Examining Factors Affecting Science Achievement of Hong Kong in PISA 2006 Using Hierarchical Linear Modeling

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This study uses hierarchical linear modeling to examine the influence of a range of factors on the science performances of Hong Kong students in PISA 2006. Hong Kong has been consistently ranked highly in international science assessments, such as Programme for International Student Assessment and Trends in International Mathematics and Science Study; therefore, an exploration of the factors that affect science performances of Hong Kong students can give a lens to examine how science education can be improved in Hong Kong and other countries. The analyses reveal that student backgrounds as male, at higher grade levels, and born in mainland (when in the same grade) are associated with better science performance. Among the attitudinal factors, enjoyment of science and self-efficacy in science play important roles in scientific achievements. Most of the parental factors, on the other hand, are not having significant impacts on achievement after student attitudes are taken into account, with only parents’ value of science having a small effect. School student intake is found to be a strong predictor of school average achievement, as well as a major mediator of the effects of school enrollment size and school socio-economic status. The findings differ from recently reported results, which suggested that school enrollment size was associated with achievement. This study also points out the problems of the use of science instruction time as a school-level variable to explain science achievement in Hong Kong.

Keywords: Attitudes toward science; PISA; Scientific literacy; Hierarchical linear modeling
Introduction

Programme for International Student Assessment (PISA) is a triennial international study organized by Organisation for Economic Co-operation and Development (OECD). It is one of the most influential large-scale research projects over the last decade with 57 countries and regions participating in PISA 2006, and 65 countries and regions participating in PISA 2009. Given its cyclical and global nature, PISA enables the policy-makers to monitor changes in student performance over time and to compare them with those of other countries. PISA assesses the basic knowledge and skills essential for participating in society among 15-year-old students, with a focus on reading, mathematics, and science.

Hong Kong first joined the PISA in 2002 (PISA 2000+) and had participated in all subsequent PISA assessments. Hong Kong consistently ranked highly in the assessment of scientific literacy and outperformed many of their Western counterparts, including Switzerland, France, Germany, and the USA. In PISA 2000, among the top 10, the performances of five countries/regions are not significantly different from that of Hong Kong, and other four countries/regions scored lower than Hong Kong significantly. In PISA 2003, among the top 10, the performances of eight countries/regions are not significantly different from that of Hong Kong, and one country scored lower than Hong Kong significantly. In PISA 2006, where scientific literacy was the major domain of assessment, Hong Kong ranks the second among the 57 participating countries/regions, with an average science score significantly higher than all other participating countries/regions except Finland. Given its good performance in PISA, Hong Kong’s education system is featured as one of the world’s top performing systems (McKinsey & Company, 2010). As a top performing region, the factors associated with the science performances of Hong Kong students would have important implications for science education in general and for Hong Kong in particular. This study seeks to re-examine a host of factors at student, parent, and school levels using hierarchical linear modeling (HLM) in order to give a more holistic picture to account for the science performances of Hong Kong students in PISA 2006.

Literature Review

PISA Performance of Hong Kong

Some studies have been undertaken to explore what contributes to Hong Kong’s success in PISA science. Ho (2010) studied the effects of parental involvement and investment on students’ scientific literacy performance in PISA 2006 using multilevel analysis. She found that ‘parental investment in cultural resources and parental involvement in terms of organizing science learning enrichment activities at an early age were found to be significantly associated with students’ scientific literacy performance’. Sun, Bradley, and Akers (2012), also using multilevel models, found that student performance in science in PISA 2006 significantly correlated with students’ sex (in favor of male), socio-economic status (SES), motivation, science self-efficacy, and parental view on science. Three school-level variables were also found associated
with performance: enrollment size, SES, and quantity of science instruction. Chiu and Ho (2006) studied one largely neglected school-level variable, school academic intake, which is the academic level of the secondary-one (Grade 7) students a school admits. They found that school academic intake is a strong predictor of science scores in PISA 2000+ and mediates the effect of school SES on performance. Using the data of PISA 2003, Pong (2009) looked into the effects of immigrant students from mainland China, which had made up a significant proportion of students in Hong Kong. Her study had corrected one mistaken interpretation of the data: immigrant students performed poorly as compared with native Hong Kong students. To the contrary, these immigrants perform even better than their native peers when the grade levels are controlled—a ‘redshirting’ effect.

These studies, however, are not without their limitations. The researchers often include in their models a limited number of variables that they are interested in, but neglect some other variables that may be important mediators of the associations. This renders the interpretations of the factors impacting Hong Kong students’ performance problematic, particularly when the researchers appear not having deep understanding of the Hong Kong’s education system. In the study by Sun et al. (2012), school enrollment size and quantity of instructional time are found positively associated with performance, which, however, is called into serious doubt in this study.

