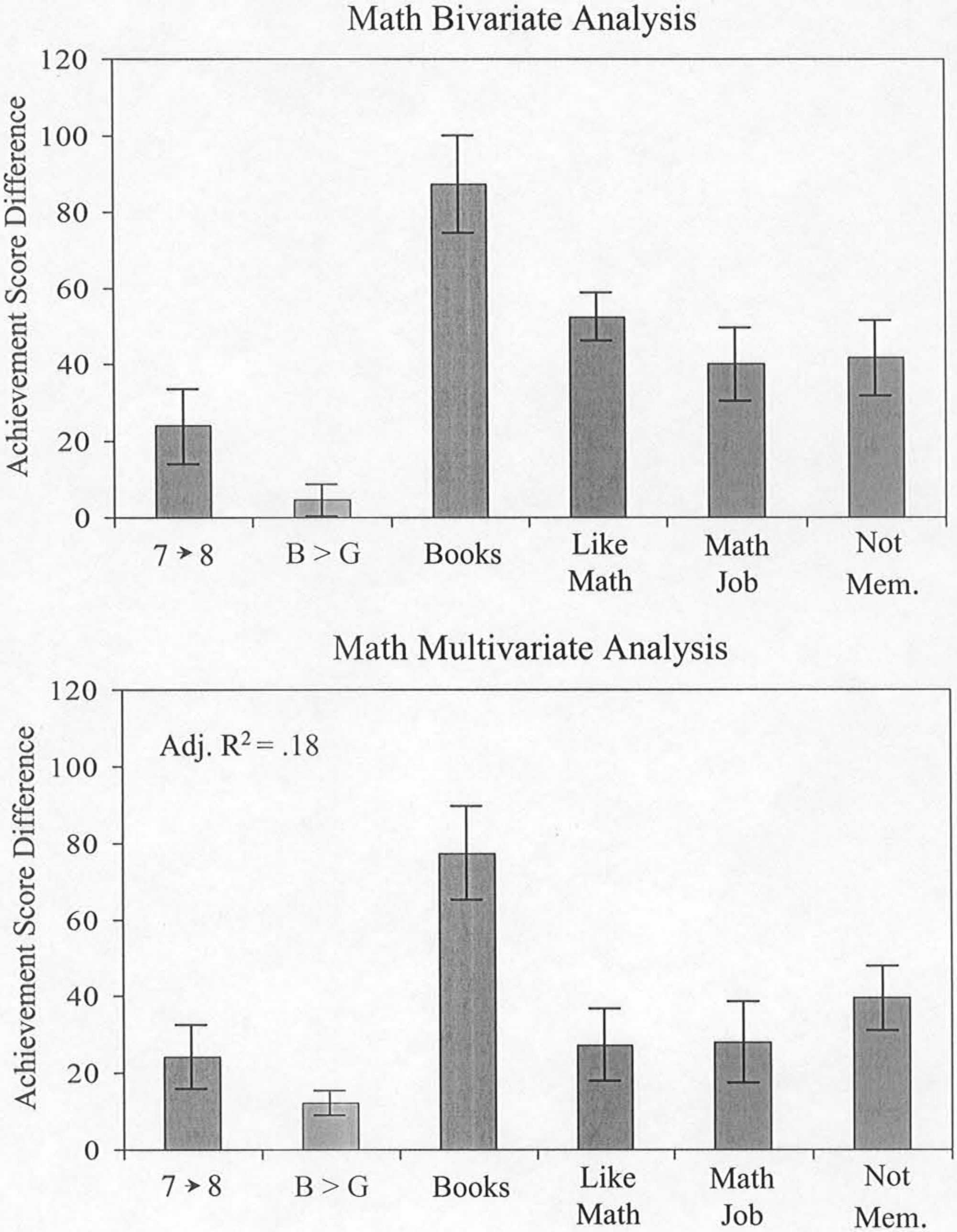


Figure 10. Bivariate and multivariate analyses of mathematics achievement in United States from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (|—|). Data Source: TIMSS.

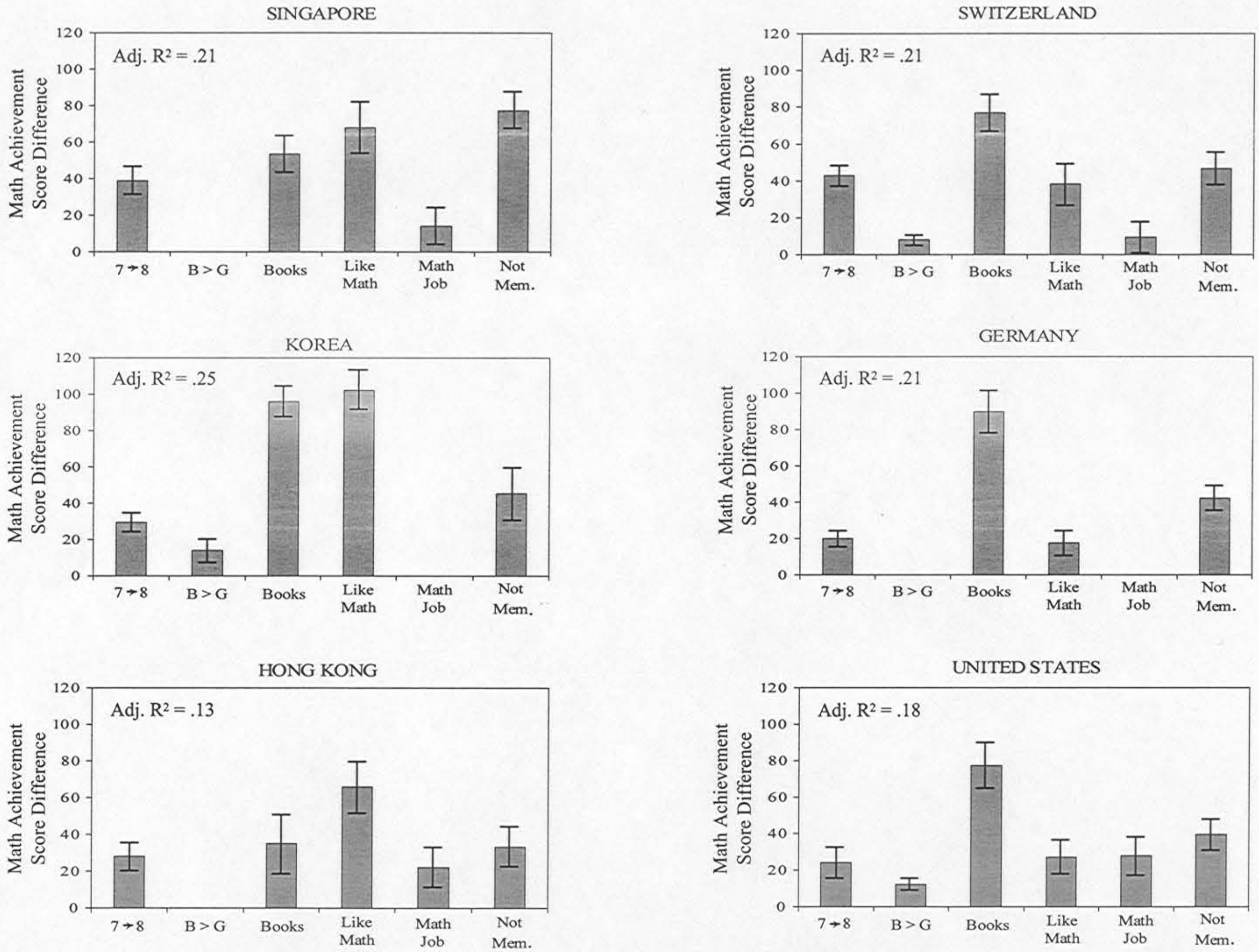


Figure 11. Six nation comparisons of multivariate analyses of mathematics achievement from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (|—|). Data Source: TIMSS.

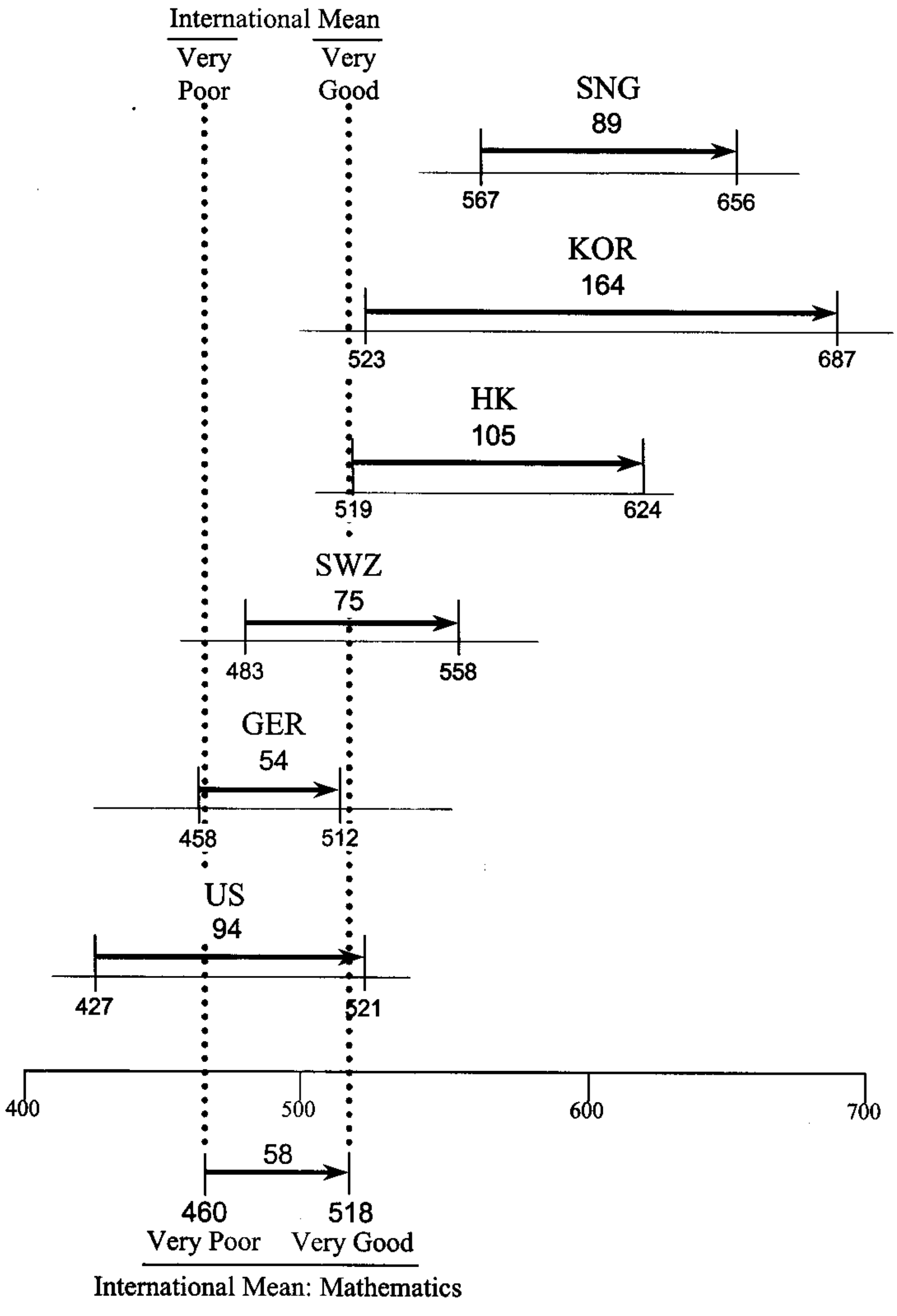


Figure 12. Mathematics achievement from TIMSS for seventh and eighth grades combined: Means for students who perceive their math performance to be "very poor" and "very good", in comparison with the international means. Data are shown for Singapore (SNG), Korea (KOR), Hong Kong (HK), Switzerland (SWZ), Germany (GER), and United States (US). Data Source: TIMSS.

