Multilevel Analysis of 2006 PISA Science Results for Taiwan: Effects of Background and Explanatory variables on Science Literacy at Student and School Levels

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Abstract

The PISA study offers an excellent opportunity to see more clearly what extent to each region or country is doing and where there might be room for improvement. Generally speaking, the students of 15-year-old in Taiwan are doing well in PISA 2006. In terms of quality and equity in the performance of students and schools, it is important to interpret the performance variation among schools jointly with the performance variation between students. Therefore, the purpose of this study is to examine to what extent Taiwan achieves in moderating the relationship between socio-economic background and student performance. Also, exploring what else factors can explain effectively the variation of students performance except for socio-economic background. To understand the quality and equity in science literacy for Taiwan students' performance, the study attempts to discover some explanatory variables which can mediate the impact of socio-economic status on students' performance in science.

Keywords: multilevel analysis, socio-economic status, PISA2006

Running head: MULTILEVEL ANALYSIS OF 2006 PISA DATA FOR TAIWAN

The PISA study offers an excellent opportunity to take a broad perspective—to stand on a higher evaluation—and to see more clearly what extent to each region or country is doing and where there might be room for improvement. What PISA measures is literacy, which is concerned with the capacity of students to infer from what they have learned, and to apply their knowledge in novel settings, and to analyze, reason, and communicate effectively as they inquire, solve and explain problems in a variety of situations. The attainment of literacy is a lifelong process. Although it is impossible to expect fifteen-year-old to have learned everything for future life, they should have established a substantial ground of knowledge to face real-life challenges of the future. Thus, PISA measures the ability of applying key concepts to complete tasks or exercises relating to real life rather than limiting to the understanding of subject-specific knowledge.

The focus of PISA 2006 is on students' competency in science. What PISA is measured in science literacy not only science knowledge and skills, but also students' attitudes towards science, the extent to which they realize the life opportunities, and the science learning opportunities and environments which their schools offer (OECD, 2007). PISA summarizes student performance on a science scale which is standardized to a mean of 500 and a standard deviation of 100. In addition, based on the scale, students are grouped into six proficiency levels, with Level 6 representing the highest scores and Level 1 the lowest scores. Students with a score below 334.9 are classified as below Level 1, with a score above 707.9 are classified as Level 6. On average across 57 regions or countries in PISA 2006, 9.0% of students reach Level 5 and 6, 19.3% of them at Level 1 and below Level 1.

Corresponding to the performance of other participated regions or countries, 14.6% of students in Taiwan reach Level 5 and 6, 11.6% at Level 1 and below Level 1. Generally speaking, the students of 15-year-old in Taiwan are doing well in PISA 2006. In terms of quality and equity in the performance of students and schools, it is important to interpret the performance variation among schools jointly with the performance variation between students. The total variance between schools accounts for 46.2% of the total variance in Taiwan. It indicates a little greater variation among students within schools and less variation in the mean performance of different schools. Comparing to the OECD average, 33.0%, the variance between schools in Taiwan is considerable.

An equitable distribution of learning outcomes together with high performance standards is a real challenge to most countries. Most we could find out is an inequitable distribution of learning outcomes among students accompanying with unrighteous socio-economic context though Coleman et al.'s (1966) study and White's (1982) review showed that as students become older, the correlation between socio-economic status (SES) and school achievement diminished. However, analyses at primary and middle school levels have showed that students whose parents have low incomes and less education, or are unemployed or have low-prestige occupations, are less likely to do well in academic than students growing up in advantaged socio-economic conditions (Datcher, 1982; Finn & Rock, 1997; Johnson et al., 2001; Voelkl, 1995). Recently, Sirin' (2005) review suggested that the relationship between SES and academic achievement increases across various levels of schooling, with the exception of the high school samples which average SES was similar to that of elementary samples. The overall trend was that the magnitude of the SES--academic achievement relationship increased significantly by each school level, starting from primary school and continuing to middle school. The greater the dependence of educational performance on socio-economic factors, the less efficiently the students' potential is utilized and the greater the inequality in educational opportunities. In other words, high performance standard for every child is just an expectation, which is specified in educational policy, but is almost impractical or unrealized.

The international evidence from PISA also supports this viewpoint. Students from more advantaged socio-economic backgrounds generally tend to have higher scores of PISA science literacy. However, the relationship between student performance and the PISA index of economic, social and cultural status (ESCS) is not definitive. An understanding of this relationship is important because it indicates how equitably the advantages of schooling are being shared by students from different socioeconomic backgrounds. It's a useful starting point for grasping the equity of educational opportunities and quality of schooling in Taiwan. Therefore, the purpose of this study is to examine to what extent Taiwan achieves in moderating the relationship between socio-economic background and student performance. Also, exploring what else factors can explain effectively the variation of students performance except for socio-economic background. To understand the quality and equity in science literacy for Taiwan students' performance, the study attempts to discover some explanatory variables which can mediate the impact of socio-economic status on students' performance in science.

