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Research

Achievement and Science Motivation of High-Ability Chinese students in Singapore during the Primary-Secondary School Transition

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Abstract

This study investigates the relations between students' achievements and their motivation towards physics before and after transition from primary to secondary school. Using a sample of Secondary 1 (Grade 7) students in Singapore (N = 272), confirmatory factor analysis was conducted on survey responses to: self-concept, self-efficacy, interest, inquiry, engagement, and educational aspiration, about learning science, particularly in the physics branch. Achievement scores in science, English, and math used in the analysis included the Primary School Leaving Examination (PSLE) scores in Grade 6, first-term test scores and mid-year examination scores in Grade 7. Achievements in PSLE were found to be weakly correlated with the physics attitude factors. Grade 7 math and physics test scores had significant relations with physics motivation, and such relations tended to grow stronger over time. Math achievement also had significant relations with physics motivation, which also tended to grow stronger over time. The results imply that students who did not do well in science in primary school (PSLE) could cultivate positive attitudes towards physics in secondary school, given proper instruction in the curriculum domains. The first secondary school year is therefore a critical time to have a curriculum that can enhance positive attitudes towards physics, which may also subsequently lead to better achievements.

Introduction

The relation between student achievement and motivation has been of interest to many researchers in education and psychology. Much research has been done on students' achievements and motivational attitudes such as self-concept and engagement towards school as well as in several curriculum domains like language, mathematics, and science [1,2,3,4,5,6,7,8,9,9,10,11,12]. While some researchers have found that achievement and motivational attitudes are significantly correlated (e.g., Kadir et al., 2017; [6,7,13,11], others have suggested that they are weakly correlated or not correlated at all [e.g. 2]. These conflicting findings showed that the relations between achievements and motivational attitudes are inconclusive. In this study, we investigated the relations between different types of achievement and students' motivational attitudes towards science in a range of motivational aspects during students' transition between primary and secondary school. We hypothesize that students' science achievement in the first year of secondary school is more highly correlated to their science motivation in secondary school than the science achievement at the end of their primary school year.

There has been much discussion about researchers' measurements of achievements and motivational attitudes. The relation between achievement and motivational attitudes depends on the types of test scores used as achievement indicators [14]. For example Marsh and Yeung (1998), found that self-concept and motivational attitude measures related more strongly to achievement in the form of school grades than to standardized tests. According to Abu-Hilal (2000), some researchers have dealt with items that do not measure motivational attitudes effectively, resulting in varying findings. In our study, we measured student achievement during the primary-secondary school transition by using the results of a national examination taken by students at the end of their primary school year (i.e., Grade 6) and the results of their school grades taken at two time points during the first five months of their secondary school year (i.e., Grade 7), in three curriculum domains:

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science, English and math. In Singapore, these are the norms when measuring achievement during primary-secondary school transition. We measured attitudes towards science in six motivational factors - self-concept, self-efficacy, interest, inquiry, engagement, and educational aspiration – as these were the factors targeted by the school during the period of our study.

In the area of science, Willson (1983) did a meta-analysis of 43 studies and found that while most studies reported positive correlations between attitude to, and achievement in, science, 75% of the correlation coefficients analyzed were less than .30 in magnitude. In his study, he found that at elementary levels, correlations were generally quite low until Grade 6. The low correlations suggest that there is little relation between science attitudes and achievement. By Grade 6, motivational attitudes of students tend to be more clearly established, as children who like science do better in it and have more positive attitudes towards it. Willson's study showed a consistent .2-.3 correlation between achievement and attitude scores in grades 6 to 10. At Grade 12, the correlation drops to .04. His study showed that students, after a certain grade, have more or less developed their attitudes, and achievement is less likely to influence their motivational attitudes towards science.

Willson's findings have sparked our inquisitiveness to find out how young students in Singapore of this generation would fare in the achievement-attitude correlation coefficients. Even though there have been studies of achievement-attitude correlations in the science domain, not much has been done to study achievement-attitude relations in physics – an area of science that many students find challenging. The results would provide a better understanding of the relations between students' achievement in three curriculum domains during the primary and secondary school transition, and their relations with motivational attitudes in physics at Grade 7. The findings would enable educators to optimize self-concept and attitude enhancement effects from a multidimensional perspective. Since we measured students' science attitudes using a range of motivational factors focusing on the physics branch of science, we will refer to students' science attitudes as motivation towards physics for the rest of the paper.

