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Hong Kong secondary school students' attitudes towards science: a study of structural models and gender differences

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ABSTRACT
This study explored two under-researched areas on students' attitudes towards science, that is, the structural models representing these attitudes and the role played by school bands in moderating the gender differences in such attitudes. The participants were 360 ninth graders in Hong Kong from 3 school bands. The structural equation modelling method was adopted to compare four hypothetical models for students' attitudes towards science. Results reflect that (i) the data supported the three-factor structure of the behavioural domain of students' attitudes towards science; (ii) the four lower level dimensions of the attitudes towards science (i.e. value of science to society, self-concept in science, anxiety towards science and enjoyment of science) could be further integrated into broader categories; (iii) male students demonstrated significantly more positive attitudes towards science in five dimensions (i.e. self-concept in science, enjoyment in science, learning science in and outside the classroom and future participation) and (iv) school bands played a prominent moderating role in gender differences in students' attitudes towards science. Implications for studying and developing students' attitudes towards science are discussed in the paper.

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Introduction

Cultivating students' positive attitudes towards science has long been considered a significant goal of science education (Baker & Doran, 1975; Navarro, Förster, González, & González-Pose, 2016; Sjøberg, 2000). As argued by Shulman and Tamir (1973), the affective outcomes of science instruction should be at least as important as the cognitive outcomes. The findings on the influence of students' attitudes towards science on their conceptual change process (Lee & Brophy, 1996; Pintrich, Marx, & Boyle, 1993), learning strategies (Lin & Tsai, 2013; Wolters, 1999) and science learning achievement (Lin, Hong, & Huang, 2012) further strengthen the significance of developing positive attitudes amongst students when they learn science.

Substantial work has been done in the past four decades to investigate students' attitudes towards science (Kennedy, Quinn, & Taylor, 2016; Saleh & Khine, 2011). The

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necessity of this investigation has been further emphasised for the past 20 years because of the continuously decreasing number of young individuals pursuing scientific careers and the study of science. This situation has now become a matter of societal concern in a good number of countries all over the world, such as the U.S. (National Science Foundation, 2002), the European Union (Commission of European Communities, 2001), Australia (Dekkers & de Laeter, 2001), Israel (Trumper, 2006b), Japan (Goto, 2001) and India (Garg & Gupta, 2003).

The present study focuses on exploring two under-researched areas on students' attitudes towards science, that is, the structural models for students' attitudes towards science and the role played by school bands in moderating the gender differences in attitudes towards science. The participants are Hong Kong secondary school students. Chinese science learners have attracted the attention of a good number of international education scholars because of their consistent outstanding performance in large-scale international assessments such as the *Trends in International Mathematics and Science Study* (TIMSS) and *Program for International Student Assessment* (PISA). However, a Chinese learner is stereotyped as an unconfident, passive, examination-oriented and silent student who learns by rote (Biggs, 1994; Cheng & Wan, 2016). The investigation into Hong Kong students' attitude towards science may provide insights that can explain the conflict between Chinese students' excellent science achievement and the common impression of their learning process. More specifically, the following three questions will be explored in this paper.

RQ1: How is the structure of Hong Kong ninth-grade students' attitudes towards science?

RQ2: Are there any gender differences in Hong Kong ninth-grade students' attitudes towards science?

RQ3: If gender differences exist in Hong Kong ninth-grade students' attitudes towards science, are such gender differences moderated by school bands?

Concept and structure of the attitudes towards science

Although extensive research has been conducted on students' attitudes towards science, two major areas still need to be clarified or further defined (Kind, Jones, & Barmby, 2007; Osborne, Simon, & Collins, 2003). The first is the confusion between or mixture of attitudes towards science and scientific attitudes. Scientific attitudes commonly refer to some features of the scientific way of thinking, including the desire to know and understand, an enquiring approach to all statements, a search for data and their meaning, a demand for verification, a respect for logic and a consideration of the premises and of consequences (Education Politics Commission, 1962). On the contrary, attitudes towards science are the beliefs, feelings and values held about a scientific enterprise; the impact of science on society; science learning inside and outside school and science-related work. Although these two concepts may be to a certain extent related, they are essentially different. Munby (1983) found that, in some instruments, scientific attitude items are mixed with items related to attitudes towards science items. In this paper, we explicitly differentiate between these two concepts and select scientific attitudes as our singular focus.