Research Questions

- What is the impact of socio-economic background on science literacy? Prior researches suggest that socio-economic background has strong association with test performance.
- Which factors have an effect on science literacy? Two-level model with individual and school explanatory variables as predictors but without background variables will be estimated.
- To what extent do the explanatory variables can mediate the impact of socio-economic background on science literacy?

Firstly, a two-level model (Raudenbush & Bryk, 2002) with students nested within schools were estimated where science performance was regressed on student-level ESCS and aggregated school level ESCS as fixed predictors. Then, other background variables such gender and school size (SCHSIZE) were added into the model to examine whether the background variables are sufficiently to account for the performance gap. In terms of gender, the question was whether there is significant contribution of gender in the average score in Taiwan. According to the PISA 2006 report, science was the one where overall gender differences were smallest in the three main PISA domains. There was no significant difference in the average score for males and females in most participated countries. Similar results could be found for TIMSS 2003 8th grade in Taiwan. However, in the same survey, the average score of males for 4th grade was 7 points higher than that of females in Taiwan. Thus, there are suspicious circumstances about the gender gap in science performance.

If there are still some room for the performance gap, do any other explanatory variables contribute to explaining the performance gap? Thus, secondly, some specific explanatory variables are employed as predictors to explore which variables can mitigate the performance difference either between students or schools. For example, if gender and ESCS do not account for all the difference, is there an irreducible performance gap between private and public schools (SCHLTYPE)?

Finally, the study intends to investigate the roles that the explanatory variables play concerning the impact of background variables on student performance. A two-step procedure is proceeded. In the first step, the effects of the said explanatory variables at student and school levels are examined. Next, in the second step, only the significant variables in the first step are included in the model.

The PISA survey population is 15 years old individuals who were born in the same year and still at school. Choosing 15 year-old individuals at school is because it's the age near the end of compulsory education. In Taiwan, the compulsory education is from Grade 1 through Grade 9 as from 6 to 14 year-old. Accordingly, there are about one-third of 15-year-olds enrolled in junior high schools and two-third of those enrolled in senior high schools which are not compulsory education in Taiwan. Considering the situation, the data analyzed here is separated by the schooling system and is divided into two subgroups.

The Data

Science was the main domain in the PISA 2006 cycle which also surveyed Reading and Math literacy. Science literacy was the focus here and it was assessed in 2-hour rotated test design that included 7, 4, 2 clusters for Science, Math and Reading. Questionnaires were administered to students and school principals. The student questionnaire included questions on student characteristics, home background, student's perspective on various issues related to science, environmental issues, careers and science, learning time, and teaching and learning science. Scale scores were obtained as weighted likelihood estimates (WLE) from each student's answers to the student questionnaire. All questionnaire scales scores have an OECD average of 0 and standard deviation of 1. The Taiwan data could be obtained from the international PISA 2006 dataset provided by OECD. The main data was extracted from the student dataset, but school variables came from the school dataset. The main outcome variable was one of the five plausible values although the OECD provided five plausible value estimates for each student. Since the intention of this study was to display patterns between explanatory variables, using five plausible values adding work loading was unnecessary. The patterns they displayed should not differ greatly.

For convenience of analysis, only cases with full data on all the selected variables were retained. Actually, the missing rates for the selected variables were less than 0.5% for every variable. A listwise deletion of cases that at least had a missing value would have reduced the sample size by 3.18% only. Therefore, a listwise deletion procedure was employed. The final dataset was comprised of 8,535 cases from 231 schools, while the original dataset was comprised of 8,815 from 236.

Based on the findings from PISA 2006 report, several student and school-level background and explanatory variables were considered in order to examine their association with student performance and the impact which socio-economic background had on student performance. The between-school variance as percentages of total variances for all considered variables was examined first. Only the variable which percentage of between-school variance was over 5% was selected in this study. The variables were list on Table 1.

These selected variables were re-coded if necessary. For example, most of PISA countries had three types of school ownership-- private independent, private government-dependent, and public. However, there was no private government-dependent school in Taiwan. Thus, the variable of SCHLTYPE was recorded as 0 for private schools and 1 for public schools. The descriptive statistics for all variables were listed in Table 2.

The PISA ESCS summarized various aspects of socio-economic background, including the occupational status (HISEI) and level of education of the students' parents (PARED) and students' access to educational and cultural resources at home (HOMEPOS). Based on the PISA results report, ESCS could explain 12.5% of variance in Taiwan student performance, lower than the average (14.4%) of OECD countries. Although Taiwan student performance in science was above-average level and below-average impact of socio-economic background, the relationship between performance and socio-economic background was not statistically significantly different from the OECD average impact. To clarify the impact of socio-economic background on student performance in science, the following analysis took into account both the individual socio-economic background of students, and the socio-economic intake of the school, as measured by the school average of the ESCS (M_ESCS).