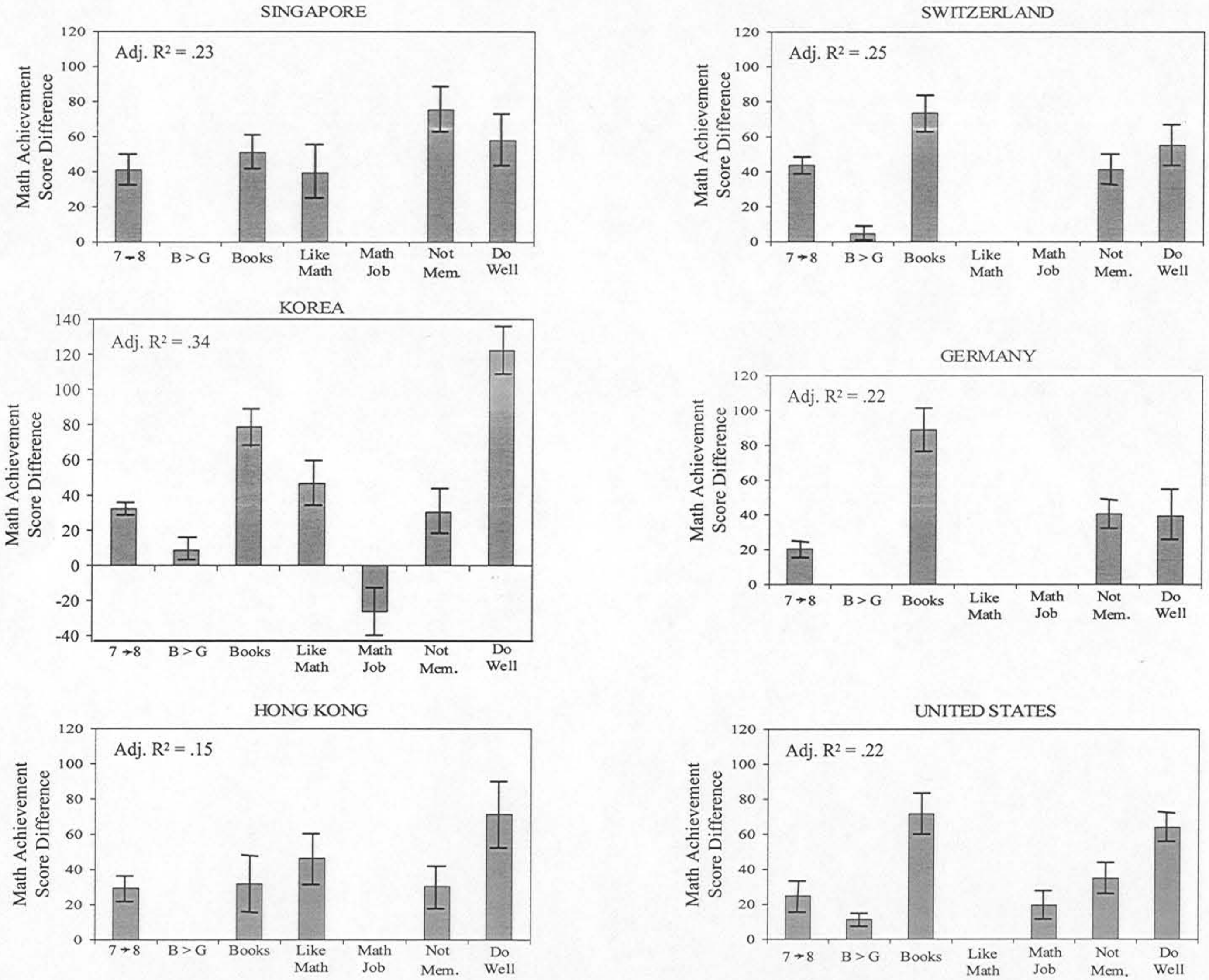


Figure 13. Six nation comparisons of multivariate analyses of mathematics achievement from TIMSS for seventh and eighth grades combined as a function of one-unit variation in seven predictor variables including student perceptions of their math performance, all as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (├┤). Data Source: TIMSS.

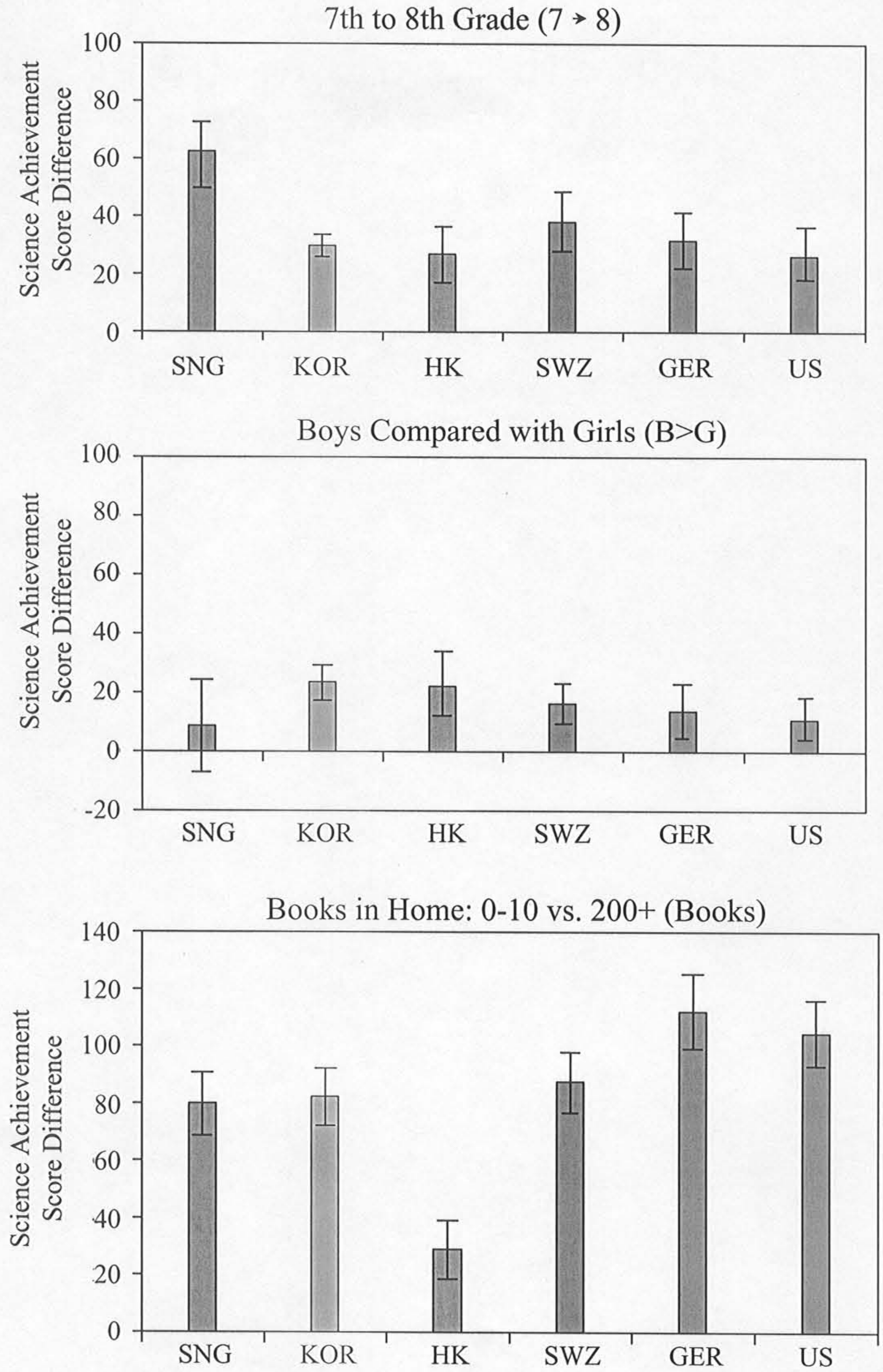


Figure 14. Bivariate analyses of science achievement from TIMSS for seventh and eighth grades combined as a function of one-unit variation in each of three control variables. Achievement score differences with 95% confidence intervals (├┤) are shown for Singapore (SNG), Korea (KOR), Hong Kong (HK), Switzerland (SWZ), Germany (GER), and United States (US). Data Source: TIMSS.