Scientific Literacy

Scientific literacy has been an overarching aim of science education for decades, representing a ‘broad and functional understanding of science for general education purposes and not preparation for specific scientific and technical careers’ (Deboer, 2000, p. 594). In Project 2061-Science for All Americans (AAAS, 1989), science literacy has been broadly defined as

the understandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on. It should equip them also to participate thoughtfully with fellow citizens in building and protecting a society that is open, decent, and vital.

As for the PISA study in 2006, scientific literacy is defined as an individual’s

(1) Scientific knowledge and the use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena, and draw evidence-based conclusions about science-related issues.

(2) Understanding of the characteristic features of science as a form of human knowledge and enquiry.

(3) Awareness of how science and technology shape our material, intellectual, and cultural environments.

(4) Willingness to engage in science-related issues and with the ideas of science, as a reflective citizen.

(OECD, 2006)
Attitudes Toward Science

PISA 2006 had put a great emphasis on the assessment of students’ attitudes toward science because it recognizes that in addition to achievement, an important educational outcome for today’s young people is an attitude that gives participation in science an important place both in their current life and their future (OECD, 2006). Only a few studies have been done on the role of attitudinal factors in couple with other school- and family-level factors on the PISA science performance of Hong Kong.

Attitudes toward science as a construct consist of a large number of sub-constructs. There are eight components of the affective domain in PISA 2006: general value of science, personal value of science, self-efficacy in science, self-concept in science, general interest in science, enjoyment of science, instrumental and future-oriented motivation. These sub-constructs can be further subdivided into two categories: attitudes toward science and attitudes toward doing school science (Osborne, Simon, & Collin, 2003). In the affective components of PISA 2006, all but general value of science are about attitudes toward learning science at school.

Among the various sub-constructs of attitudes toward science, enjoyment of science was found central in connecting achievement, value, and interest (Ainley & Ainley, 2011). Enjoyment and interest are closely related but complementary constructs: enjoyment is more about the playfulness of science learning, while interest concerns more about continued motivation in scientific inquiry (Fredrickson, 2001). In PISA 2006, interest in science is assessed in two ways: general interest in a range of science disciplines (biology, physics, etc.), and embedded interest that students want to know more about the topics related to the items students have just worked with. Embedded interest tends to be transient as it is stimulated by context, whereas general interest is more individual and stable (Ainley & Ainley, 2011). Therefore, this study only looks into student’s general interest.

How students perceive the value of science is a construct different from other attitudinal constructs as measured in PISA 2006. It is students’ attitudes toward science per se while the others are all about attitudes toward science learning at school. Value of science is found to be a strong predictor of enjoyment and mediator of interest (Ainley & Ainley, 2011). This means that students who appreciate the value of science will be expected to develop interest in and enjoyment of science, showing overall positive attitude toward science.

Self-efficacy and self-concepts are two constructs measuring how students perceive their abilities in science learning in PISA 2006. The former is about students’ perceived abilities in tackling specific science topics, such as ‘role of antibiotics in the treatment of disease’, whereas the latter refers to students’ belief in their abilities in general science learning. Compared to self-concept, self-efficacy is more uniformly associated with performance (OECD, 2007a, pp. 135, 138). It is also interesting to note that most of the high-performing Asian countries/regions, including Hong Kong, have low scores in self-concept.
Parental Involvement and Investment

According to Coleman (1988), different types of capital or resource can be transferred from one generation to the next by family social capital, or parental involvement and investment. Previous studies have suggested that both parental involvement and investment have significant benefits in enhancing student achievement (Epstein, 1990; Ho, 2010; Ho & Willms, 1996). It is commonly believed that if parents invest their time and resources to help their child in study, such as helping their child to revise for tests and examinations, the child can get better results. Coleman (1987) noticed that some Asian families in America purchase two sets of textbooks, and one set was for the mother to enable her to better help the study of her child.

Parents in Hong Kong are more willing to participate at home than in school (Ho, 2010). In addition to providing educational and cultural resources at home, they may communicate more with their child about school matters, and arrange academic-related activities for their child. However, based on the findings of previous studies (e.g. Chiu & Ho, 2006; Ho, 2010), it is not conclusive as to which types of parental investment and involvement have significant effect on children’s learning.