Significance of Motivation Towards Physics

The significance of investigating students' motivation towards the science curriculum probably stems from the increasing evidence of the rapid decline in students' aspirations in pursuing science-related higher education and careers, even for students who achieve well in science [15]. With less students pursuing higher studies related to science, there is a decline in scientific literacy in the general populace, as well as a shortage of science teachers [16], resulting in a vicious cycle generating greater problems such as threats to the health industry, national security and global competitiveness [15,17]. Physical science, or physics, seems to be the least appealing to students [18]. Osborne, Simon, and Collins (2003) suggested that physics is least popular most probably because "the relevance of the physical sciences was difficult for students to identify" (p. 1061). Students' poor attitudes towards physics have also been explained by the task difficulty associated with the subject [18]. Physics is notorious for being a difficult subject to learn where there is a need for a lot of effort to be expended, yet the resulting grades may not always be favorable [19,20]. Since past achievement has been shown to influence motivation when both achievement and motivational variables are measured within a specific domain [7,13], it is likely that because physics is challenging, and students' academic scores reflect this, that they have a poor attitude towards physics and are consequently less likely to choose to study the subject. In the study, we attempted to explicate whether this is true, using the achievements of a sample of high-ability students in Singapore.

Method

Participants

Secondary 1 students (Grade 7) from a secondary school in Singapore participated in this study (N = 272; median age = 13 years old; 40% boys). All the students were of Chinese ethnicity, which is the largest ethnic group of Singapore (>75%). Although the students were Chinese in origin, they were effectively bilingual and over 50% of them spoke mostly English at home. All government schools in Singapore uses English as the medium of instruction and all students start formal English lessons in pre-school. The students were selected for admission into the participating school by merit of their PSLE results, where only students with an aggregate score of about 240 (out of 300) and above would be admitted to this reputable school. There were also students with lower PSLE scores who were admitted to the school for other achievements such as sports excellence, but they were very few. The mean PSLE score for this sample was 242.85 (SD = 7.36).

Material and Procedure

Students' motivation was measured by asking students to complete a survey in which they were asked to rate on a Likert scale of 1 to 6 on six motivational factors: self-concept, self-efficacy, interest in physics, inquiry into physics problems, engagement during physics lessons and aspiration to pursue studies related to physics (Appendix 1). The items were randomized in the survey form. Background information such as age, gender, and language background were also collected. The variables were:

Self-Concept

Four items from Kadir et al. (2017), which were adapted from the Marsh (1992) Self-Description Questionnaire II(ASDQ) instrument, were used to ask students about the cognitive component of their self-concept (i.e., sense of competence) in physics. Even though most schools teach secondary 1 science as an integration of the three main branches of science, physics, chemistry and biology, this school adopted a modular approach to science, where physics was taught separately from chemistry and biology, so students were able to differentiate their self-concept in physics from their self-concept in other areas of the curriculum. An example is: "I am good at physics".

Self-Efficacy

The self-efficacy factor assessed students' belief in their ability to master specific skills taught in physics classes. Five items adapted from the Pintrich, Smith, Garcia, and McKeachie (1993) Motivated Strategies for Learning Questionnaire (MSLQ) were used. An example is: "I can do almost all the work in physics if I do not give up".

Interest

This is the affective component of physics self-concept. The four items used for this factor were from Yeung, Kuppan, Foong et al. (2010) who adapted them from the Marsh, Craven, and Debus (1999) study, Elliot and Church's (1997) measure of personal interest and enjoyment and the Yeung, Chow, Chow, Luk, & Wong (2004) measure of students' affect in other curriculum areas. A total of four items were used to ask students about their interest in physics. An example is: "I enjoy doing physics".

Inquiry

As inquiry is central to the science curriculum in Singapore and students are expected to engage in scientific inquiry, this measure was adapted from Yeung, Kuppan, Kadir et al. (2010). Three items asked students the extent to which they engaged themselves in scientific inquiry when solving physics problems and participating in physics learning tasks. An example is: "I do not like to be told answers to PHYSICS problems; I prefer to work through the answers myself". The other two items were reversed, asking students the extent to which they refused to engage in inquiry.

Engagement

The measure of individual engagement in physics was based on students' report of their attention and participation in physics classes. The five items used to measure this factor was adapted from Steinberg, Lamborn, Dornbusch, and Darling (1992). An example is: "I listen carefully when the teacher explains something about physics".

Educational Aspiration

The measure of education aspiration asked students about their aspiration to learn physics at advanced levels in the future. The four items for this measure were adapted from Yeung and McInerney (2005). An example is: "If I could do exactly what I wanted, I would like to study physics in future".

