Learning More Science in Single-Sex or in Coeducational Schools?

Findings from Hong Kong, SAR and New Zealand

from TIMSS 1995, 1999, and 2003

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Abstract

On October 25, 2006, the United States Department of Education published new regulations allowing single-sex education in public schools any time schools think it will student improve achievement. Thus far, studies comparing single-sex with mixed (or coeducational) schools have been carried out at the national level mostly in England, Australia and Jamaica, while in United States comparative studies have been limited to Catholic schools. This study used Trends in Mathematics and Science Study (TIMSS) datasets from 1995, 1999, and 2003 at the eighth grade for two countries to explore whether there are any patterns in the differences in science performance between students educated in single-sex schools and those in coeducational schools, and if these differences are consistent over the three points in time. The observed achievement difference between the two types of schooling was models in terms of student and school characteristics identified in the single-sex education literature. By drawing on the information from countries where same-sex education has been in place for a long time, this study generated scientifically-based evidence with respect to the merits of single-sex education as compared to coeducation.

Keywords: *hierarchical linear models, Hong Kong, New Zealand, single-sex education, TIMSS*

Introduction

This paper examined the potential benefit of single-sex education on students' science achievement and attitudes toward science in comparison to coeducation. Separate multilevel analyses were conducted for boys and girls in two countries, New Zealand and Hong Kong, SAR. The differences between two student outcomes (i.e. science achievement and attitudes toward science) in single-sex and coeducational schools were examined using data from three consecutive cycles of the TIMSS study, i.e. 1995, 1999 and 2003.

There is presently a broad interest in narrowing achievement gaps among all groups of students and improving education by any method that is scientifically sound. In the United States, the strategy of teaching boys and girls in separate classes is getting a lot more attention since October 25, 2006, when the Department of Education published new regulations governing single-sex education in public schools. The new regulations allow single-sex education any time schools think it will improve achievement, expand the diversity of courses or meet students' individual needs (US Department of Education, October 24, 2006 press release).

The 2006 policy change with respect to single-sex education started in the US an ideological debate between the proponents and critics of this type of schooling. On one end of the debate, proponents of single-sex education cite research in neuroscience showing specific brain differences between men and women (Sax, 2005 and references therein). They also cite studies suggesting that single-sex schools seem to provide boys and girls with an environment where they attain higher academic achievement and graduation rates (Finn, 1980; Hamilton, 1985; Lee & Bryk, 1986; Riordan, 1990; Cresswell, Rowe & Withers, 2002; Younger & Warrington, 2005). Scantlebury and Baker (2007) cite strong evidence that single-sex environments "provide girls with a sense of empowerment, confidence to ask questions in class, an intimidation-free classroom climate, and a positive attitude toward science" (p. 276).

At the opposite end, civil-liberties and feminist groups such as the American Association of University Women (AAUW) argue that the success of single-sex schools could be the result of educational practices such as better teacher preparation, additional school resources or parental involvement, rather than the gender composition of the school (AAUW, 1992; AAUW, 1998; Sadker & Sadker, 1994; Sadker & Zittleman, 2004).

The middle-ground is shared by people who believe single-sex environment seems to have better results only on some groups of students, such as those coming from underprivileged socio-economic backgrounds (Riordan, 1990; Riordan, 2002).

The study presented in this paper took advantage of the data collected in three consecutives TIMSS cycles and compared science performance of eighth-grade students in single-sex and coed schools in two countries that offered single-sex education, i.e. Hong Kong, SAR and New Zealand. The purpose of the study was two-fold: i) to examine if students enrolled in single-sex schools in these two countries had significant differences in science achievement and attitudes toward science compared to students in coeducational schools, and ii) to understand if the potential benefit of single-sex education can be explained by pre-existing differences in student and/or school characteristics rather than the gender composition of the school.

A systematic review of single-sex education research conducted by the US Department of Education revealed that, thus far, studies comparing single-sex with coeducational schools have been carried out at the national level mostly in England, Australia and Jamaica (Younger & Warrington, 2005; Cresswell, Rowe & Withers, 2002; Hamilton, 1985). The review also uncovered that majority single-sex education studies in US have been conducted in Catholic single-sex schools, in which students are separated by sex only when entering adolescence Also, a large number of these studies employ high school students, with a small minority using elementary school students (US Department of Education, 2005, pp. xvii). Another finding of the above mentioned review is a pronounced tendency to study girls' schools more than boys' schools. Moreover, among the academic outcomes used to evaluate the effectiveness of single-sex schools in comparison to coed schools, the review generally reports on mathematics or English achievement test scores (US Department of Education, 2005, pp. xvii). Last but not least, the systematic review of the literature suggests a dearth of randomized experiments or correlational studies with adequate statistical controls studies across all outcomes (US Department of Education, 2005, pp. xi). Only very few studies reported descriptive statistics or effect sizes and most studies differ in the criteria and statistical controls they use to compare single-sex and coeducational schooling.

The study presented in this paper offered the opportunity to fill in the gaps noted in the review of single-sex education research conducted by the US Department of Education. First, this study focused on middle school students in two countries, without regard to the funding sources for the schools (i.e. public or private). Second, it compared the performance of boys in boys' schools with boys in coed schools and similarly, girls in girls' schools with girls in coed schools. By studying the difference in science test scores, this study substantially added to the current knowledge base, especially since science is one of the academic topics repeatedly linked to gender stereotypes. Finally, this study used hierarchical linear models (HLM) that provide the appropriate technique to analyze clustered data, i.e. students clustered in classes, classes clustered in schools, schools clustered in countries. Moreover, HLM allowed for predictor variables to be added in the regression equations at each level of the hierarchy.

By drawing on the information from countries where same-sex education has been in place for a long time, this study can generate scientifically-based evidence with respect to the merits of single-sex education as compared to coeducation.

Methodology

The work presented here addressed the following research questions:

1. Are there differences in science performance and attitudes toward science between students in single-sex schools and students of the same sex educated in coeducational schools in TIMSS 1995, 1999 and 2003 administrations?
2. If any differences are observed, to what extent can these differences be accounted for by student characteristics? Moreover, if any are observed, to what extent can these differences be accounted for not only by student characteristics but also by school characteristics?
3. If any differences are observed, are they consistent across the three TIMSS cycles selected for this study?

In selecting from all TIMSS participating countries the jurisdictions analyzed in the present study, the following criteria were used: countries that participated in all three TIMSS cycles, i.e. 1995, 1999, and 2003; offered single-sex and coeducational education at the eight-grade level; offered single-sex education not only in private schools, but also in public schools; the education of boys and girls was not treated differently due to religious beliefs; and also, countries that have sufficient variability between schools (as indicated by their intra-class correlation coefficient) so that differences in science achievement between schools can be associated not only with differences in student background characteristics but also with differences in contextual variables at the school level.