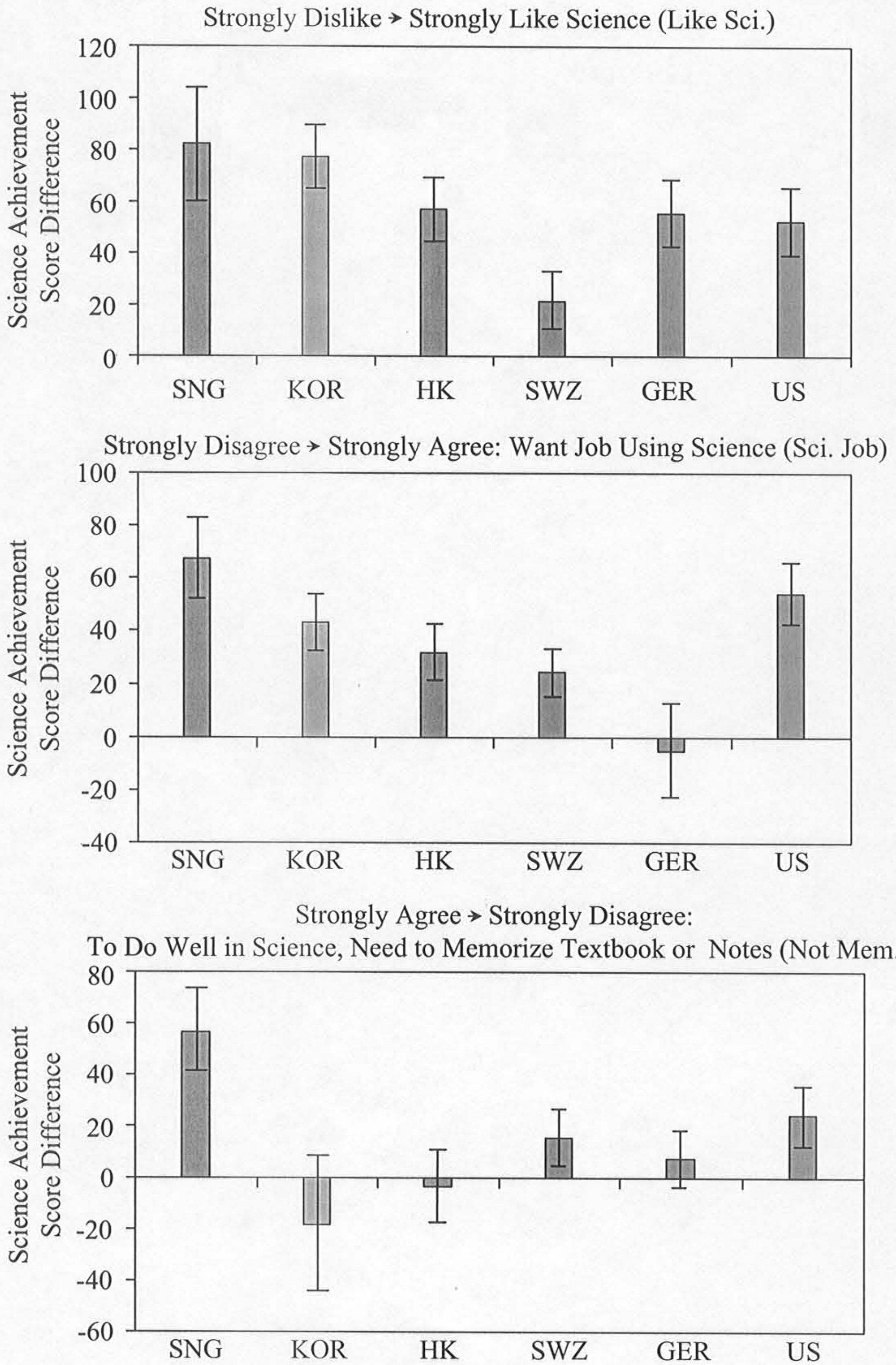
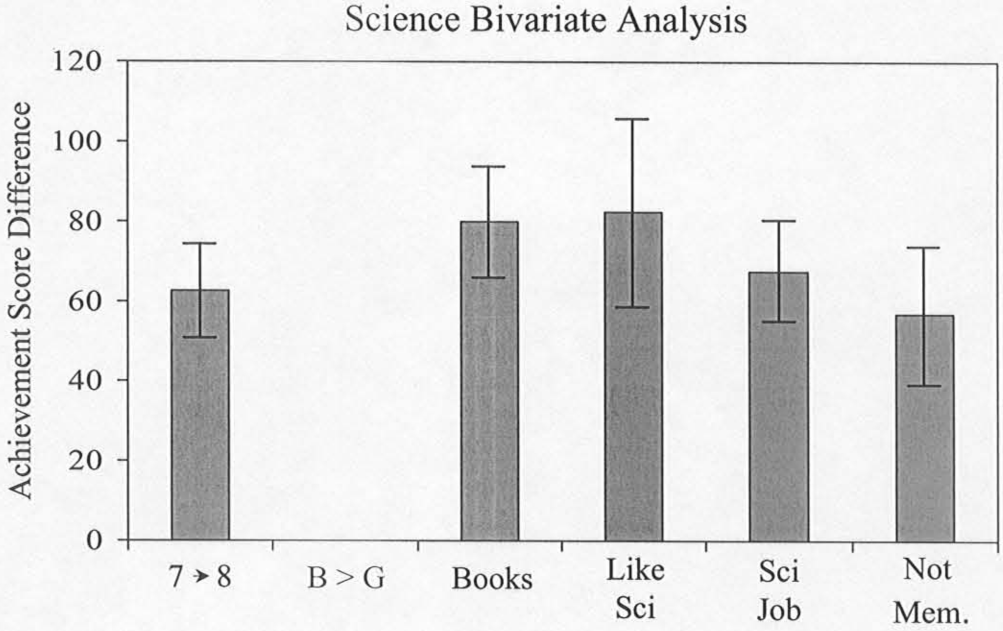


Figure 15. Bivariate analyses of science achievement from TIMSS for seventh and eighth grades combined as a function of one-unit variation in each of three student attitude and belief variables. Achievement score differences with 95% confidence intervals (|–|) are shown for Singapore (SNG), Korea (KOR), Hong Kong (HK), Switzerland (SWZ), Germany (GER), and United States (US). Data Source: TIMSS.

SINGAPORE



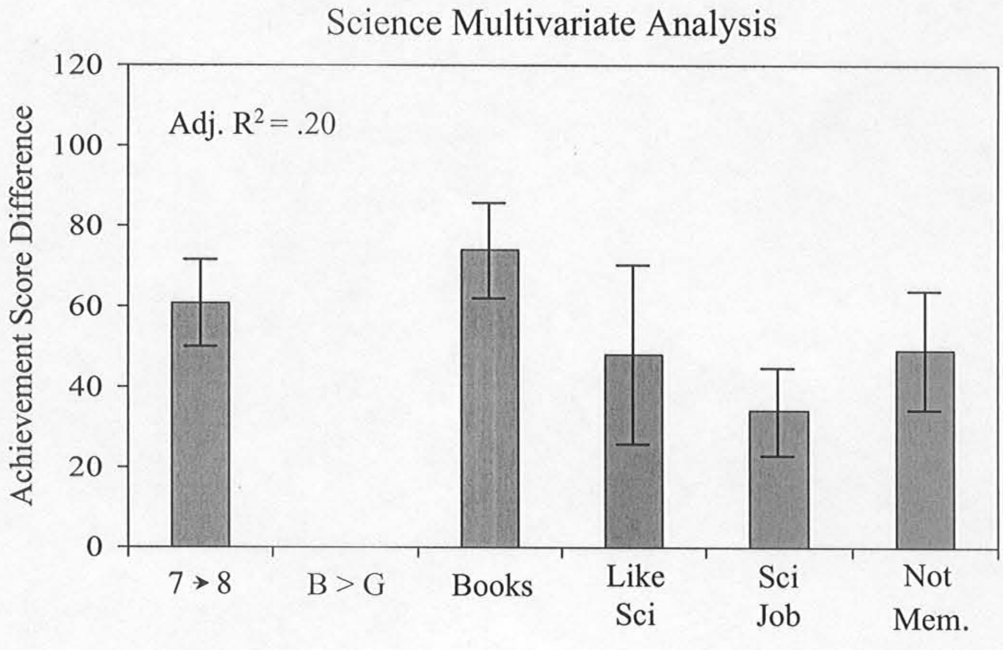


Figure 16. Bivariate and multivariate analyses of science achievement in Singapore from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (├┤). Data Source: TIMSS.

KOREA

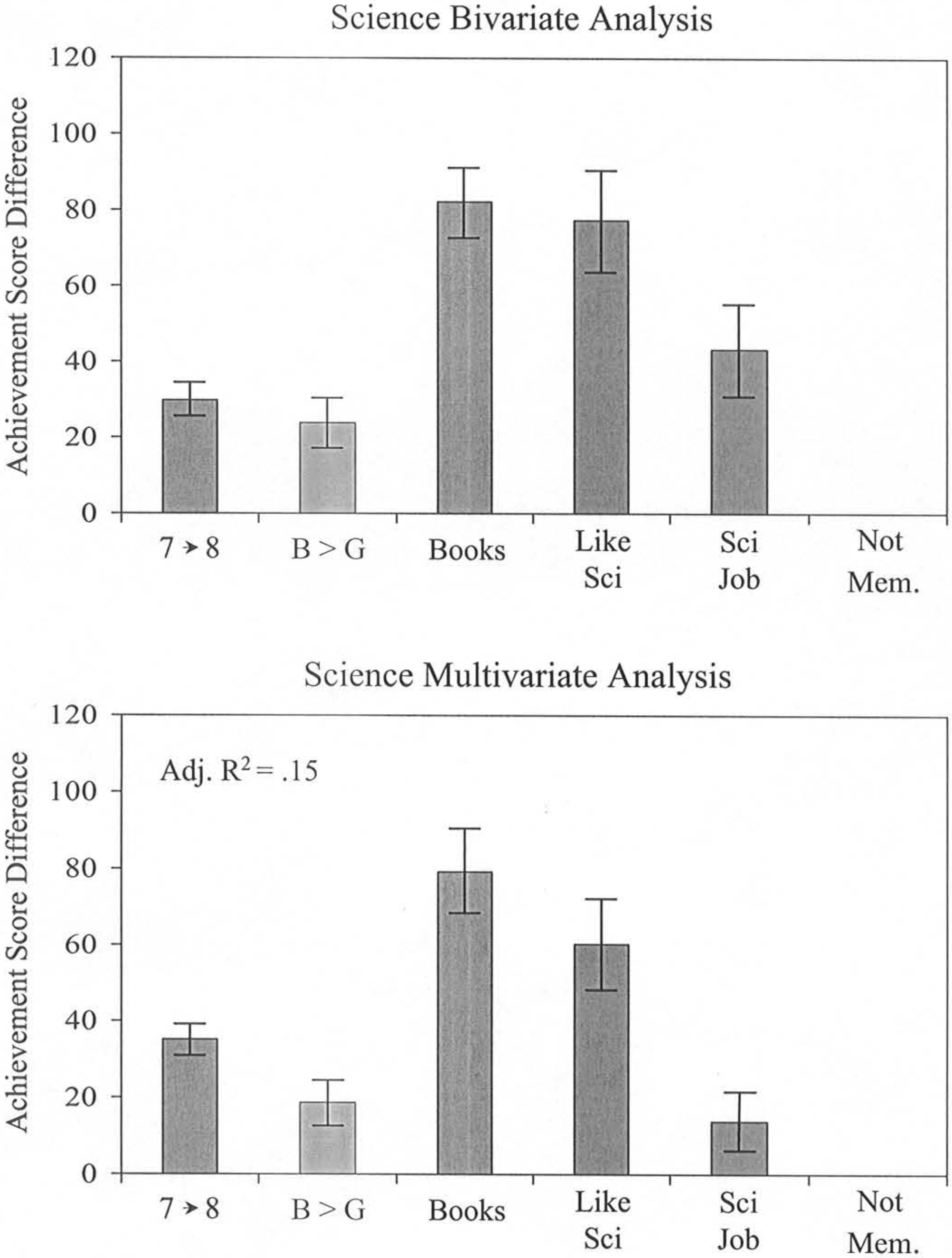
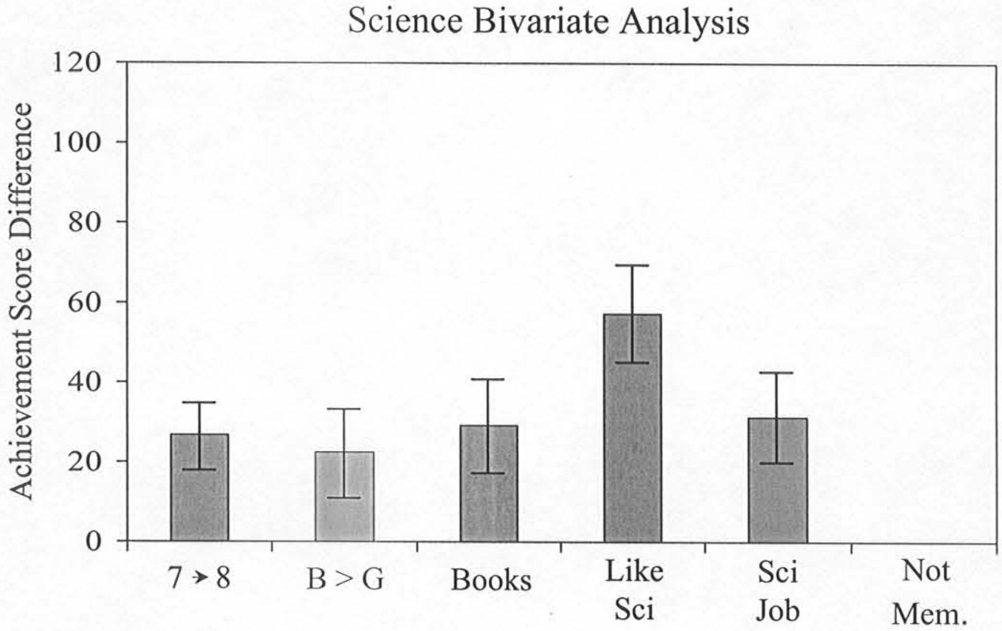


Figure 17. Bivariate and multivariate analyses of science achievement in Korea from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (├┤). Data Source: TIMSS.