Achievement

The measure of achievement comprised three sets of test scores from: (1) a nation-wide standardized test called the Primary School Leaving Examination (PSLE), (2) a term test, and (3) a mid-year examination. The following provides details of each test.

(1) PSLE scores. This is a standardized test (national examination) taken by all students in Singapore at the end of Grade 6 (final year in primary school) (see Road to PSLE, 2010; Singapore Examinations and Assessment Board, 2017). This nation-wide standardized test assesses students in four main areas, namely, science, English, math and mother tongue (Chinese, for the sample in this study). Students were rated by PSLE examiners on a scale of six grades for each area of assessment: A*, A, B, C, D, E, and U (ungraded), A* being the highest grade and U, the lowest. The overall performance of a pupil was reported in terms of an Aggregate Score, which ranged from 0 to 300. This aggregate score was derived from the T-scores (i.e., Transformed Scores) of science, English, and math. The T-score was calculated based on a bell curve. For example, if the Science examination was too difficult with too many students performing badly, there is a potential increase of the raw science score, and vice versa if the examination has many students who scored high marks. The student's actual score for individual area of assessment is not disclosed. Their examination scripts are neither returned to the students nor the school. The students' PSLE scores (aggregate scores and grades) were obtained from the school. For the analysis in this study, a numerical value (score) was given to these grades, A* = 7, A = 6, B = 5, C = 4, D = 3, E = 2, and U = **1 (Table 2)**.

(2) Test scores. Test scores were obtained from the school for each of the three curriculum domains: science, English, and math. These test scores were the sum of the scores of several formative tests taken by the students during the first school term of Grade 7 (i.e., first three months of the school year).

(3) Examination scores. Examination scores were scores obtained from a summative assessment taken at the end of the first school semester of Grade 7 (after five months of school) for each of the three curriculum domains: science, English, and math. As physics was taught in the first semester as part as the school science curriculum, only physics content was tested in the science examination.

Procedures of the research were approved by the ethics committee of the university. Assent was obtained from students, and informed consent from the school, teachers, and the parents of the students were obtained before data were collected. The procedures of the survey were explained by the researchers and the students completed the survey via the school online portal. The students responded to the survey items in a randomized order on a six-point Likert scale from 1 to 6, with 1 indicating strongly disagree and 6 indicating strongly agree.

Statistical Analysis

The students' responses were coded (and some reverse-coded) to associate higher scores with more favorable responses. In preliminary analysis, the alpha reliability of each a priori scale formed from respective items. Then confirmatory factor analysis (CFA) was used to test the ability of 25 motivation survey items to form six motivational factors (i.e., self-concept, self-efficacy, interest, inquiry, engagement and educational aspiration).

Table 1

Variables Used in the Study to Measure Students' Attitudes

Factors of Attitudes towards physics	Number of items for each factor	Cronbach's Alpha	Mean	*SD*
Self-concept	4	.93	3.42	1.19
Self-efficacy	5	.85	4.30	.78
Interest	4	.91	4.16	1.06
Inquiry	3	.75	4.37	.88
Engagement	5	.87	4.71	.69
Educational Aspiration	4	.85	3.69	1.02

Note: N=272.Items were randomized in the survey. Higher scores reflected more favorable perceptions.

Table 2

Students' Achievement Scores

Students' Achievement	Mean	*SD*	Minimum	Maximum
PSLE			0	300
PSLE Aggregate	242.85	7.36	202.00	263.00
PSLE Science	6.09	.48	4.00	7.00
PSLE English	6.01	.38	4.00	7.00
PSLE math	6.36	.60	4.00	7.00
TEST			0	100.00
Test Science	64.01	10.34	38.40	88.70
Test English	60.09	5.22	40.00	73.30
Test math	74.34	10.69	35.30	95.30
EXAMINATION			0	100.00
Exam Science	65.67	8.90	27.00	88.00
Exam English	60.95	4.49	39.00	70.00
Exam math	75.44	10.12	57.00	86.00

Note: *N*=272*;* PSLE aggregate scores were used for placement of students to this high-ability school. PSLE science, PSLE English and PSLE math grades were analysed as numerical scores (A*=7, A=6, B=5, C=4, etc). As no student scored a grade poorer than C, the minimum score is 4. Test and examination scores were obtained from the school for respective curriculum domains