Of the countries that participated in TIMSS, three met the first three selection criteria for this study, namely Hong-Kong, SAR, Korea and New Zealand. O'Dywer (2005) reported the percentage of variance between class/schools in 8th grade mathematics achievement for Hong Kong, Korea and New Zealand in TIMSS 1995 and 1999, as follows: Hong Kong - 60% (1995) and 57% (1999); Korea - 9% (1995) and 7% (1999); and New Zealand- 50% (1995) and 54% (1999). In comparison with Hong Kong and New Zealand, the percent of variance in student achievement in Korea that can be attributed to variability between class/schools seemed very small, and consequently, Korea was eliminated from this study.

Modeling Average Differences in Science Achievement

The first outcome variable examined in this study was student achievement in science. Modeling average differences between mean science achievement in single-sex and coeducational schools employed two-level hierarchical linear models. At level 1, science achievement was regressed on student characteristics within each school and each regression equation was characterized by a school-specific intercept and vector of slopes. The intercept and slopes for each school became the outcome variables in level-2, between-school regression equations.

The TIMSS methodology for reporting student achievement in mathematics and science is well-documented (for example Martin, Mullis & Chrostowski, 2004, for details of TIMSS 2003). In all the TIMSS studies, science achievement is reported as *plausible values (PVs*) of student proficiency on the science portion of the test. These PVs were generated using the IRT scaling methodology described in Gonzalez, Galia, and Li (2004). The *TIMSS User Guides* recommend using plausible values in conducting regression analyses with science scores as outcome variables.

This study employed HLM6 software program, which was designed to carry out the calculations associated with the sampling variance that is the result of TIMSS clustered datasets (Raudenbush, Bryk & Congdon, 2000). At the same time, this statistical package was designed to take into account the uncertainty associated with the estimation of individual proficiency scores, by running the model five times, with each plausible value as the outcome variable in each run. The final estimates are the averages of the results from the five analyses.

In addition to mathematics and science achievement data, all TIMSS projects administered background questionnaires to collect contextual information about students' socio-economic background, about their teachers and schools, as well as the mathematics and science curriculum required by the education system in each country (Martin et al., 2004a, 2004b, Martin, 2005). The student and school questionnaires were the sources for the variables used as predictors in the regression models, as well as the secondary student outcome variable, i.e. *Attitudes toward Science*.

The background variables used as predictors from the student and school background questionnaires were selected based on the recommendations from the literature on student achievement and school effectiveness. The final set of predictor variables for each country during each TIMSS cycle was chosen upon examination of descriptive statistics, such as means, standard deviations, number of missing data, etc as well as a sequence of exploratory analyses in which different combinations of variables were examined.

– *Highest Level of Education of Either Parent*, with response options collapsed into three categories: *finished less than high-school, finished high-school, finished university*;

– *Number of Books in the Home*, with response options collapsed into three categories: *one bookcase (<100 books), two bookcases (101-200 books), three bookcases or more (>200 books)*;

– *Index of Students' Having Educational Aids in the Home*, with *Yes/No* response options;

– *Index of Self-Concept in Learning Science* (in TIMSS 1999), and *Index of Self-Confidence in Learning Science* (in TIMSS 2003), with three levels: *low, medium, high*.

– *Index of Availability of School Resources for Science Instruction*;

– *Index of Good School and Class Attendance*;

– Schools' reports on expectation of *parents acting as volunteers*, and *parents participating in school committees,* with *Yes/No* response options;

The TIMSS background questionnaires have changed from one administration to the other and, consequently, some the items in the questionnaires either have changed, or were dropped from subsequent assessments. A thorough review of the student and school questionnaires from 1995, 1999, and 2003 revealed that the largest number of questions was asked in TIMSS 1999, followed by 1995, with 2003 asking the fewest questions at both student- and school- levels. Consequently, the research design of this study employed two phases, corresponding to the different sets of predictors in TIMSS 1995, 1999, and 2003:

– In ***Phase 1***, the set of student- and school-level predictor variables that was common to all three cycles was used in the two-level HLM analysis, with students at level 1 and schools at level 2, for each country at the three points in time. Phase 1 comprised a total of 24 HLM models.

– In ***Phase 2***, for TIMSS 1995 and TIMSS 1999 only, more predictor variables were added at the student level, corresponding to the set of variables that are common to these two administrations but not 2003. The estimated effects of school type from the model using the smaller set of predictors were compared with the results of the models using the larger set. These comparisons provided information about how sensitive estimates were from the first model (i.e. the one using the small set of predictors) to the inclusion of the new set of predictors. The second phase comprised 16 HLM models.

This study explored how the inclusion of multiple predictor variables at both student- and school- levels affects the estimated average difference in adjusted school means between single-sex and coeducation schools. In the first step, the outcome differences between the two types of schools were modeled without taking into account any student or school characteristics. Next, the paper examined the school outcome differences after including a set of student characteristics that have been reported in the literature as potential predictors of science achievement and attitudes toward science. Finally, the school outcome differences were modeled after including not only student but also school characteristics identified as potential predictors. The table below summarizes this sequence of models.

[Insert Table 1 about here]

The equations presented below follow the sequence of models included in the above table.

Model A is a fully unconditional model, with no level-1 or level-2 predictor variables.

Level 1: $SCI_{ij} = \beta_{0j} + r_{ij} \qquad r_{ij} = N(0, \sigma^2)$

Level 2: $\beta_{0j} = \gamma_{00} + u_{0j} \qquad u_{0j} = N(0, \tau_{00})$

In **Model B**, the school-type indicator $SCHTYPE_j$ is included as a contextual variable at the school level 2:

Level 1: $SCI_{ij} = \beta_{0j} + r_{ij} \qquad r_{ij} = N(0, \sigma^2)$

Level 2: $\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{SCHTYPE})_j + u_{0j} \qquad u_{0j} = N(0, \tau_{00})$

In **Model B**, the school-type indicator $SCHTYPE_j$ estimates the average difference in unadjusted school means between single-sex and coeducation schools. Running **Model B** for each country provided answers to the first research question.

By introducing student predictors as covariates at the level, **Model C** adjusts school mean scores for differences in students' characteristics among schools. After accepting the hypotheses of no significant variance in the slopes student achievement and covariates across schools, only the level 1 intercepts were allowed to vary, while the level 1 slopes were fixed.