HONG KONG



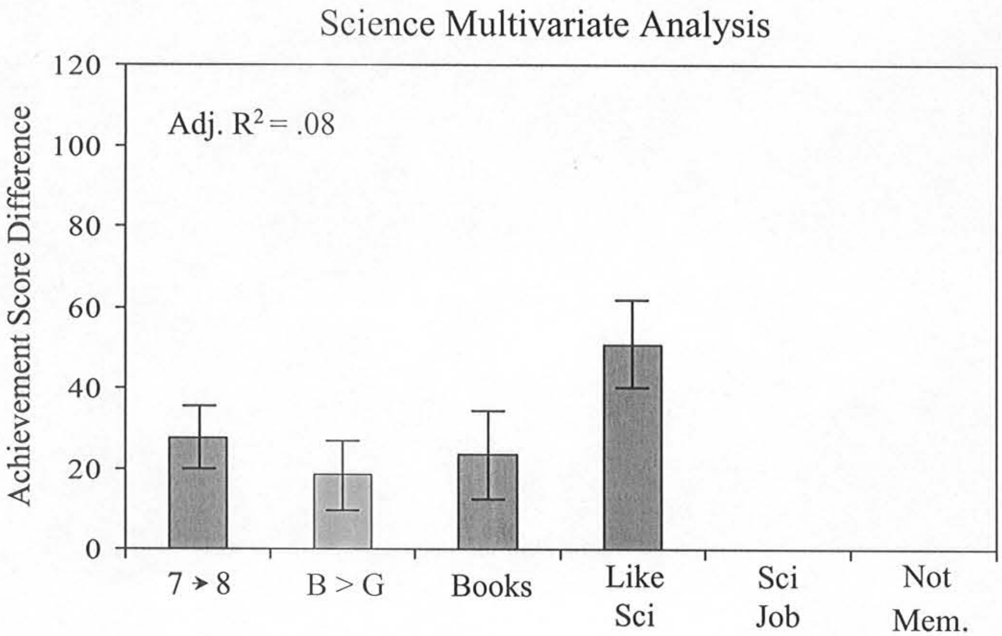
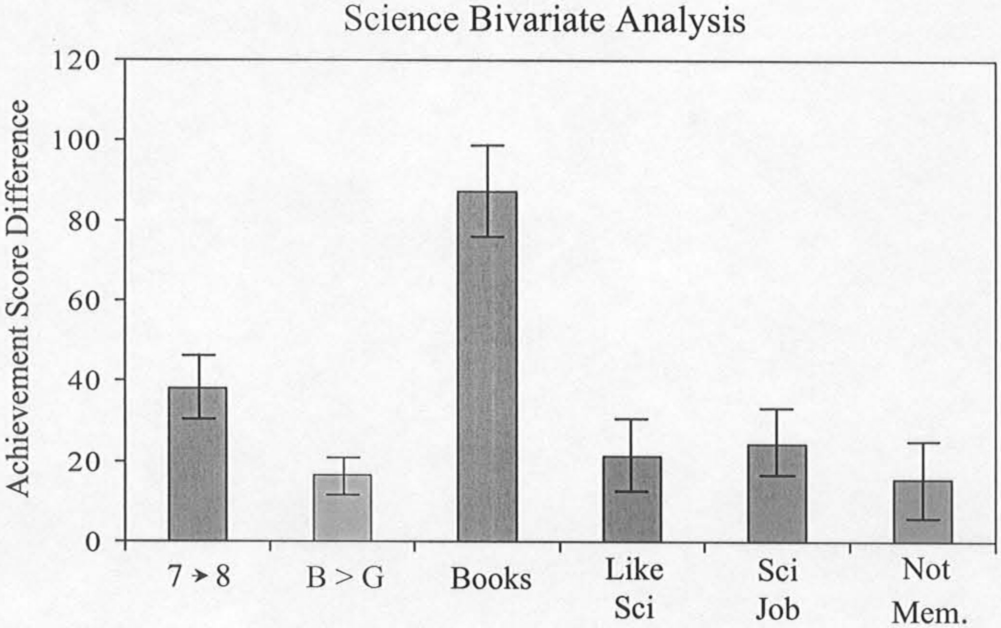


Figure 18. Bivariate and multivariate analyses of science achievement in Hong Kong from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (├┤). Data Source: TIMSS.

SWITZERLAND



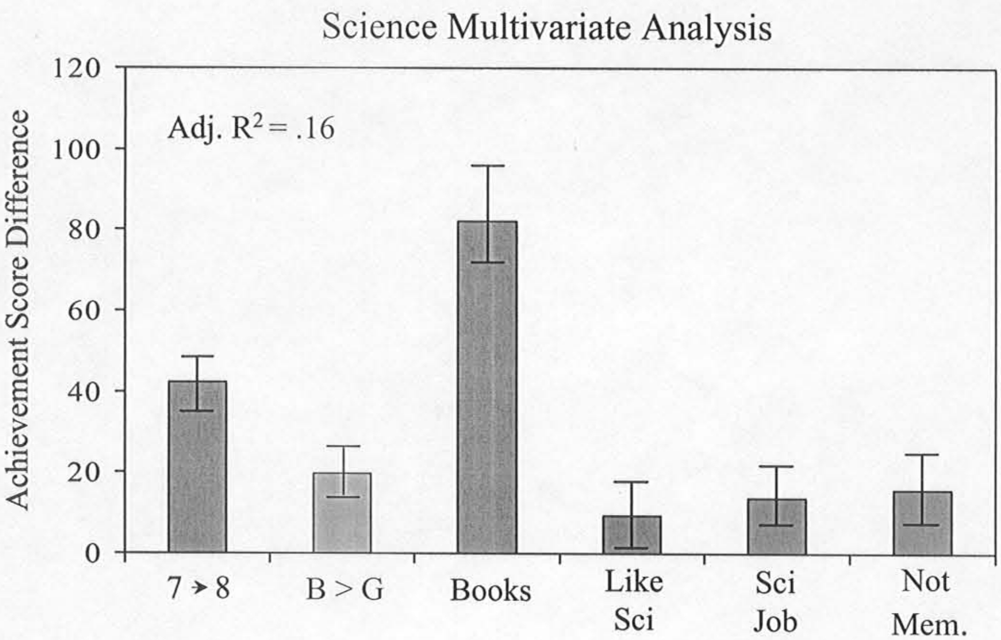


Figure 19. Bivariate and multivariate analyses of science achievement in Switzerland from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (|—|). Data Source: TIMSS.

GERMANY

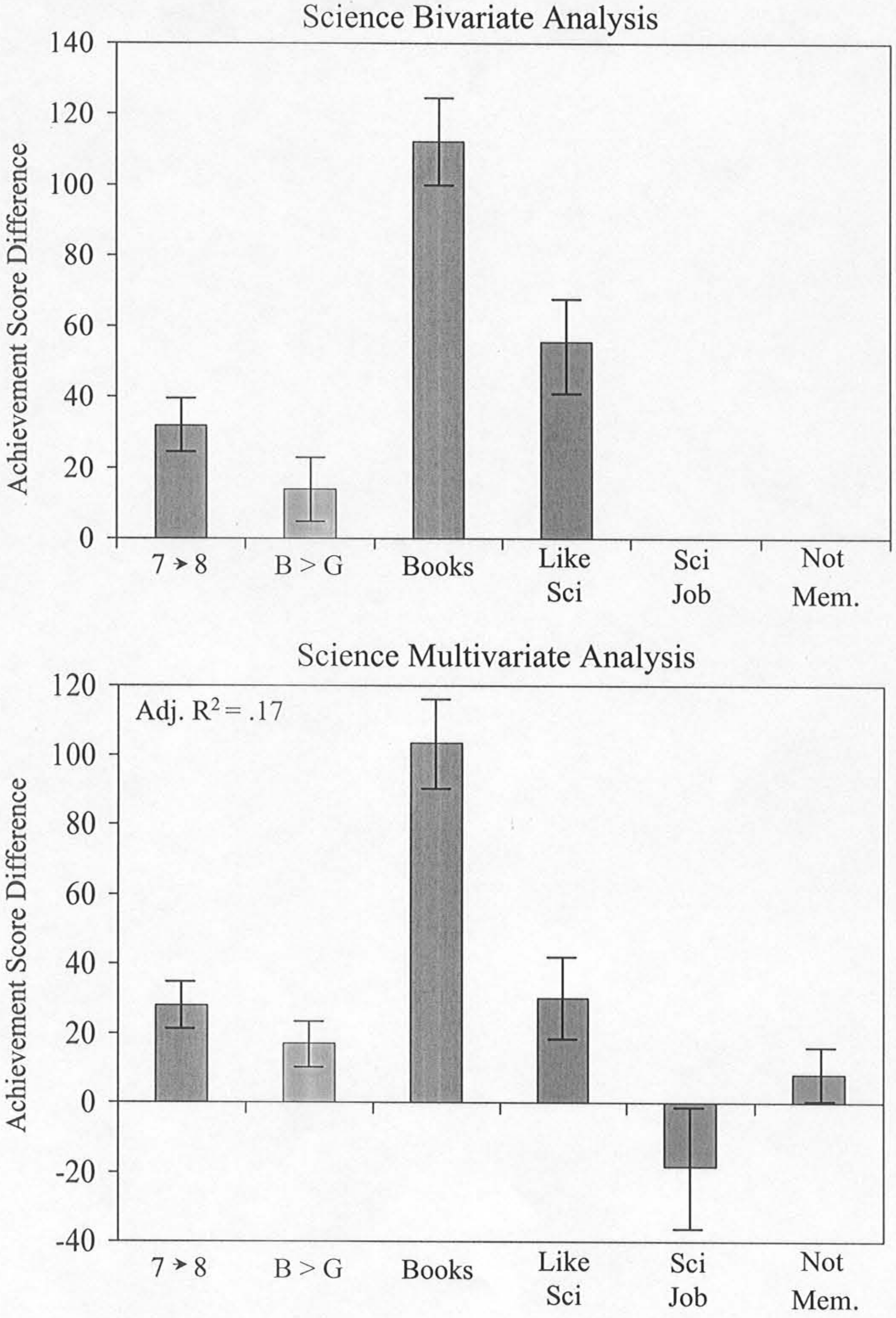
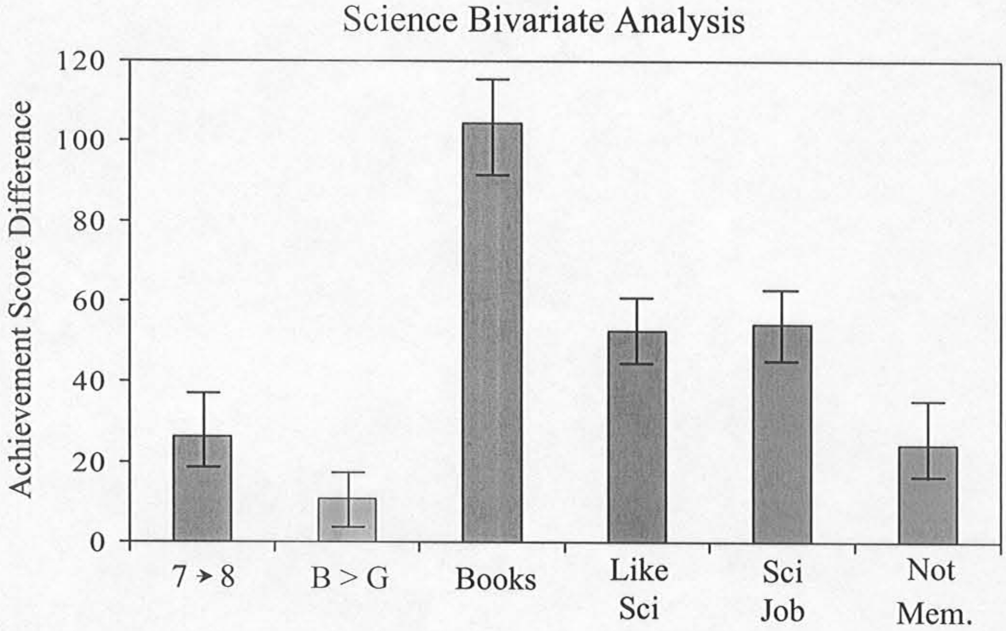