In PISA 2006, information about awareness of environmental issues was collected from students' responses on questionnaires. The issues were the consequences of clearing forests for other land use, acid rain, the increase of greenhouse gases in the atmosphere, nuclear waste, and use of genetically modified organisms. The average level of awareness varies significantly from issue to issue across countries. More than 80% students reported being aware of the first three issues and 50% more of students were aware of the last two issues in Taiwan. The results showed that males reported being more aware about environmental issues with effect size of 0.13. Actually, the index of awareness of environmental issues (ENVAWARE) had the strongest relationship (.393, p<.01) with science performance among the four student level explanatory variables, even stronger than the ECSC background variable (.331, p<.01).

School education is mainly a public enterprise. Across OECD countries, average 4% of 15-year-olds are enrolled in private schools. However, there are 35% of 15-year-olds students enrolled in private schools in Taiwan. Since a higher enrollment rate in private schools in Taiwan, is school ownership associated with students or schools performance? It is another concern in this study. The indicator of whether a school is public or private is used to examine if this indicator is a significant factor.

Aside from awareness of environmental issues, PISA 2006 also collected 15 year-olds' beliefs in their own ability to handle tasks effectively and overcome difficulties (self-efficacy) from student questionnaires. Self-efficacy might be considered as an outcome of schooling but it also had a key impact on motivation. The results of PISA 2006 showed that students' self-efficacy in science had a positive relationship with science performance in each participating country. Most of the participating countries showed no gender differences on the index of self-efficacy in science. Nevertheless, different from most of PISA 2006 countries, male students had higher levels of self-efficacy in science in Taiwan.

Except for the above factors, other school-level factors related to students' science performance were considered in this study, such as ability grouping, school activities to promote students' learning of science, teacher shortage, average number of students per teacher, quality of school educational resources. To examine the effects of the foregoing explanatory variables, a hierarchical linear model (HLM) was employed in two steps. First, the relationship between science performance and background variables was examined simultaneously at student and school levels. Then, the relationship between explanatory variables and science performance was estimated both before and after accounting for socio-economic variables at student and school levels in a combined multilevel model.

Principal Results from the Analysis

In the models for examining the impact of selected student and school-level variables on science performance, all slopes were fixed and only the intercept was randomized at both levels. All variables were centered on the grand mean. Since the slope was fixed, there is no difference for the estimated slope whether a variable is centered on the grand mean or not. However, the intercept should be interpreted as the science score for a student who has the country mean in all variables included in the model.

The impact of socio-economic background on student performance

- ESCS was significant in the analyses at both student and school levels for junior and senior high schools.
- Gender was significant at junior high school level, though not significant at senior high school level. When significant at junior high school level, male students performed better than female students.

Table 3 showed the differences in variance explanation between Model 0 (unconditional model) using no predictor and Model 1A using ESCS in secondary schools. Before discussing the impact of ESCS, it should be noted that the percentage of variance between schools in total variance which was often referred to as the intra-class correlation (ICC). According the PISA 2006 report, the ICC index of science literacy for Taiwan was 0.462 which meant differences in the performance of 15-year-olds between schools account for 46.2% of the total performance variance among students in Taiwan. Actually, Table 3 showed that the ICC indices for both schooling stages are .2485 and .6264 respectively. Since junior high schooling is compulsory education and senior high schooling is selective education in Taiwan, the result was exactly as expected. In other words, the between-school variance in senior high schools was larger than that in junior high schools.

Comparing the explained variance by ESCS showed that the pattern looked roughly similar to both schooling stages. There were almost no or only smaller percentage of variance explained by ESCS at student level (5.32% & 0.14%) but considerable quantities of variance explained by ESCS at school level (64.62% & 62.80%). Even though the ESCS had more impact on school-level, it still affected student individual performance significantly. The student-level score point difference associated with one unit of the student-level ESCS was 25 and 3 points deviated from the grand mean for respective schooling. The school-level score point difference associated with one unit of the school mean ESCS was 52 and 146 points for individual schooling. The large coefficient for the ESCS index implied that socio-economic factor affects variation within schools in junior high schools, while larger coefficient for the aggregated ESCS index (M_ESCS) indicated that school-level performance was in conjunction with the socio-economic status of schools. In Taiwan, junior high school education is compulsory education and students need to take the Basic Competence Test to be admitted into senior high schools. It implies that the socio-economic status of students within senior high schools is more homogeneous than that within junior high schools. Thus, the effects of aggregated ESCS index for school-level performance in junior high schools were inferior to those in senior high schools but ESCS did affect individual performance in junior high schools. In short, the ESCS index was a significant factor of student performance, as it always showed in literatures. It was noteworthy that the school variation explained by ESCS and M_ESCS was similar to both two schooling stages even though a higher explained school variation was expected in highly selective schooling system (Schulz, 2005).