The second problem is the lack of clarity regarding the internal structure of the attitudes towards science. Attitudes do not form a single unitary construct, but rather include a large number of sub-constructs, which can be theoretically grouped into three domains, that is, cognition, affect and behaviour (e.g. Bagozzi & Burnkrant, 1979; McGuire, 1985; Rajecki, 1990). They are defined by Reid (2006, p. 4) as follows:

- a knowledge about the object, the beliefs and ideas component (Cognitive);
- a feeling about the object, like or dislike component (Affective) and
- a tendency towards action, the objective component (Behavioural).

In the same vein, these domains may also apply to attitudes towards science. Furthermore, assuming the existence of causal relationships amongst them may be reasonable. 'We know about science and therefore have a feeling or an opinion about it that may cause us to take some actions' (Kind et al., 2007, p. 872). However, Fishbein and Ajzen (1975) regarded the affect domain of attitudes as being formed spontaneously and inevitably as individuals form beliefs about an object. In other words, the differentiation between cognition and affect in the internal structure of attitudes may not be required, and they should be combined into a single domain, which can be named the 'mental' domain.

Despite the controversies regarding the exact structure of attitudes towards science, on the basis of the discussion made in the last paragraph, three hypotheses may be made on this structure. Firstly, there exists a separate behavioural domain in the structure of attitude. This point is commonly accepted by the scholars on attitudes (e.g. Bagozzi & Burnkrant, 1979; Kind et al., 2007; Rajecki, 1990). Secondly, the various sub-constructs on beliefs and feelings about science should be integrated into broader categories. For Kind et al. (2007), there should be the cognitive and affective domains, while Fishbein and Ajzen's viewpoint (1975) agrees to the existence of these two domains but suggests further merging them into a 'mental' domain. Thirdly, the cognitive and affective domains are closely related. Kind et al. (2007) assumed a caused relationship between them, but Fishbein and Ajzen's opinion (1975) implies that they are intrinsically integrated. Of course, all these points are just theoretical hypotheses and until now no empirical study is found to test them. This is a gap that the present study intends to fill.

Gender differences in science achievement and attitudes towards science

Gender has been a long-standing issue in science education. A good number of studies have revealed the difference between male and female students in their academic achievements in and attitudes towards science (e.g. Buccheri, Gürber, & Brühwiler, 2011; Burkham, Lee, & Smerdon, 1997; Johnson 1987; Jones, Howe, & Rua, 2000; Weinburgh, 1995). In 1971, males outperformed females in science achievement in the National Assessment of Educational Progress (NAEP) in the U.S. at all four age levels (9, 13, 17 and 25–35 years or young adult). Similarly, the results of TIMSS 2003 indicated that grade 8 male students outperformed female students on average in four of the five content areas (Mullis et al., 2003). Several reviews of the literature on students' attitudes towards science consistently show that male students demonstrate more positive attitudes towards science than female students do (e.g. Becker, 1989; Brotman & Moore, 2008;

Osborne et al., 2003; Weinburgh, 1995). Weinburgh (1995) examined the results of 31 studies conducted from 1977 to 1991 to explore the gender differences in students' attitudes towards science, amongst which 25 (81%) reported more positive attitudes from male students.

In addition to the overall trend favouring male students in science achievement and attitudes towards science, the branches of science were found to moderate the gender differences in science. The NAEP 1971 report showed that male young adults outscored their female counterparts by 14% in physical science items, whereas the difference between their scores was only 2% in biological science items. Similarly, Burkham et al. (1997) revealed that no significant gender difference exists in the achievement in life sciences, but male secondary students significantly outscored females in physical sciences. The moderating effect played by the branches of science has also been reported in the studies on gender differences in the attitudes towards science. Female students have been found to be more interested in life and environmental sciences, whereas male students have been found to be more attracted to physical sciences and engineering subjects (Friedler & Tamir, 1990; Miller, Blessing, & Schwartz, 2006; Trumper, 2006a, 2006b; Walberg, 1967).