Figure 20. Bivariate and multivariate analyses of science achievement in Germany from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (|—|). Data Source: TIMSS.

UNITED STATES



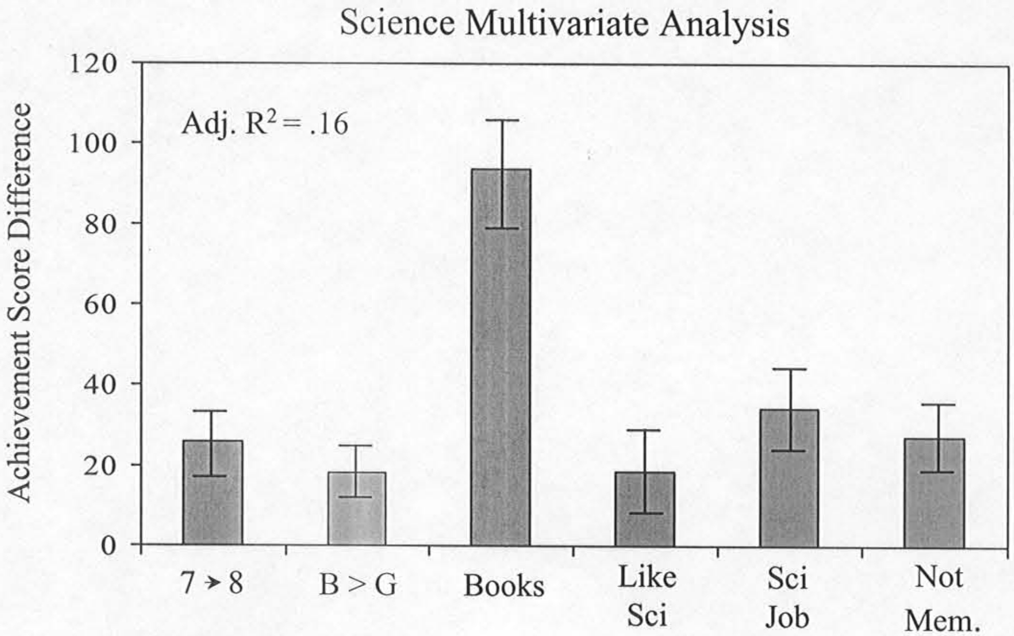


Figure 21. Bivariate and multivariate analyses of science achievement in United States from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (|—|). Data Source: TIMSS.

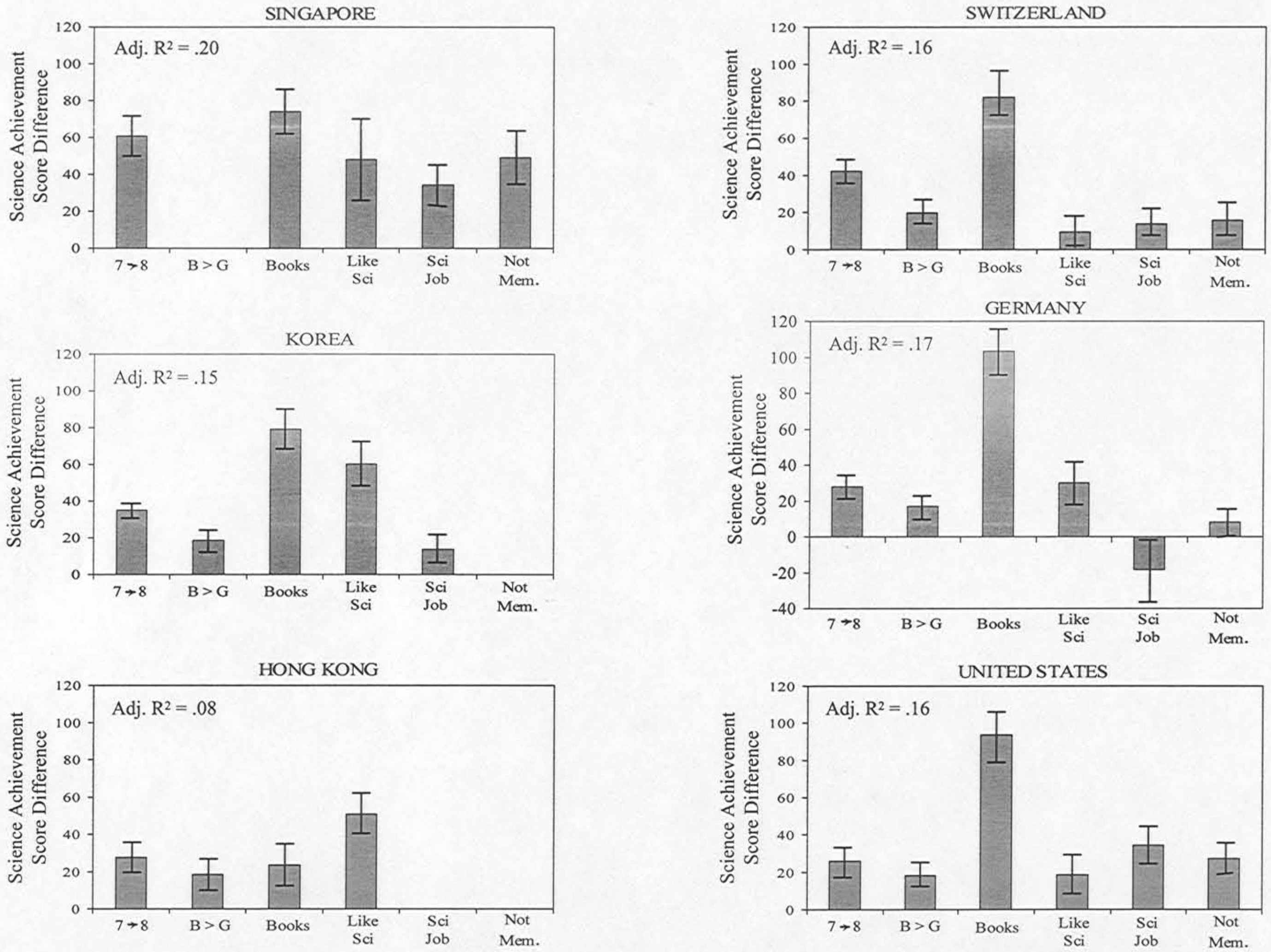
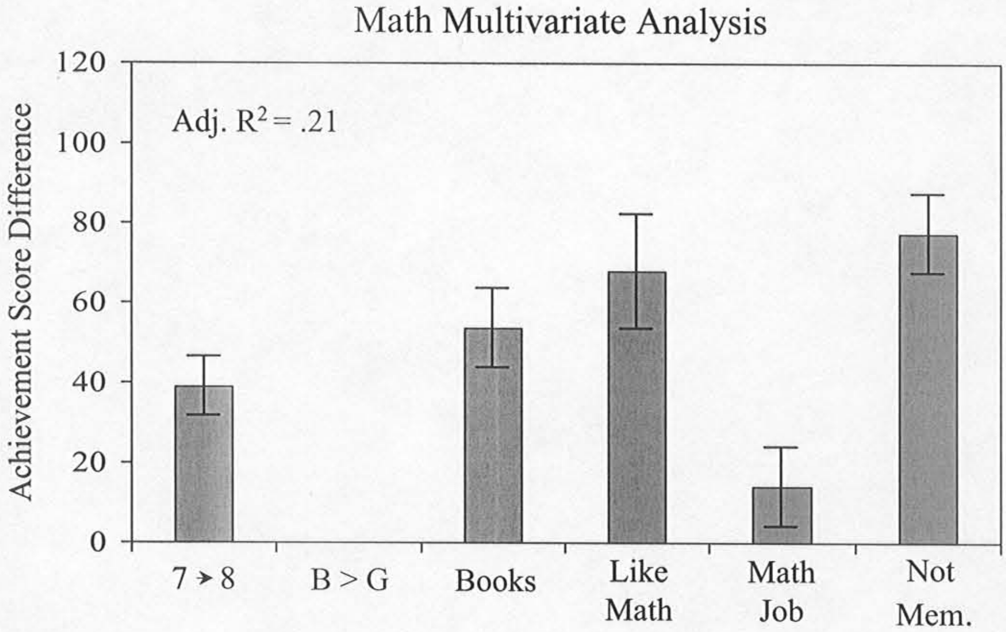


Figure 22. Six nation comparisons of multivariate analyses of science achievement from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (├┤). Data Source: TIMSS.