In Phase 1, the set of common student predictor variables among all three TIMSS cycles included parental education, number of books, home possessions and academic pressure, with the latter being common to TIMSS 1995 and 1999. The equations below present the model with the common set of covariates:

Level 1 - Phase 1:

$$SCI_{ij} = \beta_{0j} + \beta_{1j}(\text{ParentEdu1})_{ij} + \beta_{2j}(\text{ParentEdu2})_{ij} + \beta_{3j}(\text{Books1})_{ij} + \beta_{4j}(\text{Books2})_{ij} + \beta_{5j}(\text{HomePossession})_{ij} + \beta_{6j}(\text{AcadPressure}_{ij} - \overline{\text{AcadPressure}_{\bullet\bullet}})$$

Level 2 - Phase 1:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{SCHTYPE})_j + u_{0j} \quad u_{0j} = N(0, \tau_{00})$$

$$\beta_{1j} = \gamma_{10}$$

$$\vdots$$

$$\beta_{6j} = \gamma_{60}$$

In Phase 2, the model included another variable common to 1999 and 2003, *i*.e. self-confidence in learning science. The equations below present the model with the extended set of covariates:

Level 1 - Phase 2:

$$SCI_{ij} = \beta_{0j} + \beta_{1j}(\text{ParentEdu1})_{ij} + \beta_{2j}(\text{ParentEdu2})_{ij} + \beta_{3j}(\text{Books1})_{ij} + \beta_{4j}(\text{Books2})_{ij} + \beta_{5j}(\text{HomePossession})_{ij} + \beta_{6j}(\text{AcadPressure}_{ij} - \overline{\text{AcadPressure}_{\bullet\bullet}}) + \beta_{7j}(\text{SelfConfid1})_{ij} + \beta_{8j}(\text{SelfConfid2})_{ij}$$

Level 2 – Phase 2:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{SCHTYPE})_j + u_{0j} \quad u_{0j} = N(0, \tau_{00})$$

$$\beta_{1j} = \gamma_{10}$$

$$\vdots$$

$$\beta_{8j} = \gamma_{80}$$

Model D builds on **Model C**, by including contextual variables at the school-level, in addition to the school-type indicator. In Phase 1, **Model D** included the set of common predictor variables among all three TIMSS cycles not only at the student level but also at the school level. The equations below present the models fitted in Phase 1:

Level 1 – Phase 1:

$$SCI_{ij} = \beta_{0j} + \beta_{1j}(\text{ParentEdu1})_{ij} + \beta_{2j}(\text{ParentEdu2})_{ij} + \beta_{3j}(\text{Books1})_{ij} + \beta_{4j}(\text{Books2})_{ij} + \beta_{5j}(\text{HomePossession})_{ij} + \beta_{6j}(\text{AcadPressure}_{ij} - \overline{\text{AcadPressure}_{\bullet\bullet}})$$

Level 2 – Phase 1:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{SCHTYPE})_j + \gamma_{02}(\text{SchSES1})_j + \gamma_{03}(\text{SchSES2})_j + \gamma_{04}(\text{GoodSch1})_j + \gamma_{05}(\text{GoodSch2})_j + \gamma_{06}(\text{SchPolicy}_j - \overline{\text{SchPolicy}_{\bullet}}) + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\vdots$$

$$\beta_{6j} = \gamma_{60}$$

In Phase 2, **Model D** included two more school level variables common to 1999 and 2003, i.e. school expectations of parents to volunteer and to participate in school committees. The equations below present the model with the extended set of covariates.

Level 1- Phase 2:

$$SCI_{ij} = \beta_{0j} + \beta_{1j}(\text{ParentEdu1})_{ij} + \beta_{2j}(\text{ParentEdu2})_{ij} + \beta_{3j}(\text{Books1})_{ij} + \beta_{4j}(\text{Books2})_{ij} + \beta_{5j}(\text{HomePossession})_{ij} + \beta_{6j}(\text{AcadPressure}_{ij} - \overline{\text{AcadPressure}_{\bullet\bullet}}) + \beta_{7j}(\text{SelfConfid1})_{ij} + \beta_{8j}(\text{SelfConfid2})_{ij}$$

Level 2 – Phase 2:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{SCHTYPE})_j + \gamma_{02}(\text{SchSES1})_j + \gamma_{03}(\text{SchSES2})_j + \gamma_{04}(\text{GoodSch1})_j + \gamma_{05}(\text{GoodSch2})_j + \gamma_{06}(\text{SchPolicy}_j - \overline{\text{SchPolicy}_{\bullet}}) + \gamma_{07}(\text{ParentVolunteer})_j + \gamma_{08}(\text{ParentCommittee})_j + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\vdots$$

$$\beta_{8j} = \gamma_{80}$$

In this final model, the school-type indicator estimated what the average difference in school means between single-sex and coeducation schools would be, if all schools had the same distribution of student characteristics, while holding other contextual variables constant across schools. Running Model D

TIMSS database contains a complex system of sampling weights which are required to obtain correct estimate of population parameters. In this study, the HOUWGT[1] ("house weight") was

[1] Because the student sampling weight, known as TOTWGT, "inflates sample sizes to approximate the population size, software systems that use sample size to compute significance

used because it allows for a discussion of how the strength of the relationship between the outcome variable and type of school varies across TIMSS cycles, without being worried about the difference in each country sample sizes from one cycle to the next one.

In this study, predictor variables at the student level were centered at the grand mean for that variable, that is, at the mean over all students in the sample of each country (Raudenbush & Bryk, 2002). School level contextual variables were also grand-mean centered. Regression coefficients associated with student characteristics have been fixed across schools, after the null hypothesis of fixed regression coefficients have been tested and accepted at p> 0.1 level, in all cases.

Modeling Average Differences in Attitudes toward Science

Modeling *Attitudes toward Science (ATT)* employed a two-level hierarchical model that uses *cumulative probabilities* to represent the ordered nature of the data (Randenbush & Bryk, 2002). Cumulative probabilities for the categorical variable *ATT* with three categories corresponding to *low, medium, and high* are shown below:

$$\Pr(ATT \le 1) = \Pr(ATT = 1) = P(1)$$
$$\Pr(ATT \le 2) = \Pr(ATT = 1) + \Pr(ATT = 2) = P(2)$$
$$\Pr(ATT \le 3) = \Pr(ATT = 1) + \Pr(ATT = 2) + \Pr(ATT = 3) = 1$$

The cumulative probability for *ATT*≤3 is always equal to 1, therefore, only the cumulative probabilities for the first two categories need to be modeled. The cumulative log-odds for the first two categories are denoted below:

$$\log\left[\frac{\Pr(ATT \le 1)}{\Pr(ATT > 1)}\right]_{ij} = \log\left[\frac{P(1)}{1-P(1)}\right]$$
$$\log\left[\frac{\Pr(ATT \le 2)}{\Pr(ATT > 2)}\right]_{ij} = \log\left[\frac{P(2)}{1-P(2)}\right]$$

By transforming the cumulative probabilities for the first two categories of *ATT* in cumulative log-odds, hierarchical logistic regression models are used. In this framework, the cumulative logit for each category is modeled in terms of student characteristics at level 1 and school variables at level 2, using the same sequence of predictor variables as in the modeling of science achievement outcome. Level 1 student equations corresponding to **Model C** are shown below:

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tests will give misleading results for analyses weighted by TOTWGT. To avoid this problem, TIMSS provides HOUWGT, a transformation of TOTWGT that ensures that the weighted sample corresponds to the actual sample size in each country" (Martin, 2005, p. 2-45).

$$\log\left[\frac{P(1)}{1-P(1)}\right]_{ij} = \beta_{0j} + \beta_{1j}(\text{ParentEdu1})_{ij} + \beta_{2j}(\text{ParentEdu2})_{ij} + \beta_{3j}(\text{Books1})_{ij} + \beta_{4j}(\text{Books2})_{ij} + \beta_{5j}(\text{HomePossession})_{ij} + \beta_{6j}(\text{AcadPressure}_{ij} - \overline{\text{AcadPressure}_{\bullet\bullet}}) + \beta_{7j}(\text{SelfConfid1})_{ij} + \beta_{8j}(\text{SelfConfid2})_{ij}$$

$$\log\left[\frac{P(2)}{1-P(2)}\right]_{ij} = \beta_{0j} + \beta_{1j}(\text{ParentEdu1})_{ij} + \beta_{2j}(\text{ParentEdu2})_{ij} + \beta_{3j}(\text{Books1})_{ij} + \beta_{4j}(\text{Books2})_{ij} + \beta_{5j}(\text{HomePossession})_{ij} + \beta_{6j}(\text{AcadPressure}_{ij} - \overline{\text{AcadPressure}_{\bullet\bullet}}) + \beta_{7j}(\text{SelfConfid1})_{ij} + \beta_{8j}(\text{SelfConfid2})_{ij} + \delta_2$$

In the equations above, δ_2 is a variable called *threshold* denoting the difference in the *intercepts* of the logistic regression models for the first two categories, *ATT* = 1 and *ATT* = 2. Level 2 equations are similar to **Model C** and introduce the school-type indicator as a school-level predictor variable for modeling the slopes corresponding to each level 1 logistic regression equations, as shown below:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{SCHTYPE})_j + u_{0j} \quad u_{0j} = N(0, \tau_{00})$$
$$\beta_{1j} = \gamma_{10}$$
$$\vdots$$
$$\beta_{8j} = \gamma_{80}$$

Estimated School Differences for New Zealand

Estimated School Differences in Science Achievement for New Zealand's Boys

In New Zealand, the mean science achievement of boys from single-sex schools was larger than the mean science achievement of boys from coed schools, in all three TIMSS cycles. The achievement of boys in coed schools constantly increased between TIMSS 1995 and 2003, while in single-sex schools, the achievement dropped a few points from 537 in TIMSS 1995 to 525 in TIMSS 1999 and rose again in 539 in TIMSS 2003. The table below presents mean science achievement scores (standard deviations) of the average of the five plausible values. In each TIMSS cycle, the mean science scores for New Zealand's boys were broken down by school type.

[Insert Table 2 about here]

In TIMSS 1995, without adjusting for student or school covariates, boys in single-sex schools on average, outperformed boys in coed schools by 38 points and the estimated difference between school types was **statistically significant** (p = 0.01, d = 0.67) (**Model B)**. The magnitude of effect sizes confirmed the statistical significance and indicated that the estimated average difference between boys educated in single-sex and coed schools was not only statistically significant, but also educationally meaningful for New Zealand in 1995. After adjusting for differences in student characteristics (**Model C**), the estimated average school difference was still equal to half of the standard deviation of school means and 29 points higher in favor of boys in single-sex schools (p = 0.01, d = 0.50). These results indicate that in New Zealand in TIMSS 1995, even when differences in student characteristics were accounted for, on average, boys in single-sex schools still significantly outperformed boys in coed schools.

When differences in school characteristics were also accounted for (**Model D**), the estimated average difference between mean *SCI* scores in single-sex and coed schools was 22 points higher for boys in single-sex schools but only marginally significant and less than half of a standard deviation of school means (p = 0.09, d = 0.39). These results suggest that, for boys with similar background characteristics, the average school differences in science achievement in TIMSS 1999 between single-sex and coed schools can be explained to some extent by the differences in characteristics at the school level.

In TIMSS 1999 and 2003, the average of the mean *SCI* scores in single-sex was higher than the average mean *SCI* scores in coed schools before and after adjusting for differences in student and school characteristics (**Models B, C** and **D** and both Phases). However, the estimated difference was **not statistically significant** and the corresponding effect sizes were small. In 2003, after adjusting for both student and school covariates (**Model D**), the mean achievement difference between boys in single-sex and coed schools was in favor of coed schools. The table below presents the estimated school-type differences in *SCI* for boys in New Zealand.

[Insert Table 3 about here]

Estimated School Differences in Attitudes toward Science for New Zealand' Boys

Boys' attitudes toward science did not change between TIMSS 1995 and 1999 but improved from 1999 to 2003 for both single-sex and coed schools. In both 1995 and 1999, larger percentages of boys from single-sex had *high* levels of *ATT* compared to boys in coed schools (37% from single-sex schools compared to 29% from coed schools in 1995 and 36% from single-sex schools in compared to 29% from coed schools in 1999). The percentages of boys from both type of schools reporting at the *high* level of *ATT* was almost the same though in 2003 (44% from single-sex schools and 41% from coed schools).

It is important to note that the questions used in the composition of the *Index of Attitudes toward Science* have changed in TIMSS 2003 compared to previous TIMSS cycles. Therefore, a comparison in *ATT* across cycles should be done with caution, as the construct may vary across cycles.

The table below summarizes the percentages of boys at each level of the *ATT* index for New Zealand, for each type of school in all three TIMSS administrations.

[Insert Table 4 about here]

In TIMSS 1995, without adjusting for any student covariates, the predicted probability of *low* and *medium ATT* was higher in coed schools than in single-sex schools and the difference was **statistically significant** (p = 0.01, d = 0.74). Since the model uses cumulative probabilities[2], the predicted probability of *high ATT* was lower in coed schools compared to single-sex schools. In other words, the model estimates that boys in coed schools were more likely to have lower attitudes toward science than their colleagues from single-sex schools. However, after adjusting for student covariates, predicted probability of *low* and *medium ATT* was higher in coed schools than in single-sex schools but **not statistically significant**. There was no significant difference between attitudes toward science of boys in single-sex and coed schools

[2] The predicted probability of *high ATT* is calculated as the difference between 1 and the predicted probability of *low* and *medium ATT*.

in subsequent TIMSS cycles, i.e. 1999 and 2003. The table below summarizes the results for New Zealand's boys. The table below presents the estimated school-type differences in *ATT* for boys in New Zealand.