Another interesting finding revealed by Burkham et al. (1997) was the moderating effect of students' ability on gender differences in students' achievement in both life and physical sciences. As regards the achievement of eighth graders in physical sciences, the male advantage widened as students' ability increased. For the achievement of tenth graders in life sciences, less-able female students scored higher than less-able males, whereas more-able male students outscored more-able females. However, the moderating effects of students' ability on gender differences were not evident in the achievement in life sciences of eighth graders and in the achievement in physical sciences of tenth graders. A more reliable conclusion can only be drawn when additional evidence is obtained in future research. Given the close connection between academic achievement and learning attitude, it may be also meaningful to explore the moderating role played by students' ability in the gender difference in students' attitudes towards science.

A number of studies have investigated the gender differences in Chinese students' attitudes towards science and generated findings that are to some extent different from the findings in the aforementioned. In 1987, Collis and Williams investigated 287 high school mainland Chinese students' interest in science, and found that no significant difference exists between Chinese male and female students. Wang and Berlin (2010) explored the attitudes towards science of 265 Taiwanese elementary students in 3 dimensions (i.e. science enjoyment, self-concept in science and value of science to society), but no significant gender difference was found. More unexpected findings were reported in two other studies (Boone, 1997; Hong & Lin, 2011), one on mainland Chinese students and the other on Taiwan Chinese students; female students showed more interest in science than male students did. Given that Hong Kong is also a Chinese region, it may be meaningful to find if these unexpected findings apply to Hong Kong students.

Hong Kong education system and recent reforms in science education

Before the handover of the sovereignty of Hong Kong from the U.K. to China in 1997, the education system in Hong Kong followed the typical British system. Children received primary education for six years (Grades 1–6), followed by five years of secondary education (Grades 7–11), two years of pre-university learning (Grades 12 and 13) and three years of university study. Hong Kong Certificate of Education Examination and Hong Kong Advanced Level Examination were the two important public examinations, respectively, taken upon the completion of Grades 11 and 13. In 2009, a major change was implemented in the Hong Kong education system. The university study expanded from three to four years, and before the university study are three years of senior secondary school and three years of junior secondary school, which is called a 3-3-4 system. Upon the completion of secondary education, students only need to take the Hong Kong Diploma of Secondary Education (DSE) examination, whose result is the most influencing factor in university admission. The schools in Hong Kong are classified into three bands: Band 1 includes the schools whose students demonstrate the highest average academic achievement in the enrolment examination, whereas Band 3 represents the schools whose students have the lowest average academic achievement.

One important feature of the education system of Hong Kong is the low university enrolment rate. In 2015, there were 74,170 students who participated in the DSE examination, but only 13,000 can get enrolled into the government-funded Bachelor programmes. The overall enrolment rate was below 18%, which was much lower than the rates of other Asian regions, such as Taiwan, Mainland China, Japan and South Korea. Situated in the collectivist culture, another important feature of the education in Hong Kong is the strong influence of parents on students' learning (Chiu & Ho, 2006). For example, Hong Kong parents are willing to pay much money for their children's after-school tutorials. They actively monitor their children's homework and encourage them to study hard. At the same time, one of the significant motivations for Hong Kong students' learning is to meet the expectation of their parents and please their family.

Science is one of the eight key learning areas in the present school curriculum of Hong Kong. In the recent two decades, a series of reforms in science education have been implemented in Hong Kong (Wan & Wong, 2017). Scientific inquiry has been advocated as a desired means of learning scientific knowledge and generic skills such as collaboration and communication. The nature of science was explicitly stated in the revised junior secondary science curriculum (Grades 7–9) (Curriculum Development Council [CDC], 1998) as one of the curriculum goals. A new set of Curriculum and Assessment Guides devised for senior secondary science subjects (Curriculum Development Council-Hong Kong Examinations and Assessment Authority, 2007) put great emphasis on students' appreciation of the interaction amongst science, technology, society and environment (STSE). In line with the international trend, the CDC (2015) embarks on promoting STEM education so as to equip 'students to meet the changes and challenges in our society and around the world with rapid economic, scientific and technological developments' (p. 1).

Research method

Quantitative method was adopted in this study to explore the structure for students' attitudes towards science and the role played by school bands in moderating the gender differences in attitudes towards science.