Mplus V7 [21] was used to conduct the CFA. To evaluate the model fit, absolute fit statistics and incremental fit statistics were both used [22]. The absolute fit statistics included χ^2 tests of model fit and the root mean square error of approximation [23]. The incremental fit statistics included the Comparative Fit Index [24] and the Tucker-Lewis Index [25], also known as the non-normed fit index [26]. The CFI and TLI vary along a 0 to 1 continuum in which values equal to or greater than .90 and .95 are considered as acceptable and excellent fits to the data, respectively. RMSEA values close to .05 indicate "close fit," values about .08 indicate "fair fit," and values above .10 indicate "poor fit" [23]. Based on commonly accepted criteria, support for model fit would require: (a) acceptable reliability for each scale (i.e., alpha = .70 or above), (b) an acceptable model fit (i.e., TLI and CFI = .90 or above and RMSEA < .08), (c) acceptable factor loadings for the items loading on the respective factors (> .30), and (d) acceptable correlations among the latent factors such that they would be distinguishable from each other (r< .90).

Results

Preliminary Analysis

The mean score and the alpha estimate for each motivation factor are given in **Table 1**. All the six a prior motivational factors had acceptable alpha reliabilities (α = .93, .85, .91, .75, .87 and .85 for self-concept, self-efficacy, interest, inquiry, engagement and educational aspiration, respectively). These high reliabilities provided preliminary support for the motivational factors [27].

A breakdown of the achievement scores is given in Table 2. As can be seen from the table, the minimum score for all curriculum domains was 4.00, implying that no student attained a grade poorer than C, and the maximum score was 7.00, which was the best grade, A*. The mean PSLE score for each curriculum domain was about 6.00, implying that the average student's grade was A.

Correlations Between Students' Attitudes Towards Physics

The critical concern of this study was the association between achievement and motivation [28] towards physics. An inspection of the correlations among the six science motivational factors (self-concept, self-efficacy, interest, inquiry, engagement, and educational aspiration) found significantly positive correlations among them (rs between .47 and .80). The highest correlation was between interest and educational aspiration in physics (r = .80), and the lowest correlation was between self-concept and inquiry in physics (r = .47) (see Table 3).

Correlations Between Students' Achievement Scores (PSLE, Test & Exam)

For achievement scores, some interesting patterns were found. Intuitively, we would expect PSLE scores to be substantially correlated. That is, in standardized tests, we would expect high-ability students to achieve well in most areas such that the correlations between domains would be expected to be substantially positive. Nevertheless, the results showed that although the correlation between math scores and science scores in PSLE was positive (r = .11), it was not statistically significant. The correlations between the English and science scores in PSLE (r = .06) and between English and math scores in PSLE (r = -.05) were near zero and statistically non-significant.

The respective correlations for the semester test scores showed a different pattern [29]. Whereas the correlations between the English and science test scores in the semester (r = .06) and the correlation between English and math test scores (r = .05) remained to be near zero and statistically non-significant, the correlation between math and science test scores were positive and statistically significant (r = .51).

The respective correlations for the semester examination scores showed another pattern. For this end-of-first-semester examination, the correlations between the English and science scores (r = .37) was higher than the correlation between English and math scores (r = .11). The correlation between math and science scores were positive and statistically significant (r = .67).

Between the PSLE scores and the semester test scores, however, there was a clear domain-specific pattern. Positive correlations were found between PSLE and semester test scores for science (r = .25), English (r = .40), and math (r = .28). Whereas English scores in PSLE did not correlate with semester math and science test scores (rs = -.03 and .05, respectively) and semester English test scores did not correlate with math and science [30] scores in PSLE (rs = -.04 and -.02, respectively), positive and statistically significant correlations were found between PSLE math and semester science test (r = .23) and between PSLE science and semester math test scores (r = .14), although these correlations were not as strong as domain-specific correlations for each domain [31] **(Table 3)**.

The correlations between PSLE scores and the semester examination showed a clearer domain-specific pattern [32]. Higher positive and statistically significant correlations were found between PSLE and semester examination for science (r = .32), English (r = .42), and math (r = .36). Whereas English scores in PSLE did not correlate with semester math and science examination scores (rs = -.06 and .11, respectively) and semester English examination scores did not correlate with math and science scores in PSLE (rs = -.05 and .06, respectively) [33], positive and statistically significant correlations were found between PSLE math and semester science examination scores [34] (r = .26) and between PSLE science and semester math examination scores (r = .13), although these correlations were not as strong as domain-specific correlations for each domain **(see Table 3)**.