Based on the review of literature, this study seeks to re-examine a wider range of school, student, and parental factors on their impacts on the scientific literacy performance of Hong Kong students in PISA 2006. The factors include not only those that have been found significantly associated with performance in previous studies, such as science self-efficacy and school enrollment size, but also some neglected but potentially important factors, such as school academic intake, and attitudinal measures, such as general interest in learning science, enjoyment in science, and general value of science. Using HLM, the relative importance of these factors on performance can be revealed after controlling for other factors.

Methods

Sample

The study data were obtained from the PISA 2006 Hong Kong data set. Schools were first stratified based on the following criteria: type of school (government, aided, and independent/private) and student academic intake (high, medium, and low bands). The stratified sampling method ensures the appropriate proportion of each type of school in the sample, with 37% of students coming from the high-band school, 35% middle band, and 28% the lowest band. In each sampled school, about thirty-three 15-year-old students were randomly sampled, making up a total of 4,645 students from 146 schools. The grade-level distribution of the sampled students spanned from secondary 1 to secondary 5 (Grades 7–11), but most of the students (64%) were from secondary 4 (Grade 10). The sample comprised a nearly equal proportion of boys (49%) and girls (51%). As for the place of birth, the majority of the students (76%) are born in Hong Kong, but a substantial proportion is born in mainland China (22%).
Variables

The cognitive component of scientific literacy as measured in PISA 2006 is the dependent variable in this study and it is measured in two kinds of knowledge: knowledge of science and knowledge about science, and three competencies: explaining phenomena scientifically, identifying scientific issues, and using scientific evidence.

There were 108 cognitive items in forms of multiple-choice, short closed-constructed response, and open-constructed response formats of which 62 items and 46 items were used to assess knowledge of science and knowledge about science, respectively. As for the three competencies, 53 items were devoted for the assessment of explaining phenomena scientifically, and 24 items and 31 items for identifying scientific issues and using scientific evidence, respectively. Using one-parameter item response theory and plausible value methodology, five plausible values are generated for each student to represent their science performance. The reliability coefficient for the plausible value of science knowledge scale is 0.92 for Hong Kong, indicating a satisfactory reliability of the measure.

The independent variables included in these analyses are drawn from students (background and attitudinal factors), parents, and schools.

Student Background Variables

Student’ gender (being female) has been included in all multilevel models in the study, with negative values indicating lower scores for females. Student SES, defined as family economic, social, and cultural status (ESCS) in PISA, is calculated from the indices of parents’ occupational status, years of education completed, and home possessions (for details, refer to the ‘Technical report’ of PISA 2006). Immigration status is based on the place of birth of the student and three dummy variables are created: born in Hong Kong, born in mainland China, and born in other places. The grade level of students is also included in the analyses as it was found mediating other variables like immigration status (Pong, 2009).

Student Attitudinal Factors

Four attitudinal factors in the affective domain of scientific literacy in PISA 2006 were included in this study: students’ general value of science (five items, Cronbach’s alpha = 0.79), general interest in science (eight items, Cronbach’s alpha = 0.83), enjoyment of science (five items, Cronbach’s alpha = 0.91), and science self-efficacy (eight items, Cronbach’s alpha = 0.83). Students’ general value of science assesses the extent to which students value the contribution of science and technology for understanding the natural and constructed world and for the improvement of natural, technological, and social conditions of life. It is measured by items like ‘Science is valuable to society’. Interest in and enjoyment of science learning are quite similar, with the former asking students to rate the intensity of their interest in learning about a range of science topics areas, for example, physics, astronomy, and the biology of plants,
while enjoyment of science assesses the extent to which students like doing specific scientific tasks and is measured by items like ‘I generally have fun when I am learning science topics’. Students’ self-efficacy in science measures their confidence in tackling tasks, such as ‘Describe the role of antibiotics in the treatment of disease’. Self-concept should have been included in the study since it is the only attitudinal construct in which Hong Kong students are well below OECD average (OECD, 2007a). However, over 20% of the missed data on self-concept would make the interpretation of its effect problematic.

**Parental Factors**

According to Ho (2010), students’ scientific literacy performance is significantly associated with certain types of parental investment and involvement even after controlling background factors at both student and school levels. Four parental factors are used in this study. The first is parents’ Social and Cultural Communication (six items, Cronbach’s alpha = 0.83) with students at home. This variable is derived from the parents’ report on the frequency that they have dinner with their children and talk with their children on current affairs, books, films, television program, and school life. The second parental factor is the possession of Cultural Resources (three items, Cronbach’s alpha = 0.55), such as classical literature, books of poetry, and works of art. The third and fourth are, respectively, parents’ General Value of Science (five items, Cronbach’s alpha = 0.81) and the provision of Science Activities at the Age of Ten (five items, Cronbach’s alpha = 0.76) (for details, refer to the ‘Technical report’ of PISA 2006). The data on parental factors were derived from a parent questionnaire and that Hong Kong was one of 14 systems that administered a parent questionnaire.