[Insert Table 5 about here]

Estimated School Differences in Science Achievement for New Zealand's Girls

In New Zealand, the mean science achievement of girls from single-sex schools was larger than the mean achievement of girls from coed schools, in all three TIMSS cycles. The science achievement scores of girls in coed schools constantly increased between TIMSS 1995 and 2003. However, girls in single-sex schools improved their science scores between TIMSS 1995 (495) and 1999 (532), but their mean science scores decreased 7 points in 2003 (525). The table below presents mean science achievement scores (standard deviations) of the average of the five plausible values. In each TIMSS cycle, the mean science scores for New Zealand's girls were broken down by school type.

[Insert Table 6 about here]

In TIMSS 1995 and 2003, the average of the mean *SCI* scores in single-sex was higher than the average mean *SCI* scores in coed schools but the estimated difference was not statistically significant at 0.05 level.

In TIMSS 1999, the results indicate a significant difference between school-types, with girls educated in single-sex schools outperforming those educated in coed schools. Without adjusting for student and school covariates (**Model B**), the average difference between mean *SCI* of girls in single-sex and coed schools was 47 points in favor of single-sex schools, and the difference was statistically significant ($p < 0.001$, $d = 0.79$). In **Model C** Phase 1, after adjusting for the set of student covariates common to all three TIMSS cycles (i.e. *parental education, number of books, home possessions,* and *academic pressure*), the advantage of girls in single-sex schools was 35 points and statistically significant ($p = 0.01$, $d = 0.59$). In Phase 2, after adding to the set of student covariates those measured in TIMSS 1999 only (i.e. *self-confidence in learning science)*, on average, single-sex schools outperformed coed schools by 33 points and the difference was statistically significant ($p = 0.01$, $d = 0.57$). These results indicate that in New Zealand in TIMSS 1999, even when differences in student characteristics were accounted for, on average, girls in single-sex schools still significantly outperformed girls in coed schools.

However, after introducing not only student predictors but also school predictors, the mean difference in *SCI* between schools was 19 points in Phase 1 and 17 points in Phase 2, but not significant at 0.05 level. The corresponding effect sizes for **Model D** were small, i.e. $d = 0.32$ in Phase 1 and $d = 0.28$ in Phase 2. These results suggest that, for girls with similar characteristics, the average school differences in science achievement in TIMSS 1999 between single-sex and coed schools can be explained to some extent by the differences in characteristics at the school level. The table below presents the estimated school-type differences in *SCI* for girls in New Zealand.

[Insert Table 7 about here]

Estimated School Differences in Attitudes toward Science for New Zealand's Girls

Similar to New Zealand's boys, the attitudes toward science of New Zealand's girls increased between 1995 and 2003 from *medium* to *high*. The percentages of girls reporting at each level of the *ATT* index were very similar for both school types in 1995 and 1999. For coed schools, there was an increase in the number of girls that reported *high* level of *ATT* in 2003, but still more girls reported *medium* levels (43%) than *high* level (35%) of *ATT*. However, this trend has changed for single-sex school in 2003. Fewer girls from single-sex schools reported *medium* levels of *ATT* (28%) than *high* level of *ATT* (39%). The increase in percentages of girls with *high* level of *ATT* between 1995 and 2003 was larger for girls from single-sex schools (from 24% in 1995 to 39% in 2003) than for girls from coed schools (from 22% in 1995 to 35% in 2003). Same caution, though, in the interpretation of these trends applies for girls as for boys. The next table summarizes the percentages of girls at each level of the *Attitudes toward Science* (*ATT*) index for New Zealand, for each type of school in all three TIMSS cycles.

[Insert Table 8 about here]

There was no significant difference between attitudes toward science of girls in single-sex and coed schools in TIMSS 1995 and 2003.

However, in TIMSS 1999, without any student adjustments, the predicted probability of *low* and *medium ATT* was higher in coed schools than in single-sex schools and the difference was **statistically significant** ($p = 0.03$, $d = 0.76$). As explained above for boys, the model estimates that girls in coed schools were more likely to have lower attitudes toward science than their colleagues from single-sex schools. Even after adjusting for student covariates, predicted probability of *low* and *medium ATT* was still higher in coed schools than in single-sex schools, and the difference was **statistically significant** ($p = 0.01$, $d = 0.69$). The table below presents the estimated school-type differences in *ATT* for girls in New Zealand.

[Insert Table 9 about here]

Estimated School Differences in Hong Kong, SAR

In TIMSS 1995, Hong Kong has sampled two classes per school. Examining the dataset revealed that, in some schools, both classes were same-sex, while in others, one class was same-sex and the other was mixed. Some scholars suggest that the academic culture of schools where the entire building is same-sex (i.e. all-girls or all-boys schools) may be significantly different from that of schools where same-sex classes of both genders coexist in the same building (Riordan, 2002). Consequently, for TIMSS 1995, instead of two categories, the indicator of school type was coded with three categories: *Coed Schools, Single-Sex Schools* and *Single-Sex Classes in Coed Schools*.

Estimated School Differences in Science Achievement for Hong Kong's Boys

In Hong Kong, the mean science achievement of boys from single-sex schools was larger than the mean science achievement of boys from coed schools in TIMSS 1995 and 2003. The opposite was true for TIMSS 1999 though, when boys from coed schools outperformed boys in single-sex schools with 9 score points (coed: 540; single-sex: 531). The achievement of boys from both types of schools had constantly increased between TIMSS 1995 and 2003. In 19995, the mean science score for boys in single-sex classes housed in coed schools (500) was smaller than the achievement of boys from coed (508) and single-sex schools (520). The table below summarizes the mean science achievement scores and standard deviations for Hong Kong, SAR's boys, for each type of school in all three TIMSS administrations.

[Insert Table 10 about here]

In TIMSS 1995, boys in single-sex schools outperformed boys from coed schools, but the latter outperformed boys from single-sex classes housed in coed schools. None of the differences though were statistically significant at 0.05 level.

In Hong Kong in TIMSS 1999, as opposed to boys from New Zealand, boys from coed outperformed boys from single-sex schools, but the difference was not statistically significant at 0.05 level.

However, the analyses for TIMSS 2003 indicate very different results. Without adjusting for student and school covariates, the average difference between *SCI* of boys in single-sex and coed schools was 18 points in favor of single-sex schools and statistically significant (p = 0.05, d = 0.37). After adjusting for student covariates, on average, boys in single-sex schools outperformed those in coed schools by 17 points and the difference was still statistically significant (p = 0.05, d = 0.36). However, after adjusting for both student and school covariates, the average 11 points difference in *SCI* between school types was not statistically significant. The table below presents the results for science achievement differences between school-types Hong Kong's boys.