In investigating the roles of GENDER and SCHSIZE variables with the impact of ESCS played on student performance, a two-level hierarchical linear model similar to the ESCS models for student performance was conducted. Table 4 showed the differences in variance explanation between Model 1A with the only predictor ESCS and Model 1B with extra predictors, GENDER & SCHSIZE. Comparing the explained variance by GENDER & SCHSIZE showed that the pattern looked quite different in the two schooling stages though variation in student performance within schools was larger than the variation between schools. It was of interest to note that GENDER difference did exist in junior high school rather than senior high school. As mentioned before, no significant difference in the average score for males and females was found in most participated countries. However, as for the junior high school in Taiwan, the coefficient of GENDER showed that male performance was 12 points higher than female performance as ESCS, M_ESCS and SCHSIZE in the model. In other words, the gender gap in science scores was not just related to socio-economic status, but also some other unobserved reasons. In fact, according to the study of Guiso et. al (2008), they suggested that the improvement in math performance was related to the improvement of the role of women in society. The gender gap in math disappeared in more gender-equal societies. The reason might not be suitable for science performance in Taiwan since the gender gap disappeared in senior high school. The outcome remains in doubt and is needed to study further. Both GENDER and SCHSIZE could mediate the variation within schools to 16.46% but helped little variation between schools. On the other hand, GENDER &

SCHSIZE both were ineffective predictors for senior high schools while the ESCS and M_ESCS were already in the model. It implied no significant discrepancy between males and females in science literacy. Contrary to TIMSS 2003 where gender difference was found in 4th grades rather than in 8th grades, the PISA 2006 discovered gender difference in junior high students but not in senior high students.

The effects of explanatory variables on student performance

- Not all of considered explanatory variables were significant at both school levels. Three variables from student-level and one variable from school-level were selected, simultaneously at both school levels.
- School ownership was significant but opposite effects at both school levels. When significant at junior high school level, the average score of private schools was higher. When significant at senior high school level, public schools perform better than private schools.

In exploring the effects of specific variables at the student and school level had on student performance, a two-step procedure similar to the ESCS models for student performance was conducted. In the first step, the effects of the explanatory variables at both levels listed above were examined and discussed. Then, in the second step, variables that showed no significant contribution to the regression were eliminated. Only the variables with statistical significance in the first step were included in the model to re-examine their effects on science literacy and kept in the following models.

Table 5 showed the differences in variance explanation between Model 0 and Model 2A using all considered explanatory variables and Model 2B only using significant explanatory variables. Not the same set of explanatory variables was significant for both schooling stages. As for junior high level, CULTPOSS, ENVAWARE, and SCIEEFF from student level, SCHTYPE, STRATIO, and SCIPROM from school-level were selected into later models. Comparing to Model 0, these six variables could reduce 20% of between-student variance within schools as well as 72% of between-school variance. On the other hand, all five variables from student level, and TCSHORT from school level were significant in senior high schooling. In order to realize the effect of school ownership, the variable of SCHTYPE was chosen even though it was statistical insignificance. The seven explanatory variables only reduced 10% of between-student variance within schools but 39% of between-school variance. It implied that the same set of considered variables had different effects on science literacy in both schooling stages.

As mentioned before, the enrollment rate of private schools in Taiwan was much higher than OECD countries. How did the financing of schools relate to school performance? Given the results of Model 2B, the performance of advantage of private schools was 19 score points in junior high schooling. Meanwhile, the comparatively large performance advantage of public senior high schools was 50 score points. What caused the reverse phenomenon was too complicate to answer. However, the Basic Competence Test (BCTEST) for junior high school students might be a major reason. Since senior high school is not compulsory but selective education through the BCTEST, some parents who are able to provide their children with financial support would send their children to private schools. Therefore, there are quite a few private junior high schools which focus on academic studies by giving students better chances to get into distinguished senior high schools which most of them are public. Considering the specific education condition in Taiwan, the opposite performance of private and public schools in both schooling stages was just as expected. One way to examine this was to see the mediating impact for differences in the socio-economic background of students and schools in the following analysis.

The mediating effects of explanatory variables on the impact of socio-economic status on student performance

- The individual ESCS index was insignificant at senior high school level when selected explanatory variables were entered into the model.
- The variable distinguishing between public and private schools, SCHTYPE, was insignificant at junior high school level but significant at senior high school level when the ESCS index and other selected explanatory variables were admitted into the model.