**School-Level Variables**

School-level variables used in this study are school average SES, school size, and three dummy variables of school student academic intake. School average SES is obtained from the aggregation of student SES in the student level for each school. School student academic intake refers to the average achievement levels of the secondary-one students a school admits. The academic levels of primary students are determined by their school exam performances moderated by the territory-wide assessment. In the PISA assessments conducted in Hong Kong, schools were stratified as high, medium, and low based on the their student academic intake. In this study, three dummy variables are created for high, medium, and low academic intake in order to explore whether the positive associations of school size and school average SES with performance as found by Sun et al. (2012) are actually the effects of school student academic intake.

**Statistical Models and Analysis**

Because students are nested within the schools, we employed HLM (a two-level multilevel model) to examine the effects of student factors (attitudes in science) and
parental factors on the scientific literacy performance at both student and school levels in this study.

First, the null model of the HLM analysis is employed to partition the variance of scientific literacy into within- and between-school portions. Models 1–3 build on the null model by adding student background and school background variables at the student level. In Model 1, student SES, girl, student born in mainland China, and student born in other countries are added at the individual level, and school size and school average SES are added at the school level. In Model 2, two dummy variables, school medium student intake and school low student intake, are further added at the school level to find out the effect of school size and school average SES after controlling school student intake. Their effects are relative to school high student intake. In Model 3, grade is further controlled at the student level in order to explore the impact of immigrant status on students’ science performance. Then, Model 3 is extended to include the variables of student attitudinal factors (Model 4) or parental factor (Model 5) at the student level, respectively. Finally, a full model (Model 6) is constructed by including all the student and parental factors.

Results

Table 1 presents the descriptive statistics for the student factors, parental factors, and school factors. Some of these factors are the OECD questionnaire scale indices which are standardized with a mean of 0 and standard deviation of 1 for the combined student population of OECD countries. A negative value thus indicates that Hong Kong students responded less positively than the average response across OECD

<table>
<thead>
<tr>
<th>Variables</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Student background</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SES (or ESCS)</td>
<td>4,614</td>
<td>−.67</td>
<td>.92</td>
</tr>
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<td><strong>Student factors</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>General value of science</td>
<td>4,629</td>
<td>.54</td>
<td>1.01</td>
</tr>
<tr>
<td>Interest in science learning</td>
<td>4,626</td>
<td>.20</td>
<td>.97</td>
</tr>
<tr>
<td>Enjoyment of science</td>
<td>4,628</td>
<td>.37</td>
<td>.89</td>
</tr>
<tr>
<td>Science self-efficacy</td>
<td>4,629</td>
<td>.07</td>
<td>.94</td>
</tr>
<tr>
<td><strong>Parental factors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parent's general value of science</td>
<td>4,534</td>
<td>.07</td>
<td>.94</td>
</tr>
<tr>
<td>Social and cultural communication</td>
<td>4,573</td>
<td>.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Cultural possessions</td>
<td>4,628</td>
<td>−.30</td>
<td>.88</td>
</tr>
<tr>
<td>Science activities at age 10</td>
<td>4,523</td>
<td>.12</td>
<td>1.01</td>
</tr>
<tr>
<td><strong>School factors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School average SES</td>
<td>146</td>
<td>−.68</td>
<td>.48</td>
</tr>
<tr>
<td>School size</td>
<td>146</td>
<td>1,040</td>
<td>174</td>
</tr>
</tbody>
</table>

*OECD questionnaire scale indices which are standardized with a mean of 0 and standard deviation of 1 for the combined student population of OECD countries.
countries, and vice versa. Among all the student attitudinal factors, Hong Kong students are moderately or slightly above the OECD averages. As for the parental factors, parent general value of science and science activities at age 10 are slightly above the OECD averages, whereas cultural possessions is below the OECD average.

All these factors are then analyzed using HLM to explore their associations with scientific literacy performance in PISA 2006. The results are given in Table 2. Null models are first estimated to obtain the within- and between-school variances. The between-school variances are 36.6% for science test scores. It reflects that the level of segregation in terms of achievement among Hong Kong schools is quite high.