Participants

Science content for primary school students is embedded in the General Studies subject in Hong Kong, and thus it may be premature to probe Hong Kong primary students' attitudes towards science before they have very systematically learned science. Meanwhile, it is difficult to recruit senior secondary students in research projects due to the pressure of preparing for public examination. Considering the feasibility of recruiting participants and the maturity level of students, this project chose to invite ninth graders in Hong Kong secondary schools, who had accumulated considerable experience of learning science and were more willing to join research projects.

A total of 371 ninth graders in Hong Kong secondary schools responded to the questionnaire, but the data of 11 students were excluded due to missing data and so only the data of 360 students were included into the final data analysis. Amongst the participants, 183 are male and 177 are female. In order to maximise the variation of the participants, students from schools with different bands were involved in this project; 139 participating students were from Band 1 schools, 106 were from Band 2 schools and 115 were from Band 3 schools.

Data collection

The instrument assessing students' attitudes towards science includes seven dimensions, which are commonly found in the literature, including the value of science to society (e.g. Gogolin & Swartz, 1992; Kind et al., 2007), self-concept in science[1] (e.g. Koballa, 1995; Talton & Simpson, 1986), enjoyment of science (e.g. Breakwell & Beardsell, 1992; Gardner, 1975), anxiety towards science (e.g. Mallow et al., 2010; Osborne et al., 2003), learning science in the classroom (e.g. Crawley & Black, 1992; Pell & Jarvis, 2001), learning science outside the classroom (e.g. Breakwell & Beardsell, 1992; Kind et al., 2007) and future participation (e.g. Gogolin & Swartz, 1992; Klopfer, 1971). The description and sample items of these seven dimensions are presented in Table 1. As indicated in their descriptions, the first two belong to the cognitive domain (i.e. beliefs related to science),

Table 1. Description and sample items of the seven dimensions of attitudes towards science.

Dimensions of attitudes towards science (No. of items)	Description and sample items
Cognitive domain	
Value of science to society (7)	To what extent students believe the importance of science is in a wider social context. 'Science is useful for solving the problems of everyday life'
Self-concept in science (5)	To what extent students believe their own ability to master school science. 'I usually understand what we discuss in science classes'
Affective domain	
Anxiety towards science (5)	To what extent students feel anxious in the situations involving science. 'I feel tense when someone talks to me about science'
Enjoyment of science (6)	To what extent students feel pleasure when they learn science. 'Science is something I enjoy very much'
Behavioural domain	
Learning science in the classroom (7)	To what extent students tend to engage the activities of learning science in classroom. 'I look forward to having science classes'
Learning science outside the classroom (5)	To what extent students tend to participate in the extracurricular activities related to science. 'I wish to join a science club'
Future participation (4)	To what extent students tend to engage more with science in the future. 'I wish to have a science-related job'

the last three belong to the behavioural domain (i.e. the tendency towards actions related to science) and the middle two are related to the affective domain (i.e. feelings related to science). All the items were rated using a four-point Likert scale (strongly agree, agree, disagree and strongly disagree).

Data analysis

Cronbach's alpha reliability coefficients for all seven dimensions of attitudes towards science were determined (Table 2). The coefficients ranged from .710 to .815. All were above .70, which was the suggested criterion (Fink, 2015; Henerson, Moms, & Fitz-Gibbon, 1978). The construct validity of each dimension was determined using the item-to-scale correlation (Table 3). The mean correlations of the individual scales were from .43 to .64, which were above the minimum acceptance level of .30, supporting the internal consistency within each set of items (Gable, 1986).

As introduced in the section on the structure of attitudes, three hypotheses can be generated on the structure of attitudes towards science, that is, (H1) the existence of a separate behavioural domain, (H2) the necessity of integrating various sub-constructs on beliefs and feelings about science into cognitive and affective domains and (H3) the existence of a close relationship between the cognitive and affective domains. In order to test H1, the data analysis was initiated by validating the structure of this domain through structural equation modelling (SEM), as shown in Figure 1. After validating the structure of behaviour, four hypothetical models (Figure 2) were generated to test the second and third hypotheses.

- Model 1: The four lower level factors of cognition and affect are not integrated into higher level factors.
- Model 2: The four lower level factors are integrated into two higher level factors. No causal relationship exists between cognition and affect.
- Model 3: The four lower level factors are integrated into two higher level factors. A causal relationship exists between cognition and affect.
- Model 4: Cognition and affect are integrated. A causal relationship exists between the mental domain (i.e. cognition plus affect) and behaviour.