[Insert Table 11 about here]

Estimated School Differences in Attitudes toward Science for Hong Kong's Boys

Boys' attitudes toward science was constant between 1995 and 1999 but improved from 1999 to 2003 for both single-sex and coed schools. While the percentage of boys with *low* attitudes toward science decreased across TIMSS cycles, the majority of boys reported *medium* levels of *ATT* in 1995 and 1999. In 2003 though, the same percentages of boys reported *medium* and *high* levels of *ATT* in both types of schools. In both 1995 and 1999, slightly more boys from single-sex had *high* levels of *ATT* compared to boys in coed schools (27% from single-sex schools compared to 25% from coed schools in 1995 and 34% from single-sex schools in compared to 30% from coed schools in 1999). The percentages of boys from both type of schools reporting at the *high* level of *ATT* was almost the same though in 2003 (45%). The next table summarizes the percentages of boys at each level of the *ATT* index for Hong Kong, SAR, for each type of school in all three TIMSS administrations.

[Insert Table 12 about here]

As shown in the table below, there was no significant difference between the average attitudes toward science of boys in single-sex and coed schools in Hong Kong, SAR in any of the three TIMSS cycles included in this study. This result is not surprising since there were very small differences in the percentages of boys reporting at each level of the *ATT* index between schools.

[Insert Table 13 about here]

Estimated School Differences in Science Achievement for Hong Kong's Girls

In Hong Kong, mean science achievement of girls from single-sex schools was larger than the mean achievement of girls from coed schools, in all three TIMSS cycles. The achievement of girls from both types of schools had constantly increased between TIMSS 1995 and 2003. In 19995, the mean science scores for girls in single-sex classes housed in coed schools were smaller than the achievement of girls from coed and single-sex schools.

It is interesting to note that, in TIMSS 2003, girls in single-sex schools outperformed girls in coed schools by 43 score points. This is the largest score difference between school-types observed in the current study. The table below summarizes mean science achievement scores and standard deviations for Hong Kong, SAR's girls, for each type of school in all three TIMSS administrations.

[Insert Table 14 here]

In TIMSS 1995 and 1999, girls in single-sex schools outperformed girls from coed schools; the latter outperformed girls from single-sex classes housed in coed schools in TIMSS 1995. None of the differences were statistically significant at 0.05 level.

In TIMSS 2003, however, the results indicate a different picture on their science scores. Without adjusting for student and school covariates, on average, girls in single-sex schools outperformed girls in coed schools by 51 points and the difference was **statistically significant** ($p < 0.001$, $d = 1.06$). After adjusting for student covariates, the average difference in *SCI* between single-sex and coed schools was 49 points and **statistically significant** ($p < 0.001$, $d = 1.03$). These results indicate that in Hong Kong in TIMSS 2003, even when differences in background characteristics were accounted for, on average, girls in single-sex schools still significantly outperformed girls in coed schools.

Even after adjusting for both student and school covariates, on average, single-sex schools outperformed coed schools by 39 points and the difference was **statistically significant** ($p < 0.001$, $d = 0.8$). These results indicate that in Hong Kong in TIMSS 2003, even when differences in both student and school characteristics were accounted for, on average, girls in single-sex schools still significantly outperformed girls in coed schools. The table below presents the results for *SCI* analyses for Hong Kong's girls.

[Insert Table 15 here]

Estimated School Differences in Attitudes toward Science for Hong Kong's Girls

In Hong Kong, the percentages of girls reporting at each level of the *ATT* index were very similar for both school types in 1995 and 1999. In both years, the majority of girls from both types of schools reported at the *medium* level of the *ATT* index (coed: 70% in both years; single-sex: 73% in 1995, 67% in 1999). For coed schools, there was an increase in the number of girls that reported *high* level of *ATT* in 2003, but still more girls reported *medium* levels (59%) than *high* level (31%) of *ATT*. However, girls in single-sex schools had a big increase in their attitudes toward science between 1999 and 2003. While only 24% of girls from single-sex schools reported *a high* level of *ATT* in 1999, this percentage increased to 45% in TIMSS 2003.

As mentioned before, the trends in *ATT* across TIMSS cycles should be done with caution, since the questions used in the composition of the *Index of Attitudes toward Science* changed in 2003 compared to previous cycles. The next table summarizes the percentages of girls at each level of the *ATT* index for Hong Kong, SAR, for each type of school in all three TIMSS administrations.

[Insert Table 16 about here]

In Hong Kong, SAR, there was no statistically significant difference between the average attitudes toward science of girls in single-sex and coed schools in TIMSS 1995, although, on average, girls in coed schools had higher probabilities of *low* and *medium ATT* than those in single-sex schools.

However, the analyses for TIMSS 1999 and 2003 indicate very different results. In TIMSS 1999, without adjusting for any student covariates, the average predicted probability of *low* and *medium ATT* was higher in coed schools than in single-sex schools and the difference was **statistically significant** ($p = 0.01$, $d = 0.76$). Even after adjusting for student covariates, it was more likely for girls in coed schools to have *low* and *medium ATT* than for girls in single-sex schools and the difference was **statistically significant** ($p = 0.02$, $d = 0.51$).

Similar to 1999, in TIMSS 2003, without adjusting for any student covariates, the predicted probability of low and medium *ATT* was higher in coed schools than in single-sex schools and the difference was **statistically significant** ($p < 0.001$, $d = 1.23$). Even after adjusting for student covariates, girls in coeds schools had **significantly** higher predicted probabilities of low and medium *ATT* than girls in single-sex schools ($p < 0.001$, $d = 0.81$). These results indicate that in both 1999 and 2003, Hong Kong's girls with similar background characteristics were more likely to have positive *ATT* when enrolled in single-sex schools than in coed schools.

[Insert Table 17 about here]

Significance

Previous studies showed that single-sex education contributed to positive student attitudes towards science, especially in the case of girls, but the evidences are mixed with respect to science achievement. This paper compared both outcomes for boys and for girls from two countries, i.e. New Zealand and Hong Kong, in three consecutive TIMSS administrations, i.e. 1995, 1999, and 2003. Also, analyses of the effect of single-sex schooling on both science achievement and attitudes towards science were conducted in parallel. The study examined trends in the outcome differences between school-types when combinations of student and school predictors were included.

Within each country, no pattern was observed in the results from one TIMSS cycle to the next. However, similar patterns were observed in the results of the analyses for science achievement and attitudes toward science, confirming the observations noted in the science education literature. The effect of the schools' gender composition was very different for boys than for girls, confirming again the findings from the literature.

For boys from both countries, the single-sex school environment did not account for significant improvements in either science achievement or attitudes toward science. The initial advantage in science scores of boys in single-sex schools (i.e. in TIMSS 1995 in New Zealand, and TIMSS 2003 in Hong Kong) or in attitudes toward science (in TIMSS 1995 in New Zealand) was not statistically significant after adjusting for school characteristics. Hence, as noted in the literature, it seems that, in the case of boys, the benefit of single-sex education can be explained by the advantage in school resources rather than the gender composition of the school.