**Student Background Variables**

Results from all models show that gender has significant associations with science scores, with girls having 11–24 points lower than boys. In Models 4 and 6, the effect of gender is reduced by half when students’ attitudinal factors are taken into account. This suggests that a substantial part of the influence of gender on science test score is mediated by students’ attitudes toward science. Girls perform not so well as boys in science because they do not develop the interest, enjoyment, and self-efficacy in science learning as boys do. As seen in Model 5, where attitudinal factors are not included, the gender gap remains large even after controlling for the parental factors. The data seem not giving support to Sun and others’ (2012, pp. 2117) conjecture that the gender gap is caused by the lower investment and expectation of parents on girls.

As for the effect of student SES, it positively contributes to students’ science performance as shown in Model 1, but the effect is small, with only about seven point scores increase for one standard deviation higher in SES value. Besides, we found that its effect is no longer significant when grade level is controlled in Model 3. This suggests that grade level mediates the effect of SES on student science performance in that students with low SES tend to study at lower-grade levels, which in turn leads to their lower performance. Part of this effect may be a result of the ‘redshirting’ of the mainland immigrants as discussed below.

As shown in Model 2, students born in mainland China have significantly weaker science performance (about 12 points lower) than their native counterparts. Interestingly, the association becomes positive after grade level of students has been controlled in Model 3. This means that students born in mainland China on average have about 24 points higher than those born in Hong Kong when they are in the same grade level. This result supports Pong’s (2009) finding that, as a result of academic ‘redshirting’, immigrant students from mainland China in Hong Kong tend to study at lower-grade levels so that they appear to have weaker performance when compared with the same age native students who are studying at higher grade levels. The ‘redshirting’ effect, however, actually gives advantages rather than disadvantages to the immigrant students after the grade level is controlled.

The grade level of students is a strong predictor of performance, with about 38 points higher for an increase in one grade level as shown in Models 3–6. The effect
Table 2. Effects of factors on students’ science achievement in Hong Kong

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
<th>Model 5</th>
<th>Model 6</th>
</tr>
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<tr>
<td></td>
<td>Coeff.</td>
<td>S.E.</td>
<td>Coeff.</td>
<td>S.E.</td>
<td>Coeff.</td>
<td>S.E.</td>
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<tr>
<td>Intercept</td>
<td>544.55***</td>
<td>3.44</td>
<td>545.57***</td>
<td>2.28</td>
<td>545.92***</td>
<td>2.34</td>
</tr>
<tr>
<td><strong>Student level</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Student background</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Girl (relative to Boy)</td>
<td>−22.09***</td>
<td>2.46</td>
<td>−22.38***</td>
<td>2.41</td>
<td>−24.60***</td>
<td>2.26</td>
</tr>
<tr>
<td>SES</td>
<td>6.60**</td>
<td>1.72</td>
<td>6.61**</td>
<td>1.73</td>
<td>2.32</td>
<td>1.92</td>
</tr>
<tr>
<td>Born in mainland (relative to born in Hong Kong)</td>
<td>−12.45**</td>
<td>3.3</td>
<td>−12.12**</td>
<td>3.32</td>
<td>23.94***</td>
<td>3.93</td>
</tr>
<tr>
<td>Born in other countries (relative to born in Hong Kong)</td>
<td>−1.28</td>
<td>9.22</td>
<td>−0.16</td>
<td>9.23</td>
<td>4.12</td>
<td>8.71</td>
</tr>
<tr>
<td>Grade level</td>
<td>38.26***</td>
<td>2.29</td>
<td>38.89***</td>
<td>2.16</td>
<td>38.38***</td>
<td>2.13</td>
</tr>
<tr>
<td><strong>Student factors</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General value of science</td>
<td>4.60***</td>
<td>1.2</td>
<td></td>
<td></td>
<td>4.70**</td>
<td>1.65</td>
</tr>
<tr>
<td>Interest in science learning</td>
<td>4.68**</td>
<td>1.63</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Enjoyment of science</td>
<td>17.18***</td>
<td>1.6</td>
<td></td>
<td></td>
<td>16.42***</td>
<td>1.58</td>
</tr>
<tr>
<td>Science self-efficacy</td>
<td>12.57***</td>
<td>1.33</td>
<td></td>
<td></td>
<td>12.60***</td>
<td>1.33</td>
</tr>
<tr>
<td><strong>Parental factors</strong></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parent’s general value of science</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10.70***</td>
<td>1.23</td>
</tr>
<tr>
<td>Social and cultural communication</td>
<td>−0.03</td>
<td>1.35</td>
<td>−1.23</td>
<td>1.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cultural possession</td>
<td>1.24</td>
<td>1.68</td>
<td>−2.09</td>
<td>1.5</td>
<td></td>
<td></td>
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</tbody>
</table>
### Examining Factors Affecting Science