Table 3

Solution of CFA Model

Item no	SC	SE	IT	IQ	EN	EA	PSc	PEn	PMa	TSc	TEn	TMa	ESc	EEn	EMa
Factor Loadings															
S9Q10	**.94**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S2Q6	**.87**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S9Q3	**.93**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S8Q6	**.81**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S4Q1	.00	**.75**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S8Q1	.00	**.77**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S5Q10	.00	**.77**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S7Q3	.00	**.64**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S4Q9	.00	**.75**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S10Q14	.00	.00	**.92**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S5Q9	.00	.00	**.91**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S8Q5	.00	.00	**.72**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S1Q4	.00	.00	**.83**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S4Q5	.00	.00	.00	**.71**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S9Q1	.00	.00	.00	**.63**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S9Q4	.00	.00	.00	**.79**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S3Q1	.00	.00	.00	.00	**.82**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S6Q7	.00	.00	.00	.00	**.83**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S1Q2	.00	.00	.00	.00	**.75**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S5Q4	.00	.00	.00	.00	**.72**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S7Q8	.00	.00	.00	.00	**.67**	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
S4Q7	.00	.00	.00	.00	.00	**.79**	.00	.00	.00	.00	.00	.00	.00	.00	.00
S10Q13	.00	.00	.00	.00	.00	**.80**	.00	.00	.00	.00	.00	.00	.00	.00	.00
S2Q3	.00	.00	.00	.00	.00	**.60**	.00	.00	.00	.00	.00	.00	.00	.00	.00
S10Q6	.00	.00	.00	.00	.00	**.91**	.00	.00	.00	.00	.00	.00	.00	.00	.00
PSc	.00	.00	.00	.00	.00	.00	**1.00**	.00	.00	.00	.00	.00	.00	.00	.00
Pen	.00	.00	.00	.00	.00	.00	.00	**1.00**	.00	.00	.00	.00	.00	.00	.00
PMa	.00	.00	.00	.00	.00	.00	.00	.00	**1.00**	.00	.00	.00	.00	.00	.00
TSc	.00	.00	.00	.00	.00	.00	.00	.00	.00	**1.00**	.00	.00	.00	.00	.00
TEn	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	**1.00**	.00	.00	.00	.00
TMa	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	**1.00**	.00	.00	.00
Esc	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	**1.00**	.00	.00
EEn	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	**1.00**	.00
EMa	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	**1.00**
Factor Correlations															
	SC	SE	IT	IQ	EN	EA	PSc	PEn	PMa	TSc	TEn	TMa	ESc	EEn	EMa
SC	1.00														
SE	.70**	1.00													
IT	.74**	.78**	1.00												
IQ	.47**	.66**	.65**	1.00											
EN	.49**	.60**	.59**	.57**	1.00										
EA	.67**	.68**	.80**	.57**	.47**	1.00									
PSc	.25**	.20**	.17**	.07	.09	.15*	1.00								
PEn	.04	.03	-.03	.08	.09	-.07	.06	1.00							
PMa	.24**	.14*	.16**	.08	.05	.14*	.11	-.05	1.00						
TSc	.54**	.38**	.39**	.23**	.31**	.31**	.25**	.05	.23**	1.00					
TEn	-.03	.01	-.08	.06	-.01	-.14*	-.02	.40**	-.04	.06	1.00				
TMa	.39**	.22**	.26**	.20**	.26**	.20**	.14*	-.03	.28**	.51**	.05	1.00			
ESc	.59**	.43**	.42**	.31**	.41**	.33**	.32**	.11	.26**	.73**	.21**	.54**	1.00		
EEn	.06	.05	-.06	.06	.10	-.08	.06	.42**	-.05	.19**	.73**	.06	.37**	1.00	
EMa	.43**	.27**	.31**	.27**	.33**	.22**	.13*	-.06	.36**	.55**	.08	.81**	.67**	.11	1.00

Note: $N = 272$. Parameters estimates are completely standardized. Motivation towards Physics include: SC: Self-concept; SE: Self-efficacy; IT: Interest; IQ: Inquiry; EN: Engagement; EA: Educational Aspiration; Achievement in science include: PSc: PSLE science; PEn: PSLE English; PMa: PSLE math; TSc: Science Test; TEn: English Test; TMa: math Test; ESc: science Exam; EEn: English Exam; EMa: math. *p<.05. **p<.001. PSLE science, PSLE English, and PSLE math correlated with PSLE.