The last part in the analysis was to look at socio-economic background and explanatory factors jointly. This analysis allowed for realizing the extent to which explanatory variable had unique effect – an association with performance that was not explained only by other factors, including socio-economic background. The analysis was conducted in three steps. In the first step, the significant explanatory variables from student level were entered into the model while the ESCS background variables were already in. Then, the significant explanatory variables from school level were admitted into the foregoing model. Finally, only significant variables were retained in the final model. The relationship between these factors and science performance was estimated after accounting for socio-economic variables at student and/or school levels.

Table 6 showed the differences in variance explained by Model 3A, 3B, and 3C. As for junior high school level, only Model 3A and 3B were constructed. Clearly, the three student-level variables had effects on science learning before and after accounting for the socio-economic context. Nevertheless, the school-level variables had effects on science learning before accounting for the socio-economic contextual factors, but the effects were not longer statistically significant after accounting for the socio-economic context. To decide the final model, the principal means was the change in the Deviance between the two models. The significance of the individual regression coefficients served as a second check. Since the Deviance difference between the two models was 7.4611 with df of 3, it was not significant ($\chi^2_{.95(3)} = 7.815$). The individual regression coefficients for three school-level variables were insignificant either. Thus, Model 3A was the final model for junior high school.

The model 3A, which only included ESCS, GENDER, SCHSIZE background variables, as well as the student-level explanatory variables, explained 36.07% of the total performance variance. Of the 36.07% of explained variance, 16.39% occurred between students within schools, 19.68% occurred between schools. On the basis of Model 1B, it was easy to find that the three student-level explanatory variables only account for 2.17% of performance variation between schools. The socio-economic background variables explained uniquely 17.51% of performance variation at school level. Actually, comparing to the total performance variation between schools in Model 0, the percentage of performance variation between schools explained by Model 3A was 79.20%. The result showed that socio-economic background variables and some student-level variables had considerable effect on student performance.

Based on the Model 3A, GENDER was still a significant variable on science literacy but the effect of SCHTYPE was no longer statistically significant after accounting for other variables. That meant, on average male student was associated with a performance difference of 10 score points as well as no significant difference between public and private schools. It proved to make a non-significant contribution when some combination of ESCS and other variables were present and the public-private indicator ultimately dropped out completely. Regarding the cultural possessions at home (CULTPOSS), the index was derived from students' responses on if they had classic literature, books of poetry and works of art, dishwasher, VCD/DVD player, and other indicators of wealth at home. The higher values indicated higher levels of cultural possessions. Students with one unit higher on the index score 7 points higher on science literacy performance, all other things being equal. Regarding to the other two student-level explanatory variables, ENVAWARE and SCIEEFF, the relationships between the measures and student performance were definite. Each unit increased on the index of students awareness of environmental issues corresponded to a performance difference of 28 score points. An increase of one unit of self-efficacy in science represented a performance difference of at least 12 score points.

As for senior high school level, three models were constructed. Clearly, the five student-level variables had effects on science learning before and after accounting for the socio-economic context (see Model 2B and 3A). Although the teacher shortage variable—TCSHORT had effect on science learning before accounting for the socio-economic contextual factors (see Model 2B), the effect was no longer statistically significant after accounting for the socio-economic context (see Model 3B). Also, the effect of ESCS was not significant any more. Thus, both variables were removed from the regression model (see Model 3C). To decide if Model 3C was the final model, the principal means was the change in the Deviance was checked first. Since the Deviance difference between Model 3B and 3C was only 4.2394 with df of 2, which was insignificant ($\chi^2_{.95(2)} = 5.991$), plus the regression coefficient of TCSHORT was not significant, the Model 3C was better than Model 3B. Comparing Model 3C to Model 3A, the Deviance of Model 3C was smaller with the same degree of freedom and all coefficients were significant. It inferred that Model 3C was more appropriate for the explanation of student performance in Science.

Comparing to Model 0, the model 3C reduced 53.57% of the total performance variance. Of the 53.57% of explained variance, 3.79% resulted from the variation between students within schools, 49.77% resulted from the variation between schools. In other words, the aggregated ESCS index and these explanatory variables had a great contribution to the variation between schools even though most explanatory variables came from individual student. Given the results of Model 3C, it was interesting to note that the individual ESCS index wasn't included in the model but the aggregated mean of ESCS index within school. Though the model not including the ESCS index signaled that this factor did not affect student performance in science, larger coefficient of the aggregated ESCS index indicated that difference on the school-level estimate of ESCS leaded to quite different results on the mean of school performance as all other things were constant.

Different from junior high school, SCHTYPE was the only effective school-level explanatory variable. On average, the advantage of public schools was 49 score points in Taiwan as all other things are equal. Maybe there were many factors that affected school choice. However, the major factor that affected students' choice of senior high school was the BCTEST. The testing result decided the qualification for admission to each high school. In the event, the most quality students would be admitted into public schools which were known for their academic performance. Although a few private schools had enough prestige to shoot for quality students, they wouldn't be the first priority for most students, especially for those with excellent performance in the BCTEST. Therefore, the effect of SCHTYPE in senior high school was exactly as expected. It proved to make a significant contribution even though ESCS and other explanatory variables were present. The difference M_ESCS of public and private schools seemed insufficient to account for the difference in science literacy between these two types of school.