SINGAPORE



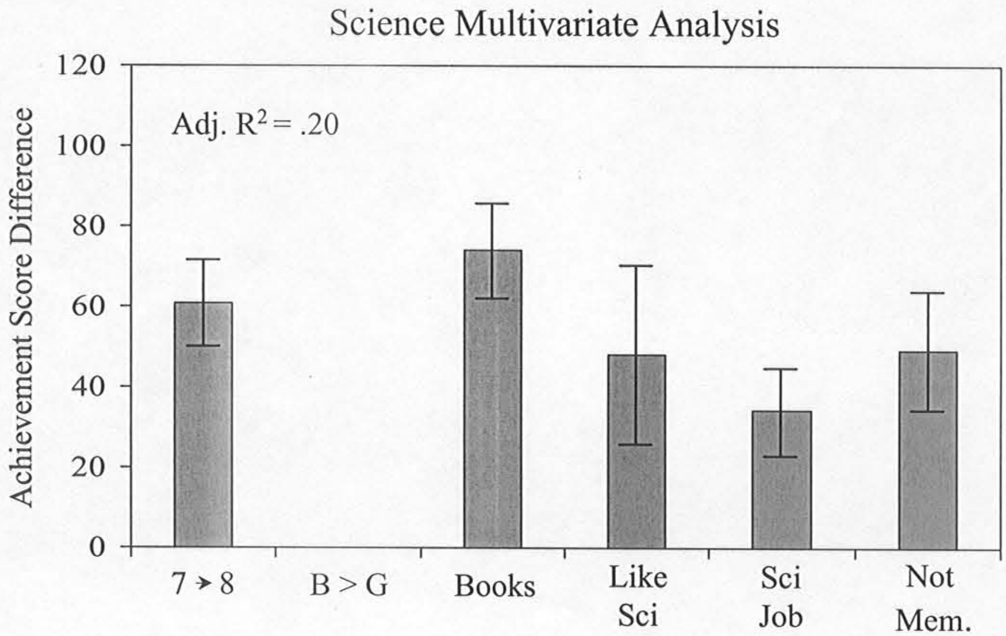
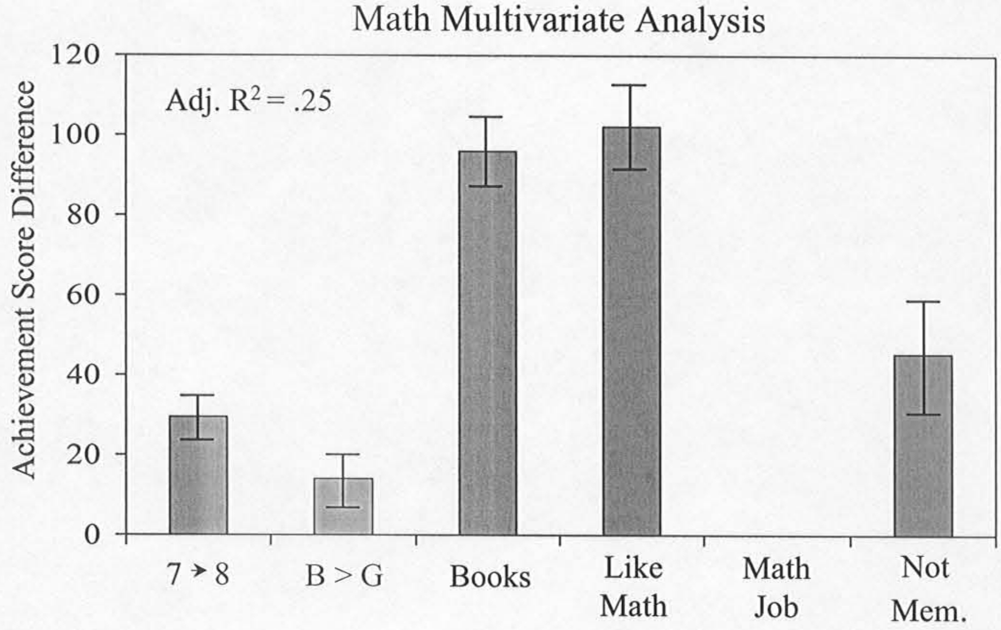


Figure 23. Comparison of multivariate analyses mathematics and science achievement in Singapore from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (|–|). Data Source: TIMSS.

KOREA



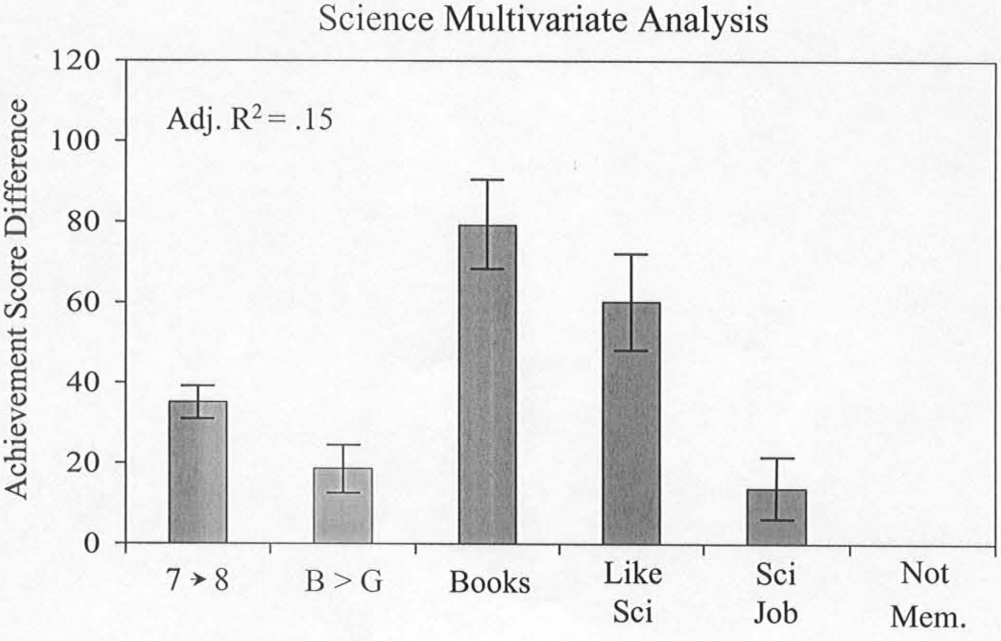
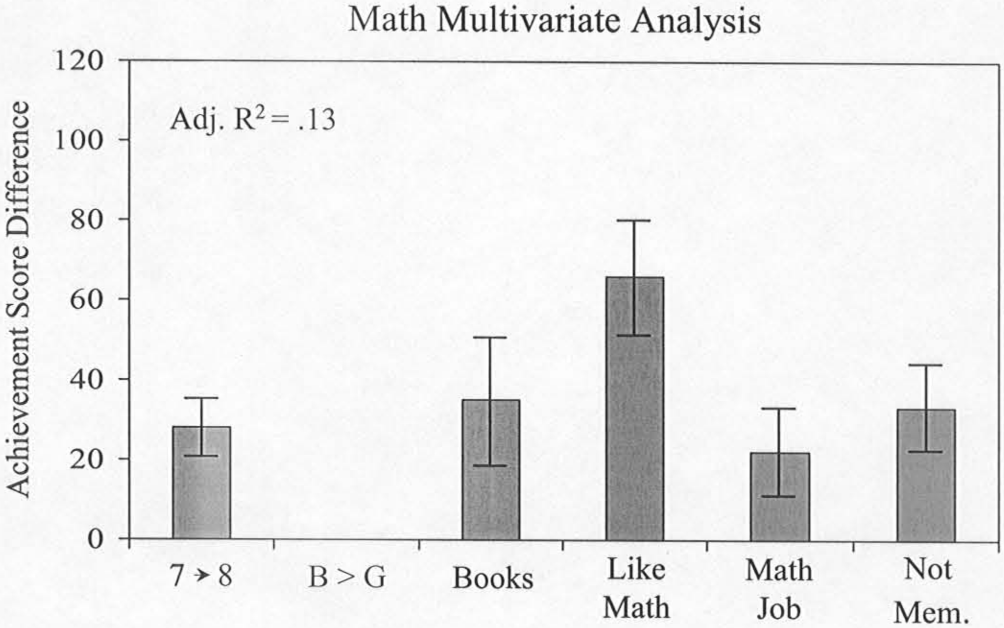


Figure 24. Comparison of multivariate analyses mathematics and science achievement in Korea from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (├┤). Data Source: TIMSS.

HONG KONG



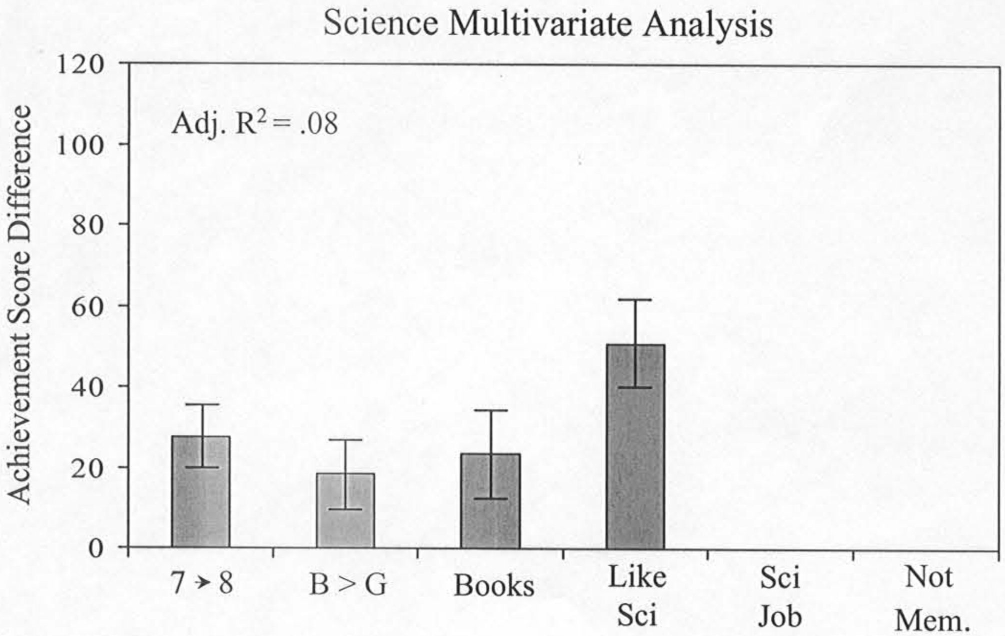
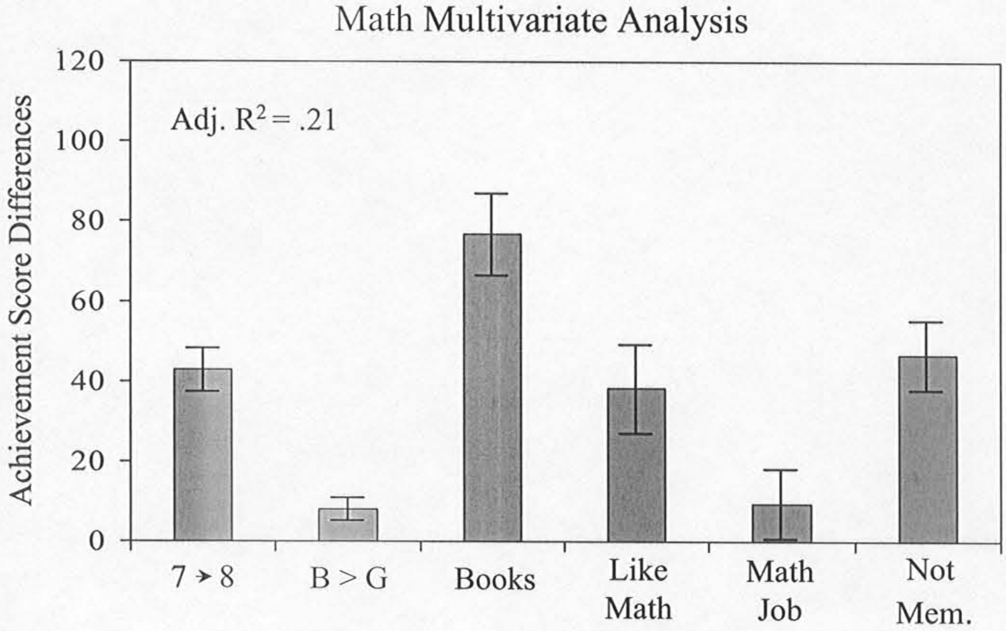


Figure 25. Comparison of multivariate analyses mathematics and science achievement in Hong Kong from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (├┤). Data Source: TIMSS.