Correlations Between Students' Achievement And Attitudes Towards Physics

An inspection of the correlations of each achievement score with the students' motivation towards physics found some interesting patterns (see Table 3) [35]. Weak correlations were observed between students' motivation towards physics and their PSLE scores; the weakest being with inquiry in physics (rs= .07, .08 and .08 with PSLE science, English and math, respectively) [36], followed by engagement (rs= .09, .09 and .05 with PSLE science, English and math, respectively). As for the other motivational factors, higher correlations were found with PSLE science and PSLE math than with PSLE English. PSLE English had the lowest correlations with all of the motivational factors towards physics, which were statistically non-significant

Another interesting finding was that even though domain specificity was observed (science achievement scores were more highly correlated to science self-concepts and motivation towards science [37], compared to other curriculum domains), the correlations of achievement with students' motivational factors were stronger with more recent achievement scores [38]. For example, Grade 7 physics achievement had higher correlations with Grade 7 physics motivation than Grade 6 science achievement [39]. This pattern of stronger correlations of achievement over time with students' motivation towards physics was also observed with math achievement scores (i.e., Grade 7 math achievement had higher correlations with Grade 7 physics motivation than Grade 6 math achievement) but not with English achievement scores [40].

Discussion

Whereas students' learning experiences in different domains tend to have distinctly different influences on their development of skills and motivation, competence in certain domains may help students' self-development in other related domains. For example, correlation (r = .52) between semester math and physics test scores and between semester math and physics examination scores (r = .67), although smaller than those within the same subject domain, were positive and statistically significant. This could be because the effective learning of physics often requires the knowledge of math and related logical thinking. Correlations of students' motivation towards science (i.e., physics here) with PSLE math scores were also similar to the correlations with PSLE science. It seems that the science and math achievements in PSLE may have very similar relations with students' motivation towards science (i.e., physics) in Grade 7.

Based on these results, there seem to be some close relations between physics and math. For example, math achievement is not only positively associated with math motivation, but is also positively associated with physics achievement. A possible reason for this could be that students who achieve well in math may feel equipped with mathematical skills necessary to do well in physics, thus having positive attitudes towards physics. This new understanding of students' academic motivation would enable us to help students build up their self-concept and enhance their motivation in new learning areas such as physics in secondary school.

As for the motivational attitudes, the correlations of students' motivation towards science (i.e., physics) with PSLE science scores are not high. This means that science achievement in PSLE (or in primary school) may not be very important for positive attitudes towards science in secondary school. This finding is contrary to the assumptions held by most parents and some teachers that PSLE scores will determine students' positive attitudes towards that subject in secondary school. Based on similar findings with math, an inspection of math achievement in PSLE also showed weak relations with students' motivation towards physics. In contrast, the science achievement scores in Grade 7 has significant relations with students' motivation towards science and such relations tend to grow stronger over time, based on the positive correlations (Table 3) between students' motivation and examination scores (taken at the end of the semester) than with test scores (taken within the first 3 months in Grade 7). The implications for this is that focus should be given to developing good school science curriculum in Grade 7, as no matter what their PSLE science scores were in the past, students can develop positive attitudes towards science in secondary school.

Math achievement follows a similar pattern as above. Math achievement scores in Grade 7 has significant relations with students' motivation towards physics and such relations tend to grow stronger over time as well (i.e., positive correlations showing a higher correlation between students' motivation and examination scores than with test scores), although not as strong as the relations between science achievement and attitude towards physics. Having a good curriculum for math may improve students' achievement in math, which may positively influence students' motivation in physics, to some extent. However, further research will be necessary to test this implication.

Since students' achievement in Grade 6 does not seem to have much bearing on students' motivation towards physics in the first semester of secondary school, Grade 7 may thus be a critical time for developing positive attitudes towards physics. For physics education, it is important not only to improve physics achievement, but also to enhance motivation towards physics at an early stage in secondary school. It also seems crucial to enhance skills in math as well.

One of the limitations of this study is the sample of high-ability students. Even though we may claim contribution to the understanding of higher-ability students' achievements in their relation to students' motivation towards physics, we are unable to generalize it to the whole Grade 7 student population. However, the findings in this study have important implications that could be beneficial to many other students.

Educators need to be aware of the students' development of motivation towards physics in order to provide them with the best learning environment to optimize their potential. Since there are significant correlations between the science and math domains, curriculum could be designed such that the lessons learned from each of these domains complement each other to strengthen students' skills in both domains. Further implications for parents and educators are that while it is not too late to develop positive attitudes towards science, there should not be complacency that good academic achievement in the past will guarantee good attitudes towards physics in the future. An engaging and interesting physics curriculum is necessary to enhance students' positive attitudes and help them excel in the domain.

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