As opposed to boys, girls from both countries included in this study benefited more from single-sex education than coeducation. The evidences were stronger in TIMSS 2003 for Hong Kong's girls in single-sex schools; their advantage in science scores remained statistically significant ($p < 0.001$) even after accounting for differences in background and school characteristics. Also, girls from single-sex schools had more positive attitudes toward science than girls from coed schools in New Zealand in TIMSS 1999, and in Hong Kong in both 1999 and 2003 TIMSS administrations.

In conclusion, the results of this study confirmed the findings from the literature that single-sex education improved girls' attitudes toward science and possibly their science performance. The results of this study were inconclusive in the case of boys from both countries.

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Table 1:
Sequence of fitted models

Model	***Level 1- student:*** **predictor variables**	***Level 2- school:*** **predictor variables**
A	None	None
B	None	School type
C	Student characteristics (grand-mean centered)	School type
D	Student characteristics (grand-mean centered)	School type + other school characteristics

*Table **2**:*
Mean Science Scores (Standard Deviations) for New Zealand's Boys in TIMSS 1995, 1999, and 2003

TIMSS	**Coed Schools**	**Single-Sex schools**
	Mean (S.D.)	**Mean (S.D.)**
1995	491.29 (98.47)	536.62 (86.02)
1999	507.75 (95.17)	524.95 (96.45)
2003	520.25 (75.87)	538.81 (73.82)

*Table **3**:*
Estimated Average Differences between Mean Science Scores in Single-Sex and Coed Schools for New Zealand's Boys

TIMSS	**Model**	**γ_{01} Coefficient**	**SE**	***p***	**Effect size[a]**
1995	**B**	**38.32****	**13.83**	**0.01**	**0.67**
	C	**29.01****	**11.70**	**0.01**	**0.50**
	D	**22.17***	**13.35**	**0.09**	**0.39**
1999 Phase 1	**B**	18.74	18.26	0.31	0.33
	C	14.54	16.20	0.37	0.25
	D	7.36	15.60	0.64	0.13
1999 Phase 2	**B**	18.74	18.26	0.31	0.33
	C	11.76	15.18	0.44	0.21
	D	6.15	14.42	0.67	0.11
2003	**B**	10.16	11.47	0.38	0.20
	C	7.04	11.06	0.53	0.14
	D	-2.62	10.26	0.80	-0.05

Note: Effect-size computed as ratio of school-type coefficient to the standard deviation of the distribution of school mean (SD). [a]Unconditional Standard Deviations for *SCI*: SD=57.46 in 1995; SD= 57.17 in 1999; SD=51.53 in 2003. * p <0.05. **p <0.01. ***p<0.001.

Table ***4****:*
The Percentages of New Zealand's Boys at Each Level of the Index of Attitudes toward Science (ATT) in TIMSS 1995, 1999, and 2003

TIMSS	***ATT***	**Coed Schools**	**Single-Sex schools**
1995	Low	15%	11%
	Medium	57%	52%
	High	29%	37%
1999	Low	15%	12%
	Medium	57%	52%
	High	29%	36%
2003	Low	18%	18%
	Medium	41%	38%
	High	41%	44%

Table ***5***
Estimated Average Differences between Attitudes toward Science in Single-Sex and Coed Schools for New Zealand's Boys

TIMSS	**Model**	γ_{01} **Coefficient**	**SE**	***p***	**Effect size**[b]
1995	**B**	**-0.34****	**0.13**	**0.01**	**0.74**
	C	-0.06	0.12	0.56	0.13
1999	**B**	-0.12	0.26	0.65	0.22
	C	0.11	0.22	0.62	0.20
2003	**B**	0.09	0.13	0.48	0.18
	C	0.09	0.14	0.51	0.18

Note: Effect-size computed as ratio of school-type coefficient to the standard deviation of the distribution of school mean (SD). [a]Unconditional Standard Deviations for *ATT*: SD= 0.46 in 1995; SD= 0.54 in 1999; SD= 0.51 in 2003. **p <0.01.

*Table **6**:*
Mean Science Scores (Standard Deviations) for New Zealand's Girls in TIMSS 1995, 1999, and 2003

TIMSS	**Coed Schools**	**Single-Sex schools**
	Mean (S.D.)	**Mean (S.D.)**
1995	474.79 (89.77)	496.45 (80.74)
1999	493.42 (86.33)	532.02 (91.68)
2003	510.33 (74.54)	524.59 (66.15)

*Table **7**:*
Estimated Average Differences between Mean Science Scores in Single-Sex and Coed Schools for New Zealand's Girls

TIMSS	**Model**	**γ_{01} Coefficient**	**SE**	***p***	**Effect size[a]**
1995	**B**	12.81	13.87	0.36	0.24
	C	10.16	13.22	0.44	0.19
	D	8.67	16.22	0.59	0.17
1999 Phase 1	**B**	**46.50*** **	**14.88**	**<0.001**	**0.79**
	C	**34.46** **	**12.66**	**0.01**	**0.59**
	D	18.90	12.85	0.14	0.32
1999 Phase 2	**B**	**46.50*** **	**14.88**	**<0.001**	**0.79**
	C	**33.32** **	**11.97**	**0.01**	**0.57**
	D	16.54	11.59	0.16	0.28
2003	**B**	14.5	9.86	0.14	0.30
	C	12.89	9.42	0.17	0.27
	D	-1.27	8.90	0.89	-0.03

Note: Effect-size computed as ratio of school-type coefficient to the standard deviation of the distribution of school mean (SD). [a]Unconditional Standard Deviations for *SCI*: SD=52.52 in 1995; SD= 58.70 in 1999; SD=47.74 in 2003. * p <0.05. **p <0.01. ***p<0.001.

*Table **8**:*
The Percentages of New Zealand's Girls at Each Level of the Index of Attitudes toward Science (ATT) in TIMSS 1995, 1999, and 2003

TIMSS	*ATT*	Coed Schools	Single-Sex schools
1995	Low	19%	19%
	Medium	59%	58%
	High	22%	24%
1999	Low	20%	15%
	Medium	58%	57%
	High	22%	28%
2003	Low	22%	23%
	Medium	43%	28%
	High	35%	39%

Table 9:
Estimated Average Differences between Attitudes toward Science in Single-Sex and Coed Schools for New Zealand's Girls

TIMSS	Model	γ_{01} Coefficient	SE	*p*	Effect size[a]
1995	**B**	0.02	0.18	0.92	0.03
	C	0.17	0.16	0.28	0.26
1999	**B**	**-0.41***	**0.18**	**0.03**	**0.76**
	C	**-0.37***	**0.15**	**0.01**	**0.69**
2003	**B**	0.18	0.17	0.29	0.30
	C	0.11	0.14	0.44	0.18

Note: Effect-size computed as ratio of school-type coefficient to the standard deviation of the distribution of school mean (SD). [a]Unconditional Standard Deviations for *ATT*: SD=0.67 in 1995; SD= 0.54 in 1999; SD=0.61 in 2003.* $p < 0.05$.