In addition, two extra student-level explanatory variables were included in Model 3C, SCSCIE and HEDRES. The measure of SCSCIE was about students their own academic abilities in science (the index of self-concept in science). The index of home educational resources (HEDRES) was derived from students' reports on the availability of some items in their home, like a dictionary, a computer, a desk, and so on. In contrast to other explanatory variables, the relationships between both variables and student performance were negative while other factors were already in the model. In fact, the relationship between each variable and student performance per se was positive. For the impact of M_ESCS and other explanatory variables, the association was none the less positive. According to Model 3C, the regression coefficient of SCSCIE indicated that one unit increase of the measures leaded to 4 score points lower on student performance in science. Meanwhile, every one unit increase on the index of home educational resources translated to a loss of 5 points on the PISA scale score after accounting for aggregated socio-economic differences and other explanatory variables.

Discussion and Conclusion

To know the differences in quality and equity in education, PISA data provide the needed information about the effects of ESCS on performance and describe the extent to which the characteristics of students and schools can mediate the impact of ESCS on student performance.

The analyses presented in this paper showed that the effects of socio-economic background measures on student performance were analogous across the two schooling stages. No fundamentally different conclusions about the relationship between ESCS and achievement would be derived. The results of our study illustrated that student performance in science were generally influenced by socio-economic background and other explanatory variables. Our research questions were mainly answered regarding the effects of awareness of environmental issues, cultural possessions, and science self-efficacy before and after accounting for the impact of socio-economic status on student performance in science. The higher the aggregated ESCS index was in school level, the higher the student performance of the school. The study didn't find any significant school-level variable after accounting for the impact of socio-economic factor. However, the indicator of distinguishing whether the school was public or private did show some effect in senior high school student performance. The study also found that male students performed better than female students in junior high school.

According to the final model, while the index of socio-economic status contributed significantly at student level and school level, some variables, gender, cultural possessions, awareness of environmental issues, and science self-efficacy were still effectively at student level in junior high school. Despite several variables contributing significantly at student level, the percentage of student-level variance explained was relatively small at about 22%, while that explained at school level was significant at about 79%. Since the variance between schools was little below 25% of the total variance, explaining 79% of 25% amount to explaining about 20% only of the total variance, similar to that explained at student level, 16%. At the same time, not only did the aggregated index of socio-economic status account for significantly at school level, but more variables from student level and whether the school was public or private also had significant contributions on student performance in science for senior high school. It was noteworthy that the percentage of student-level variance explained was only about 10% even though more student-level variables were admitted into the model, while that explained at school level was significant at about 79%. Since the variance between schools was little below 63% of the total variance, explaining 79% of 63% amounts to explaining about 50% of the total variance, much higher than that explained at student level, 4%. The results indicated that the pattern looked considerably dissimilar to both schooling stages.

Comparing the model estimates for science literacy, it appeared that the predictors tended to have somewhat similar effects on both schooling stages. For example, without considering the index of ESCS, awareness of environmental issues had the strongest correlation with science performance across both two schooling stages. Except for the index of ESCS, cultural possessions, awareness of environmental issues, and science self-efficacy all contributed to the variation of science performance. Beyond the similarity, there some discrepancy and issues could still be found and be studied. First, although the correlations between science self-concept, home educational resources and science literacy were positive, they changed to negative after ESCS and other specific variables were entered into the final model for senior high school. However, the effects of these two variables were not significant to explain the performance variation in senior high school. Since self-concept and self-efficacy are part of self-beliefs, their relationships with science performance need to be clarified. Second, the gender gap was pronounced in junior high schooling and females had lower performance than males but the gap disappeared in senior high schooling. Thus, what caused the gender gap is needed further study. Third, the student performance in senior high school was likely to be influenced by the indicator of school ownership and students' performance in public schools was superior to that in private schools. Except for the BCTEST, whether there are some unobserved reasons to cause this result should be explored.