SWITZERLAND



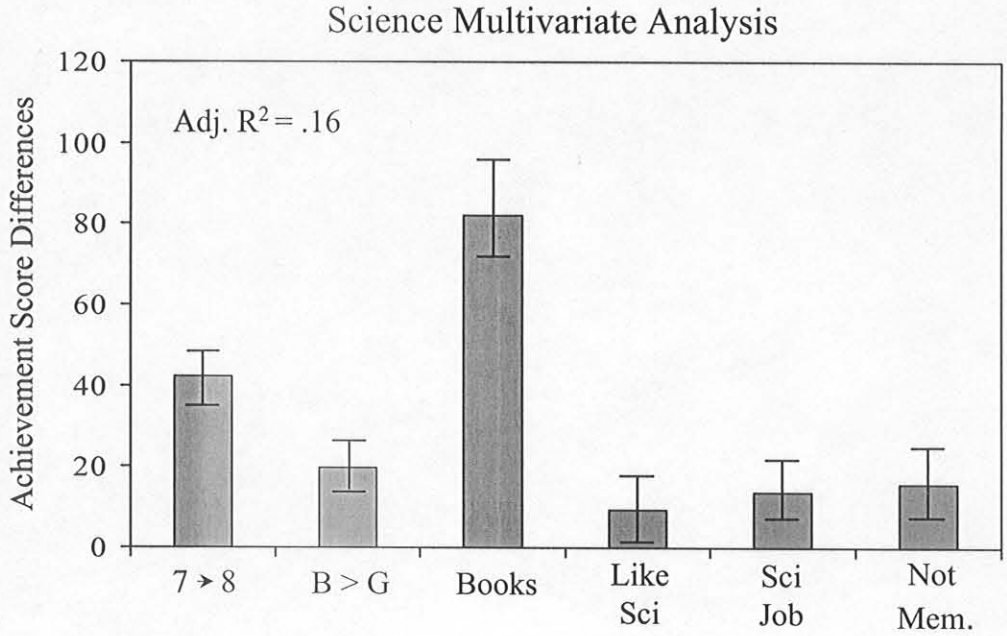


Figure 26. Comparison of multivariate analyses mathematics and science achievement in Switzerland from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (|–|). Data Source: TIMSS.

GERMANY

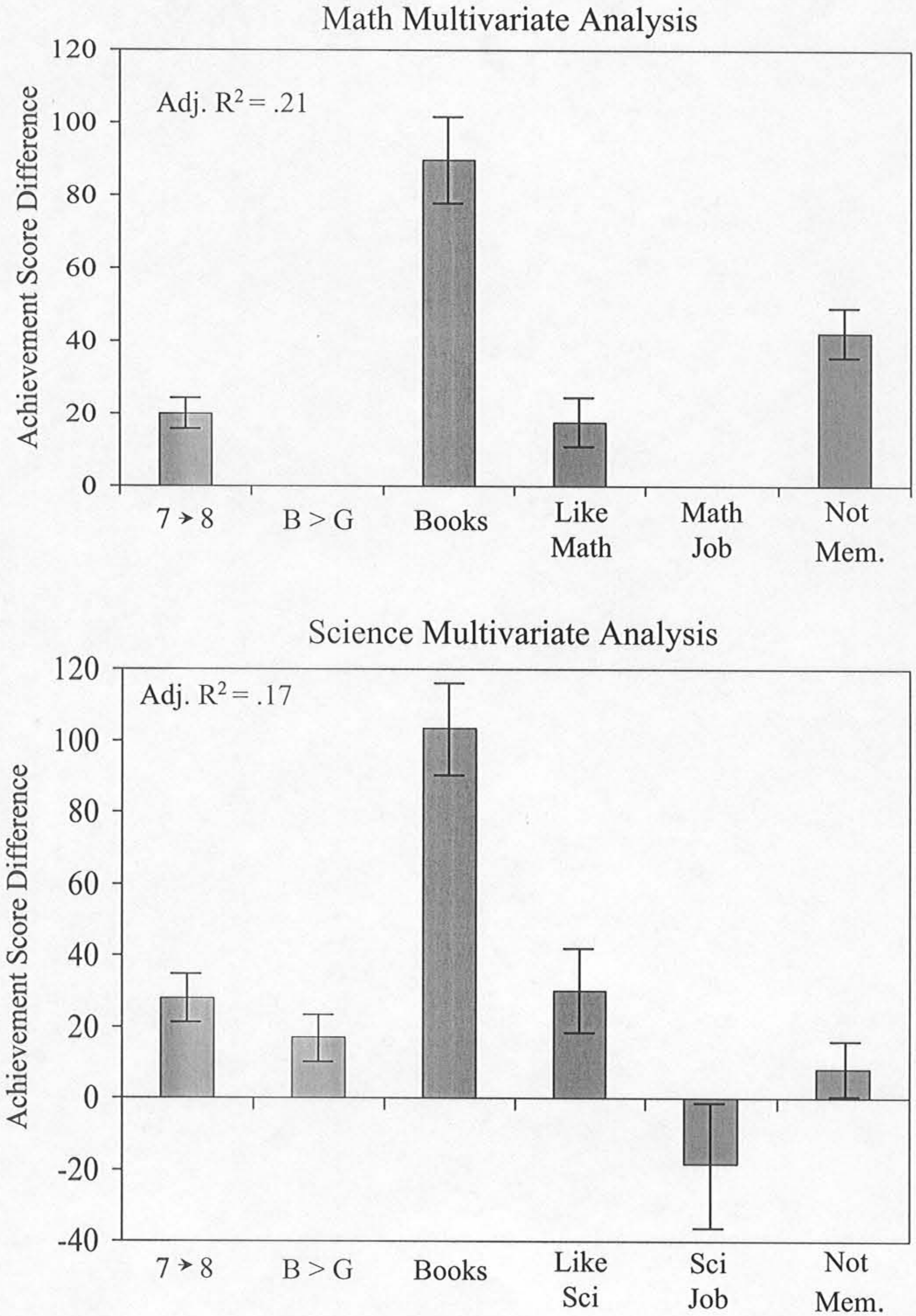


Figure 27. Comparison of multivariate analyses mathematics and science achievement in Germany from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (|—|). Data Source: TIMSS.

UNITED STATES

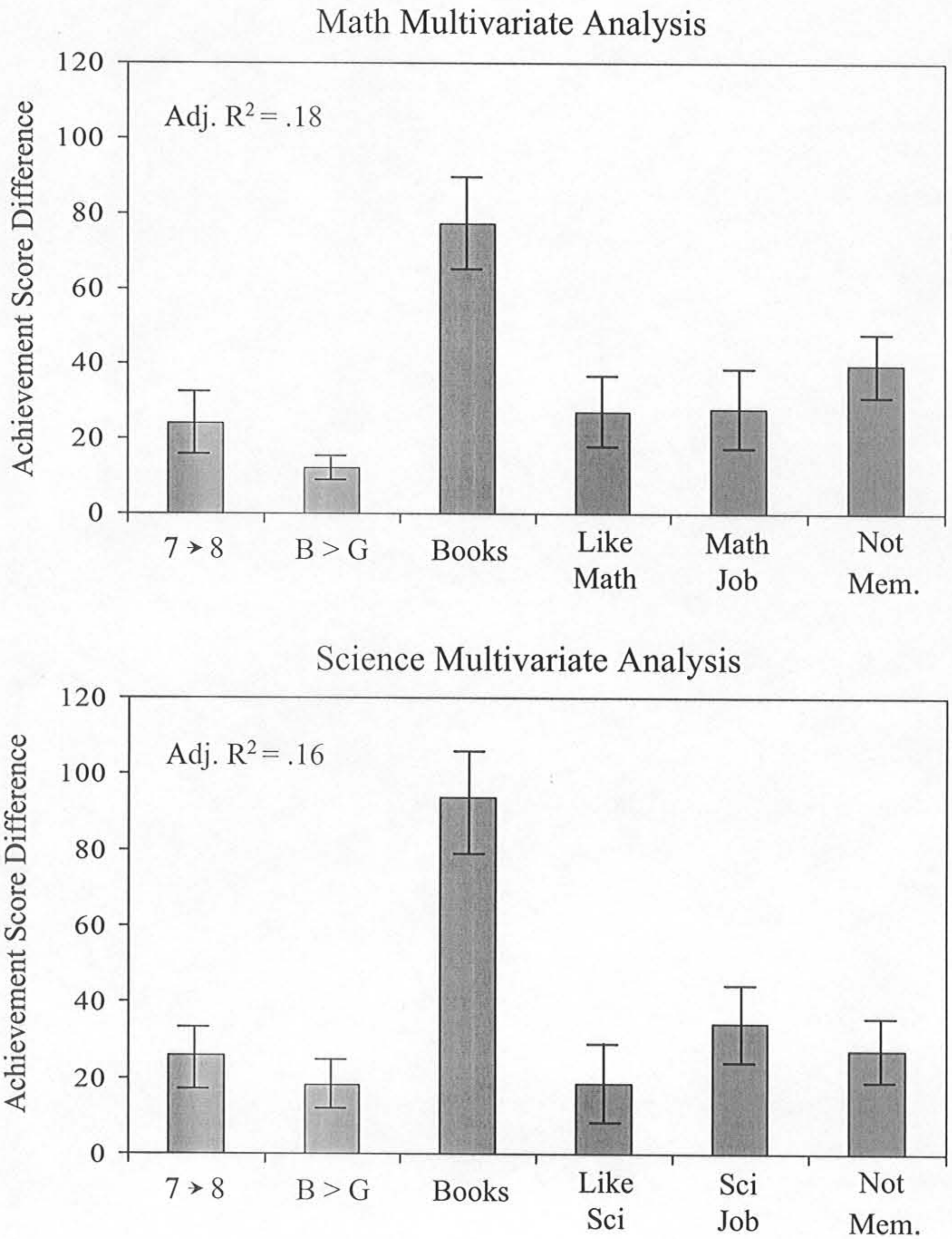


Figure 28. Comparison of multivariate analyses mathematics and science achievement in the United States from TIMSS for seventh and eighth grades combined as a function of one-unit variation in six predictor variables as defined in the text. Achievement score differences are shown only for statistically significant predictor variables along with 95% confidence intervals (├┤). Data Source: TIMSS.