Table 10:
Mean Science Scores (Standard Deviations) for Hong Kong's Boys in TIMSS 1995, 1999, and 2003

TIMSS	**Coed Schools**		**Single-Sex schools**		**Coed Schools with Single-Sex classes**	
	Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
1995	507.87	81.42	520.36	85.21	500.19	107.21
1999	540.16	68.69	530.79	84.19	-	-
2003	558.10	70.30	574.36	52.26	-	-

Table 11
Estimated Average Differences between Mean Science Scores in Single-Sex and Coed Schools for Hong Kong's Boys

TIMSS	**Model**	**γ_{01} Coefficient**	**SE**	***p***	**Effect Size[a]**
1995	**B**	5.10	28.51	0.86	0.09
		-19.92	25.54	0.44	0.34
	C	4.79	26.95	0.86	0.08
		-20.26	24.44	0.41	0.35
	D	2.42	21.14	0.91	0.04
		1.97	20.32	0.92	0.03
1999 Phase 1	**B**	-18.33	20.18	0.37	0.38
	C	-19.66	20.04	0.33	0.40
	D	-17.87	18.89	0.35	0.37
1999 Phase 2	**B**	-18.33	20.18	0.37	0.38
	C	-19.31	19.37	0.32	0.40
	D	-15.57	20.69	0.45	0.32
2003	**B**	**17.64***	**9.46**	**0.05**	**0.37**
	C	**17.35***	**9.79**	**0.05**	**0.36**
	D	11.33	8.70	0.20	0.24

Note: Effect-size computed as ratio of school-type coefficient to the standard deviation of the distribution of school means (SD). [a]Unconditional standard deviations for *SCI*: SD = 57.90 in 1995. SD= 48.71 in 1999. SD= 48.10 in 2003. *p<0.05.

Table 12:
The Percentages of Hong Kong's Boys at Each Level of the Index of Attitudes toward Science (ATT) in TIMSS 1995, 1999, and 2003

TIMSS	***ATT***	**Coed Schools**	**Single-Sex schools**	**Coed school w/Single-Sex class**
1995	Low	11%	12%	9%
	Medium	64%	61%	62%
	High	25%	27%	29%
1999	Low	7%	7%	
	Medium	63%	59%	
	High	30%	34%	
2003	Low	8%	8%	
	Medium	47%	47%	
	High	45%	45%	

Table 13:
Estimated Average Differences between Attitudes toward Science (ATT) in Single-Sex and Coed Schools for Hong Kong's Boys

TIMSS	**Model**	**γ_{01} Coefficient**	**SE**	***p***	**Effect Size[a]**
1995	**B**	0.05	0.24	0.85	0.10
		-0.13	0.19	0.51	0.25
	C	0.05	0.20	0.80	0.10
		-0.11	0.17	0.52	0.21
1999	**B**	-0.20	0.16	0.21	0.39
	C	-0.11	0.13	0.40	0.22
2003	**B**	0.05	0.12	0.67	0.12
	C	0.15	0.13	0.25	0.35

Note: Effect-size computed as ratio of school-type coefficient to the standard deviation of the distribution of school means (SD). [a]Unconditional Standard Deviations for *ATT*: SD = 0.52 in 1995; SD = 0.51 in 1999; SD = 0.43 in 2003.

Table 14:
Mean Science Scores (Standard Deviations) for Hong Kong's Girls in TIMSS 1995, 1999, and 2003

TIMSS	Coed Schools		Single-Sex schools		Coed school with Single-Sex class	
	Mean	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
1995	481.95	78.78	497.09	79.87	469.77	83.73
1999	520.46	62.17	528.51	67.67	-	-
2003	542.33	63.52	585.26	45.13	-	-

Table 15:
Estimated Average Differences between Mean Science Scores (SCI) in Single-Sex and Coed Schools for Hong Kong's Girls

TIMSS	Model	γ_{01} Coefficient	SE	*p*	Effect Size[a]
1995	B	1.05	27.78	0.97	0.02
		-11.38	21.95	0.61	0.23
	C	0.02	26.62	0.99	0.00
		-13.98	20.48	0.50	0.28
	D	16.71	31.72	0.60	0.33
		-1.68	-19.59	0.93	0.03
1999 Phase 1	B	13.77	10.64	0.20	0.29
	C	12.47	10.35	0.23	0.26
	D	9.22	11.90	0.44	0.19
1999 Phase 2	B	13.77	10.64	0.20	0.29
	C	12.23	9.99	0.22	0.26
	D	8.90	11.53	0.44	0.19
2003	B	**50.62*** **	**7.52**	**< 0.001**	**1.06**
	C	**48.99*** **	**7.35**	**< 0.001**	**1.03**
	D	**38.39*** **	**8.37**	**< 0.001**	**0.80**

Note: Effect-size computed as ratio of school-type coefficient to the standard deviation of the distribution of school mean (SD). [a]Unconditional Standard Deviations for *SCI*: SD=50.53 in 1995. SD=39.05 in 1999. SD=47.75 in 2003.***p<0.001.

Table 16:
The Percentages of Hong Kong's Girls at Each Level of the Index of Attitudes toward Science (ATT) in TIMSS 1995, 1999, and 2003

TIMSS	*ATT*	Coed Schools	Single-Sex schools	Coed school with Single-Sex class
1995	Low	16%	12%	14%
	Medium	70%	73%	70%
	High	14%	15%	16%
1999	Low	12%	9%	
	Medium	70%	67%	
	High	18%	24%	
2003	Low	10%	7%	
	Medium	59%	48%	
	High	31%	45%	

Table 17:
Estimated Average Differences between Attitudes toward Science (ATT) in Single-Sex and Coed Schools for Hong Kong's Girls

TIMSS	Model	γ_{01} Coefficient	SE	*p*	Effect Size[a]
1995	**B**	-0.33	0.22	0.14	0.70
		-0.21	0.19	0.27	0.45
	C	-0.31	0.25	0.21	0.66
		-0.22	0.21	0.30	0.47
1999	**B**	**-0.48***	**0.19**	**0.01**	**0.76**
	C	**-0.32***	**0.14**	**0.02**	**0.51**
2003	**B**	**-0.59*****	**0.15**	**<0.001**	**1.23**
	C	**-0.39****	**0.11**	**<0.001**	**0.81**

Note: Effect-size computed as ratio of school-type coefficient to the standard deviation of the distribution of school mean (SD); [a]Unconditional Standard Deviations for *ATT*: SD = 0.47 in 1995; SD = 0.63 in 1999; SD = 0.48 in 2003. * p<0.05. **p<0.01. ***p<0.001.