Table 1

Background and Explanatory variables

Variable Name	Measure of ……
Student Level	
GENDER	
ESCS	Index of economic, social and cultural status
HISEI	Highest parental occupational status
PARED	Highest parental education in years
HOMEPOS	Index of home possessions (WLE)
CULTPOSS	Cultural possessions at home (WLE)
ENVAWARE	Awareness of environmental issues (WLE)
SCIEEFF	Science self-efficacy (WLE)
SCSCIE	Science self-concept (WLE)
HEDRES	Home educational resources (WLE)
School Level	
SCHSIZE	School size
SCHTYPE	School ownership (public vs. private)
PROPCERT	Proportion of certified teachers
STRATIO	Teacher-student ratio
TCSHORT	Teacher shortage (negative scale) PISA 2006 (WLE)
SCIPROM	School activities to promote the learning of science PISA 2006 (WLE)
SCMATEDU	Quality of educational resources PISA 2006 (WLE)

Table 2
Descriptive statistics for background and explanatory variables

	Grade 9 and below (N=2646)				Grade 10 and above (N=5889)			
Variable	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.
Gender	0.53	0.50	0	1	0.52	0.50	0.	1
ESCS	-0.24	0.79	-4.16	2.28	-0.22	0.80	-4.08	2.34
CULTPOSS	0.13	0.87	-1.37	1	0.17	0.87	-1.37	1
ENVAWARE	0.49	0.85	-3.44	3.01	0.53	0.85	-3.44	3.01
SCIEEFF	0.23	0.99	-3.77	3.22	0.24	0.99	-3.77	3.22
HEDRES	-0.51	0.86	-4.19	0.58	-0.41	0.86	-4.19	0.58
SCSCIE	-0.40	0.99	-2.36	2.24	-0.39	0.96	-2.36	2.24
SCHSIZE	2220.39	1317.16	152	5972	2356.36	1348.81	246	7727
SCHTYPE	0.69	0.46	0	1	0.52	0.50	0	1
PROPCERT	0.96	0.09	0.36	1	0.93	0.13	0.17	1
STRATIO	17.15	5066	4.18	36.43	17.77	6.23	3.73	37.5
TCSHORT	-0.32	1.28	-1.06	3.62	-0.48	1.01	-1.06	3.62
SCIPROM	1.25	0.63	-1.07	1.64	0.76	1.04	-2.27	1.64
SCMATEDU	0.61	1.28	-3.43	2.14	0.72	1.30	-3.43	2.14
PV1SCIE	534.70	88.24	226.07	788.16	549.85	92.23	204.44	808.40

Table 3
The impact of ESCS on science literacy

Grade	Variable	Model 0 (Unconditional)			Model 1A (ESCS + M_ESCS)		
	Fix Effect	Coefficient	SE	p	Coefficient	SE	p
Junior High	γ_{00}	503.1909	8.6903	.000	525.7952	4.3856	.000
	ESCS				25.4627	3.9414	.000
	M_ESCS				52.1996	9.7694	.000
Variance	Student Level	6418.9222	75.15%		6077.6718	89.00%	5.32%
Explained	School Level	2122.8995	24.85%		751.0310	11.00%	64.62%
	Total	8541.8217			6828.7028		
Senior High	γ_{00}	511.2017	11.5113	.000	542.1533	4.7839	.000
	ESCS				3.3506	1.6539	.042
	M_ESCS				146.2099	11.9062	.000
Variance	Student Level	3773.2628	37.36%		3767.8385	61.55%	0.14%
Explained	School Level	6327.8134	62.64%		2353.7051	38.45%	62.80%
	Total	10101.0762			6121.5436		

Table 4
GENDER and SCHSIZE with the impact of ESCS on science literacy

Grade	Variable	Model 1B (GENDER+SCHSIZE)		
	Fix Effect	Coefficient	SE	p
Junior High	γ_{00}	534.5168	3.0742	.000
	ESCS	25.4310	3.8280	.000
(Female=0)	GENDER	12.5877	3.9046	.002
	M_ESCS	32.3989	10.5568	.003
	SCHSIZE	0.0150	0.0040	.001
Variance Explained	Student Level	6032.4362	90.58%	0.74%
	School Level	627.3877	9.42%	16.46%
	Total	6659.8239		
Senior High	γ_{00}	540.6690	4.8333	.000
	ESCS	3.3543	1.6497	.042
(Female=0)	GENDER	0.3315	2.6894	.902
	M_ESCS	149.9395	11.9841	.000
	SCHSIZE	-0.0042	0.0044	.341
Variance Explained	Student Level	3767.8019	61.82%	0.00%
	School Level	2326.7664	38.18%	1.14%
	Total	6094.5683		