<table>
<thead>
<tr>
<th></th>
<th>Science activities at age 10</th>
<th><strong>6.63</strong>*</th>
<th><strong>1.47</strong></th>
<th><strong>0.65</strong></th>
<th><strong>1.49</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>School level</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School average SES</td>
<td>53.75***</td>
<td>7.46</td>
<td>4.46</td>
<td>5.68</td>
<td>8.1</td>
</tr>
<tr>
<td>School size</td>
<td>.121***</td>
<td>0.022</td>
<td>.044*</td>
<td>0.017</td>
<td>.047**</td>
</tr>
<tr>
<td>School student intake (low)</td>
<td>-105.67***</td>
<td>6.89</td>
<td>-99.01***</td>
<td>6.9</td>
<td>-91.40***</td>
</tr>
<tr>
<td>Between-school variance explained (%)</td>
<td>56.1</td>
<td>84</td>
<td>83</td>
<td>84.1</td>
<td>83.4</td>
</tr>
<tr>
<td>Within-school variance explained (%)</td>
<td>3.2</td>
<td>3.2</td>
<td>14.3</td>
<td>28.9</td>
<td>17.4</td>
</tr>
<tr>
<td>Total variance explained (%)</td>
<td>22.6</td>
<td>32.8</td>
<td>39.4</td>
<td>49.1</td>
<td>41.6</td>
</tr>
</tbody>
</table>

*p < 0.05.

**p < 0.01.

***p < 0.001
persists after controlling for all other student, parental, and school variables. In the Hong Kong sample in PISA 2006, 64% of the students are Grade 10 while only 24% are of Grade 9. The high proportion of Grade 10 students likely contributes significantly to the overall performance of Hong Kong.

Student Attitudinal Factors

The results in Model 4 show that all four variables measuring students’ attitude and interest in science are significant predictors of science achievement even after controlling for all the student background and school variables. The impact of enjoyment and self-efficacy on achievement is much stronger than that of value and interest. An increase in one unit of the index of enjoyment and self-efficacy is associated with about 17 and 13 points increase in science scores, respectively. Interest in science should be closely related to enjoyment of science and the discrepancy of their impacts on performance may lie in the ways in which they are measured. Items measuring enjoyment of science ask students to express their degree of enjoyment toward science learning in general, whereas items measuring interest in science ask students to express their degree of interest in specific science disciplines, such as biology and physics. A student having high general enjoyment may make reference to the science learning experiences they enjoy the most (e.g. biology), but may not necessarily be interested in other science disciplines, such as physics (Krapp & Prenzel, 2011), which leads to the discrepancy of these two constructs.

Parental Factors

As shown in Model 5, two parental factors are found significantly associated with science performance: parents’ general value of science and provision of science activities for students at the age of 10. Parents’ general value of science is a strong predictor of achievement, with an increase in one unit associated with about 11 points increase in score. However, as shown in Model 6, the effect of it is reduced by about 50% after students’ attitudinal factors are controlled, and the effect of science activities at age 10 even becomes insignificant. It indicates that the effects of parents’ general value in science and science activities at age 10 are largely mediated by students’ attitudes toward science. Parents who have higher value of science and provide more science activities to their children tend to make their children more interested in science, which in turn leads to better science performance.

School Factors

As shown in Model 1, school average SES and enrollment size have significant positive effects on students’ science performance. Students’ scores increase by about 54 points for every unit increase in school average SES and about 12 points for every 100 more students enrolled. This is consistent with the findings of Sun et al. (2012) and Ho (2010). However, in Model 2, when the variables of school student academic
intake are included, the effect of school SES becomes insignificant and the effect of school enrollment size decreases by more than 60%. Instead, school student academic intake as a variable shows strong association with school average science achievements. Compared with students in ‘band 1 school’ (best student intake), students in ‘band 2 school’ (medium student intake)” score an average of 52 points lower and students in ‘band 3 school’ (lowest student intake) an average of 106 points lower. The results are consistent with Chiu and Ho’s (2006) findings but contradictory to Sun et al.’s (2012). The results evidently show that it is mainly the academic abilities of the secondary one students admitted by a school that affects the school’s average science achievement, rather than the school enrollment size and average student SES. The relationships among school student intake, enrollment size, and average SES are discussed further in the section ‘Discussion and Conclusion’.

Variance Explained in Scientific Literacy Performance

In Hong Kong, the between-school variance accounts for 36.4% of the differences in cognitive achievement in science. For the final model or Model 6, the within-school variance and between-school variance explained are 29.5% and 84.1%, respectively. The total variance explained is 49.5%.