References

American Association for the Advancement of Science (1990). Science for all Americans. New York: Oxford University Press.

Beaton, A. E., Martin, M. O., Mullis, I. V. S., Gonzalez, E. J., Smith, T A., & Kelly, D. L. (1996). Science Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study (TIMSS). Chestnut Hill, MA: Center for the Study of Testing, Evaluation, and Educational Policy, Boston College.

Beaton, A. E., Mullis, I. V. S., Martin, M. O., Gonzalez, E. J., Kelly, D. L., & Smith, T. A. (1996). Mathematics Achievement in the Middle School Years: IEA's Third International Mathematics and Science Study (TIMSS). Chestnut Hill, MA: Center for the Study of Testing, Evaluation, and Educational Policy, Boston College.

Eaton, J. S. (1999, March 10). The "excuse" schools: Accommodating ourselves to death. Education Week, pp. 33,.

Martin, M. O., & Kelly, D. L. (Eds.) (1996). Third International Mathematics and Science Study Technical Report: Volume I: Design and Development. Chestnut Hill, MA: Center for the Study of Testing, Evaluation, and Educational Policy, Boston College.

Martin, M. O., & Kelly, D. L. (Eds.) (1997). Third International Mathematics and Science Study Technical Report: Volume II: Implementation and Analysis (Primary and Middle School Years). Chestnut Hill, MA: Center for the Study of Testing, Evaluation, and Educational Policy, Boston College.

Martin, M. O., & Mullis, I. V. S. (Eds.) (1996) Third International Mathematics and Science Study: Quality Assurance in Data Collection. Chestnut Hill, MA: Center for the Study of Testing, Evaluation, and Educational Policy, Boston College.

National Council of Teachers of Mathematics (1989). Curriculum and Evaluation Standards for School Mathematics. Reston, VA: Author

National Council of Teachers of Mathematics (1991). Professional Standards for Teaching Mathematics. Reston, VA: Author

National Research Council (1996). National Science Education Standards. Washington, DC: National Academy Press.

Turner, H. M., & Boe, E. (1999). Mathematics Achievement of 7th and 8th Grade Students in the United States: Do Attitudes and Beliefs About Mathematics Make a Difference? (Research Rep. No. 1999-MSE1). Philadelphia: University of Pennsylvania, Graduate School of Education, Center for Research and Evaluation in Social Policy.

APPENDIX: RESEARCH METHODS

Data Source: TIMSS

The Third International Mathematics and Science Study (TIMSS) was conducted in over 40 nations at the seventh and eighth grade levels[5] in 1995 under the auspices of the International Association for the Evaluation of Educational Achievement (IEA). In TIMSS, this group is referred to as Population 2. Furthermore, a subset of 24 of these nations participated in the study at the third and fourth grade levels (called Population 1)[6], and another subset of 21 nations participated in studying students in the final year of secondary school (called Population 3)[7]. In addition to the administration of internationally standardized achievement examinations in mathematics and science, extensive questionnaire data were collected from students, their mathematics and science teachers, and the principals of the schools in which data collection occurred. The design of TIMSS yielded large national probability samples of schools and students for each participation nation at each grade level. Overviews of TIMSS is found in Beaton, Mullis, et al. (1996, Appendix A) and Martin and Kelly (1996, Chapter 1) while a more detailed description, along with technical information, is found in Martin and Kelly (1996, 1997) and Martin and Mullis (1996).

Student Samples

The student samples selected for analysis in this research were separate national probability samples of seventh and of eighth grade students in six nations. The nations selected, student sample sizes, nationally estimated number of students, and student response rates (i.e., participation percentages from Martin & Mullis, 1996) are shown in Table A-1. All students included in the sample, but who did not participate in TIMSS, were absent from school at the time the achievement examinations and questionnaires were administered.

---

[5]More specifically, 41 nations participated at the seventh grade level and two additional nations participated at the eighth grade level.

[6]Two additional nations participated at the fourth grade level.

[7]One additional nation participated during the final year of secondary school.

Table A-1. *The TIMSS Student Sample: Sample Size, Nationally Estimated Number of Students, and Questionnaire Response Rate*

		Grade Level	
Nation	Statistic	Seventh	Eighth
Singapore	Sample (n)	3,641	4,644
	National Estimate	36,181	36,538
	Response Rate	98%	95%
Korea	Sample (n)	2,907	2,920
	National Estimate	798,409	810,404
	Response Rate	94%	95%
Hong Kong	Sample (n)	3,413	3,339
	National Estimate	88,591	88,574
	Response Rate	98%	98%
Switzerland	Sample (n)	4,085	4,855
	National Estimate	66,681	69,732
	Response Rate	99%	98%
Germany	Sample (n)	2,893	2,870
	National Estimate	742,346	726,087
	Response Rate	87%	87%
United States	Sample (n)	3,886	7,087
	National Estimate	3,156,847	3,188,297
	Response Rate	94%	92%

Note. Data from the Third International Mathematics and Science Study (TIMSS).

[a]National Estimate is the nationally weighted estimates of the total number of students in the seventh and eighth grades, respectively.

All students who participated in TIMSS received scores on the same standardized mathematics and science achievement examinations for Population 2. In addition, all students participating in the achievement examinations in Singapore, Korea, Switzerland, and the United states also completed the Student Questionnaire for Population 2, while students from Germany completed the Student Questionnaire for Population 2 (s), a special version with more detailed questions about the study of science.

Variables Analyzed[8]

The first dependent variable studied was the continuous TIMSS achievement score in mathematics for each student in the samples studied. This score is the first plausible value (Martin & Kelly, 1997). Seven independent (or predictor) variables were studied for mathematics. Except for the "grade" variable, the remaining six predictor variables were all taken from student responses to items included in the student questionnaires.

The selection of three control variables and four student attitude, belief, and perception variables for study here was based in part on the related and more extensive multivariate analyses as performed by Turner and Boe (1999) for mathematics achievement in the United States. In addition to the three control variables described below (numbered 1, 2, and 3), Turner and Boe analyzed student place of birth (outside the US vs. within the US) and found it not to be a statistically significant predictor in a multivariate model of mathematics achievement. In addition to the four attitude, belief, and perception variables described below (numbered 4 through 7), Turner and Boe analyze the following student belief variable: "I need to do well in mathematics to get the job I want." However, it was redundant with other predictor variables in a multivariate model. Thus, the most promising predictor variables of mathematics achievement in the US (as identified by Turner and Boe) were selected for this research, and their analysis was extended to science achievement and to five other nations.

Thus, the seven predictor variables analyzed in this research were as follows:

1. Grade: Since independent national probability samples of both seventh and eighth grade students were studied by TIMSS, the dichotomous "grade" variable was defined by seventh (coded 0) versus eighth grade students (coded 1).

2. Sex: The dichotomous "sex" variable was defined by student self reports of being a girl (coded 0) or a boy (coded 1).

---

[8]Operational definitions of variables analyzed in this research are available upon request from the senior author.

3. Number of Books in Home: The five-level "Books in Home" variable was defined by student responses to the question "About how many books are there in your home?". Students chose an answer among the following options: none or very few (0 - 10 books), enough to fill one shelf (11 - 25 books), enough to fill one bookcase (26 - 100 books), enough to fill two bookcases (101 - 200 books), or enough to fill three or more bookcases (more than 200). For the bivariate and multivariate analyses, the five levels of "Books in Home" were coded as four indicator variables as shown in Table 3. The reference category (coded 0) was the lowest level (0 - 10 books), while the comparison levels were all coded "1."

4. Like Mathematics: The four-level "Like Math" variable was defined by student responses to the question "How much do you like mathematics?". Students chose an answer among the following four options: dislike a lot, dislike, like, or like a lot. For the bivariate and multivariate analyses, the four levels of "Like Math" were coded as three indicator variables as shown in Table 3. The reference category (coded 0) was "dislike a lot," while the comparison levels were all coded "1."

5. Job Using Mathematics: The four-level "Math Job" variable was defined by student responses to the statement "I would like a job that involved using mathematics." Students chose an answer among the following four options: strongly agree, agree, disagree, or strongly disagree. For the bivariate and multivariate analyses, the four levels of "Math Job" were coded as three indicator variables as shown in Table 3. The reference category (coded 0) was "strongly disagree," while the comparison levels were all coded "1."

6. Not Memorize Textbook or Notes: The four-level "Not Mem." variable was defined by student responses to the statement "To do well in mathematics at school you need to memorize the textbook or notes." Students chose an answer among the following four options: strongly agree, agree, disagree, or strongly disagree. For the bivariate and multivariate analyses, the four levels of "Not Mem." were coded as three indicator variables as shown in Table 3. The reference category (coded 0) was "strongly agree," while the comparison levels were all coded "1." Thus, responses coded "1" indicated a belief that "not memorizing" was the best strategy for doing well in mathematics.

7. Do Well in Mathematics: The four-level "Do Well Math" variable was defined by student responses to the statement "I usually do well in mathematics." Students chose an answer among the following four options: strongly agree, agree, disagree, or strongly disagree. For the bivariate and multivariate analyses, the four levels of "Do Well Math" were coded as three indicator variables. The reference category (coded 0) was "strongly disagree," while the comparison levels were all coded "1."

The second dependent variable studied was the continuous TIMSS achievement score in science for each student in the samples studied. This score is the first plausible value. The first six of the seven independent or predictor variables listed above were studied similarly for science (the seventh variable was not analyzed for science). Of course, the science version of items 4, 5, and 6 above were used. This was straightforward for the five nations (SNG, KOR, HK, SWZ, US) that administered the standard Student Questionnaire for Population 2 in which the questions about mathematics and science were in parallel form.

However, students from Germany completed the Student Questionnaire for Population 2 (s), a special version with more questions specifically about the study of biological science, earth science, and physical science (chemistry and physics). Of the variables studied here, these questions about particular scientific disciplines pertained to the "Like Science" and "Science Job" variables (see the related mathematics items numbered 4 and 5 above). With respect to "Like Science," an average response to "liking the three scientific disciplines" was computed for each student, and recoded as dislike a lot, dislike, like, or like science a lot. For "Science Job," each student responded in terms of the particular science (biological, earth, chemistry, or physics) he/she was studying during the TIMSS year. Thus, a student's "liking a job" involving the particular science then being studied was coded as the "Science Job" variable.

Data Analysis Procedures

Based on the sample sizes reported in the Tables A-1, weighted national estimates of the numbers of students (as well as their percentages and standard errors) were computed by special procedures developed by IEA for complex sample survey data (Martin & Kelly, 1997) for the various levels of the seven predictor variables. These national estimates were used in the bivariate and multivariate statistical analyses testing for associations among variables. Because TIMSS data are subject to design effects due to the structure of the sample, replicate weights were created using the jackknife 2 method in the statistical software WesVarPC. These replicate weights were used in WesVarPC to compute the standard errors for the national estimated numbers of students.

The bivariate and multivariate relationships among the predictor variables and the mathematics and science achievement dependent variables were analyzed by using PROC REG in the statistical software SAS. Based on the replicate weights, standard errors of the parameter estimates (and computations of their statistical significance) were computed using WesVarPC.