Table 5
Explanatory factors and student science performance

Grade	Variable	Model 2A			Model 2B		
	Fixed Effect	Coeff.	S.E.	P-value	Coeff.	S.E.	P-value
Junior High	γ_{00}	528.4611	2.7981	.000			
	CULTPOSS	10.6486	2.7097	.000	11.8086	2.9287	.000
	ENVAWARE	29.7408	3.2403	.000	29.4636	3.2961	.000
	SCIEEFF	13.8832	3.2910	.000	13.5061	2.9875	.000
	SCSCIE	-2.8166	2.9264	.336			
	HEDRES	3.2338	2.4227	.182			
(Private=0)	SCHTYPE	-22.1706	8.0429	.008	-19.0642	7.9124	.018
	PROPCERT	34.4855	25.9299	.187			
	STRATIO	2.4357	0.7912	.003	2.6254	0.9827	.009
	TCSHORT	3.6775	2.7277	.181			
	SCIPROM	16.4072	5.1897	.003	18.9639	5.3528	.001
	SCMATEDU	3.4069	208453	.235			
Variance	Student Level	5113.7586	90.65%	20.33%	5120.8901	89.88%	20.22%
explained	School Level	527.2719	9.35%	75.16%	576.3679	10.12%	72.85%
	Total	5641.0305			5697.2580		
Senior High	γ_{00}	523.4165	10.2560	.000	518.6917	8.5516	.000
	CULTPOSS	7.5280	1.7845	.000	7.5454	1.7623	.000
	ENVAWARE	17.0195	2.1166	.000	17.0497	2.1228	.000
	SCIEEFF	8.7569	1.5161	.000	8.7824	1.5242	.000
	SCSCIE	-3.9822	1.7415	.022	-3.9967	1.7491	.022
	HEDRES	-4.9722	1.8446	.007	-4.9955	1.8534	.007
(Private=0)	SCHTYPE	31.2259	19.0364	.103	50.2419	15.2128	.002
	PROPCERT	91.2120	56.1223	.106			
	STRATIO	0.5105	0.8437	.546			
	TCSHORT	-15.8154	6.5828	.018	-14.1451	6.8395	.040
	SCIPROM	11.7466	6.9229	.091			
	SCMATEDU	-5.6582	6.6016	.393			
Variance	Student Level	3390.1699	49.53%	10.15%	3390.2976	47.15%	10.15%
explained	School Level	3455.1894	50.47%	45.40%	3800.0038	52.85%	39.95%
	Total	6845.3593			7190.3014		

Table 6
All significant factors combined and student performance in science

Grade	Variable	Model 3A			Model 3B		
	Fixed	Coeff.	S.E.	P-value	Coeff.	S.E.	P-value
Junior High	γ_{00}	534.8337	2.6944	.000	534.5033	2.5933	.000
	ESCS	12.1341	3.5241	.001	12.1488	3.5160	.001
(Female=0)	GENDER	10.9557	3.7438	.004	10.6232	3.7432	.005
	M_ESCS	29.4637	9.9316	.004	22.1825	11.4758	.056
	SCHSIZE	0.01195	.0030	.000	0.0083	0.0031	.010
	CULTPOSS	7.7595	2.7428	.005	7.6993	2.7332	.005
	ENVAWARE	28.0360	3.2195	.000	28.2293	3.1972	.000
	SCIEEFF	12.8255	2.9251	.000	12.7158	2.9229	.000
(Private=0)	SCHTYPE				-1.1071	7.4451	.883
	STRATIO				1.0365	0.9584	.283
	SCIPROM				8.9492	5.9045	.133
Variance	Student Level	5018.8549	91.91%		5017.6844	92.71%	
explained	School Level	441.6260	8.09%		394.3331	7.29%	
	Total	5460.4808			5412.0175		
Senior High	γ_{00}	542.8982	4.2765	.000	541.4815	3.5436	.000
	ESCS	-2.5922	1.632	.113	-2.5694	1.6282	.114
	M_ESCS	132.1880	10.1724	.000	126.0511	11.5834	.000
	CULTPOSS	7.8428	1.8065	.000	7.9236	1.8226	.000
	ENVAWARE	17.0561	2.0954	.000	17.0756	2.1257	.000
	SCIEEFF	8.8893	1.5399	.000	8.8556	1.5192	.000
	SCSCIE	-4.0655	1.7568	.021	-4.0924	1.7476	.019
	HEDRES	-4.6380	1.9369	.017	-4.7373	1.9593	.016
(Private=0)	SCHTYPE				48.9859	9.1177	.000
	TCSHORT				-0.5750	3.7684	.879
Variance	Student Level	3388.0982	64.13%		3388.0251	72.37%	
explained	School Level	1894.8256	35.87%		1293.4258	27.63%	
	Total	5282.9238			4681.4509		

Table 6
(Continued)

Grade	Variable	Model 3C		
	Fixed	Coeff.	S.E.	P-value
Senior High	γ_{00}	541.4011	3.4198	.000
	M_ESCS	124.8797	9.8745	.000
	CULTPOSS	7.2628	1.7570	.000
	ENVAWARE	17.0564	2.1373	.000
	SCIEEFF	8.7891	1.5106	.000
	SCSCIE	-4.0982	1.7374	.018
	HEDRES	-5.2392	1.8757	.006
(Private=0)	SCHTYPE	49.4898	9.7950	.000
Variance explained	Student Level	3390.0667	72.28%	
	School Level	1300.1733	27.72%	
	Total	4690.2400		

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