Discussion and Conclusion

Through HLM analyses of a range of factors at student, parent, and school levels, this study has delineated the most important factors impacting the science performances of Hong Kong students in PISA 2006. Students being male, at higher grade levels, and born in mainland (in the same grade) are the background variables that associate with better performance. Among the attitudinal factors, enjoyment of science and self-efficacy in science play important roles in scientific achievements. Most of the parental factors, on the other hand, are not having significant impacts on achievement after student attitudes are taken into account, with only parents’ value of science having a small effect. School student academic intake is found to be a strong predictor of a school’s average science achievement, as well as major mediators of the apparent effects of school enrollment size and school SES.

This study shows that boys in Hong Kong significantly outperformed girls in science achievement, which is partly mediated by the enjoyment and self-efficacy in science learning, but relatively free from the influence of parental factors. Hong Kong is among a few countries in PISA 2006 that have significant gender gaps across all eight affective scales, with a medium effect size in self-concept, enjoyment, and future motivation (OECD, 2007b, pp. 90–91). The gender gaps in Hong Kong, both cognitive and affective, should not be oversimplified as a result of the male-dominated Chinese culture, as Sun et al. (2012) suggest. Some Western countries such as the UK, Luxembourg, Denmark, and Austria have even wider gender gaps in favor of male in PISA 2006 (Ho, 2008, p. 24). After all, Hong Kong is an international city ruled by British for over 100 years, where the influence of traditional Chinese
culture may not be as profound as people generally think. The cause of the gender gap would likely be multiple at social, school, family, and classroom levels. According to the findings of this study, improving girls’ enjoyment of and self-concept in science learning would be the key to narrowing down the gap, which can be done through addressing the differential treatments of boys and girls during science instruction (Jones & Wheatley, 1990).

The attitudinal factors play central role in students’ science achievement. All four attitudinal factors in this study are significantly associated with achievement, with enjoyment of science and self-efficacy in science being the strongest. Similar findings were obtained in the non-immigrant students of Canada (Areepattamannil & Kaur, 2013). Controlling for attitudinal factors reduces the effects of many other variables: gender, parental involvement, and school student intake (low), showing that these attitudinal factors are key mediators for these variables. The relationships between these factors are worth further exploring using the path analysis.

Hong Kong, together with Korea, Japan, and Taiwan, are high-performing Asian countries/regions with low self-efficacy/self-concept in science learning, as shown in PISA 2006. This phenomenon may be explained partly by the Asian cultures that emphasize modesty, but the sense of failure caused by the highly competitive exam cultures in these regions is likely one of the main causes. This can be supported by the observation that Hong Kong students had one score particularly well below the OECD average (38 against 65) in the measure of self-concept—‘I can usually give good answers to test questions on school science topics’. Despite the relatively low self-concept/self-efficacy, the results of this study and others indicate that these attitudinal factors are significantly associated with the science performances of Hong Kong students. Attitudes toward science and science achievement likely affect each other reciprocally (OECD, 2007a, p. 137), so making students enjoy and feel confident about science learning would be one important way to further enhance the science performance of Hong Kong. Nonetheless, how to strike a balance between the enjoyment of science learning and the positive effects of testing would need more empirical study grounded in specific context.

The parental involvement seems not having a large impact on science achievement, only parents’ value of science and science activities at age 10 having significant positive effects. The results are generally consistent with that of Ho (2010) except cultural resources at home. Ho found cultural resources significantly associated with achievement, but its small effect is likely to be absorbed after student attitudes have been controlled in this study. Parent’s general value of science likely affects students’ science achievement through influencing students’ attitudes toward science. This transmission of the value of science from parent to student may occur in the early ages of students well before secondary school, as shown in the positive influence of science activities at age 10 on science performance at age 15.

In this study, the average academic levels of school student intake is found to be an important variable associated with school SES, school enrollment size, and student’s immigrant status. When the band into which the school falls is taken into account, the
effect of school SES becomes insignificant and the effect of school enrollment size becomes very small, while the effect of being born in mainland China is even reversed from negative to positive. To explain these, we have to first understand how students are admitted in secondary schools in Hong Kong.

In Hong Kong, all subsidized and government secondary schools have 70% of their places centrally allocated based on students’ academic ability and district (school net), while the remaining 30% are discretionary places allocated by school based commonly on students’ academic ability, sibling policy, and religions. The Direct Subsidy Scheme and international schools, which make up about 14% of secondary schools in Hong Kong, have 100% discretionary places. This admission system makes Hong Kong one of the countries/regions having the heaviest emphasis on students’ academic records for admission in PISA 2006 (OECD, 2007b, p. 161). Hong Kong secondary schools are thus heavily academically segregated, having about 36% of the difference in students’ science achievement explained by between-school variance in PISA 2006. The prestigious schools that admit academically strong students are highly welcomed by parents, making them able to enroll more students during the shrinkage of student population in recent years. On the other hand, lower band schools can only enroll fewer students, who are also more likely in lower SES and from mainland China. Although it may appear that school enrollment is positively correlated with science achievement (Sun et al., 2012), this association may be spurious. When school student intake is controlled, the association disappears. A similar study of Canadian non-immigrant students also suggested positive effects of school size (Areepattamannil & Kaur, 2013) but it would need an examination of its school admission system before a conclusion is derived.

Quantity of instruction is one school variable used by Sun et al. (2012), which was found positively correlated with science scores. Apparently, it makes perfect sense that more instruction leads to better performance, but a closer look at the variable of quantity of instruction would find this conclusion problematic. The quantity of science instruction of a school is constructed from aggregation of the time each student reports they spent per week studying science at the regular lessons in the testing school year. Aggregation of the student science lesson time into a school-level science lesson time is problematic when looking into the situation of Hong Kong schools. In 2006, while Grades 7–9 students in Hong Kong have similar amount of compulsory science lessons in a school, Grade 10 students are allocated either into science stream class (typically six or more hours of science lesson per week) or non-science stream class (zero hour per week). The proportion of students in science stream and non-science stream classes varies across schools, but high-band schools tend to have more Grade 10 classes and more science students. Therefore, the overall science instruction time of a school reflects to some extent the proportion of science and non-science Grade 10 students sampled in a school, rather than the actual science instruction time each student receives. Three Hong Kong schools participating in PISA 2006 are used here to illustrate this problem (Table 3). The student sample of school A consists of a high percentage of Grade 10 students in which there is also a high percentage of science students. As a result, school A has the highest average
science instruction time among the three schools. At the same time, school A also has better science achievement due to its greater proportions of Grade 10 students and Grade 10 science students, who definitely perform better than their non-science or lower-grade peers (Pong, 2009). A mean comparison of the Grade 10 science and non-science students in Hong Kong shows a difference of 55 scores in PISA 2006. As a result, there appears positive association between science instruction time and achievement in science. It is thus incorrect to aggregate student science lesson time into a school variable and based on it to claim that the ‘instruction quantity positively influences student learning in science’ (Sun et al., 2012, p. 2118).

**Limitations and Future Directions**

One limitation of the current study is that using HLM to find out the effects of student and parental factors on science test score would only give correlational conclusions. In order to know more about the causal relationship of the variables, e.g. whether the parental general value of science is mediated by students’ general value of science, or whether the effect of science activities at age 10 is mediated by interest in learning science or enjoyment of science, multilevel path analysis (Mplus) should be done.

More variables of student, parental, and school factors can be included in future study to develop a fuller understanding of the factors contributing to achievement. However, there are problems of missing data for some variables, such as science self-concept and instrumental motivation in science. Because more than 20% of data of these variables are missing and imputation of missing data was not done in this study, these variables could not be included in the HLM.

Although Hong Kong students did very well in the PISA science test, this may have come at the expense of other aspects of student development, for instance, their enjoyment and interest in learning (Ho, 2000). Further study can be done to investigate the relationships between the cognitive and non-cognitive outcomes of science learning. On the other hand, medium of instruction is found as an important factor affecting self-concept in science learning in Hong Kong (Yip & Tsang, 2007). Under the current language policies, a significant part of science lesson time has been devoted

<table>
<thead>
<tr>
<th>School</th>
<th>School average science achievement</th>
<th>% of Grade 10 students</th>
<th>% of Grade 10 science students</th>
<th>% of Grade 10 non-science students</th>
</tr>
</thead>
<tbody>
<tr>
<td>School A (a ‘Band 1’ school)</td>
<td>644</td>
<td>78.5</td>
<td>57.1</td>
<td>21.4</td>
</tr>
<tr>
<td>School B (a ‘Band 2’ school)</td>
<td>527</td>
<td>64.7</td>
<td>38.2</td>
<td>26.5</td>
</tr>
<tr>
<td>School C (a ‘Band 3’ school)</td>
<td>479</td>
<td>62.5</td>
<td>34.4</td>
<td>28.1</td>
</tr>
</tbody>
</table>
to preparing student to learn science in English at higher grades, which would adversely affect both the affective and cognitive learning of science.

References