The comparison between the SEM results of Model 2 and Model 1 was used to indicate if it is meaningful to integrate the sub-constructs on beliefs and feelings about science into the broader cognitive and affective domains (H2). Comparing Models 3 and 4 with Model

Table 2. Cronbach's alpha coefficients for the seven dimensions of attitudes towards science.

Domains	Dimensions of attitudes towards science	Alpha coefficients
Cognitive	Value of science to society	.712
	Self-concept in science	.710
Affective	Anxiety towards science	.787
	Enjoyment of science	.772
Behavioural	Learning science in the classroom	.779
	Learning science outside the classroom	.765
	Future participation	.815

Table 3. Item-to-scale correlations for the seven dimensions of attitudes towards science.

Cognitive				Affective				Behavioural					
Value of science to society		Self-concept in science		Anxiety towards science		Enjoyment of science		Learning science in the classroom		Learning science outside the classroom		Future participation	
Item	Corr.	Item	Corr.	Item	Corr.	Item	Corr.	Item	Corr.	Item	Corr.	Item	Corr.
1	*.50*	4	*.39*	15	*.50*	2	*.63*	12	*.55*	8	*.53*	14	*.67*
16	*.41*	10	*.47*	27	*.62*	13	*.53*	20	*.58*	39	*.57*	21	*.70*
22	*.56*	24	*.56*	28	*.49*	26	*.51*	23	.60	40	*.48*	36	*.58*
34	*.38*	44	*.47*	30	*.60*	32	*.45*	46	*.38*	53	*.53*	43	*.61*
47	*.32*	49	*.47*	55	*.50*	42	*.54*	51	*.33*	60	*.57*		
54	*.39*					6	*.49*	57	*.45*				
58	*.47*							64	*.68*				
Mean	*.43*		*.47*		*.47*		*.52*		*.51*		*.54*		*.64*

2 could generate evidence on whether it is necessary to add relationships between cognitive and affective domains so as to improve the model fit (H3). In addition, the comparison between Models 3 and 4 was used to test whether cognitive and affective domains should be merged or considered as separated constructs with a causal relationship between them.

Numerous fit indices are used in the SEM field. Amongst them, the most commonly used is the ratio of chi-square statistic to degrees of freedom (χ^2/df). The three other commonly used fit indices in the SEM analysis are the root-mean-square error of approximation (RMSEA), parsimonious normed fit index (PNFI) and comparative fit index (CFI). The criterion values were set based on the prescription of Hu and Bentler (1999). The χ^2/df ratio should be below 3 and above 1. For the RMSEA, .05 and below represent the best fit, and .08 and below indicate a good fit. For the PNFI, .50 and above suggest a good fit. For the CFI, .90 and above represent a good fit. In this study, these four fit indices were employed.

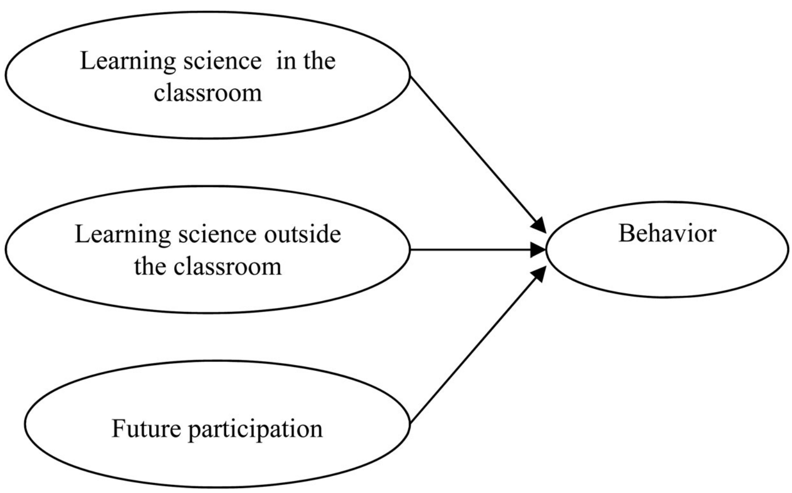

Figure 1. Structure of behavioural domain of attitudes towards science.

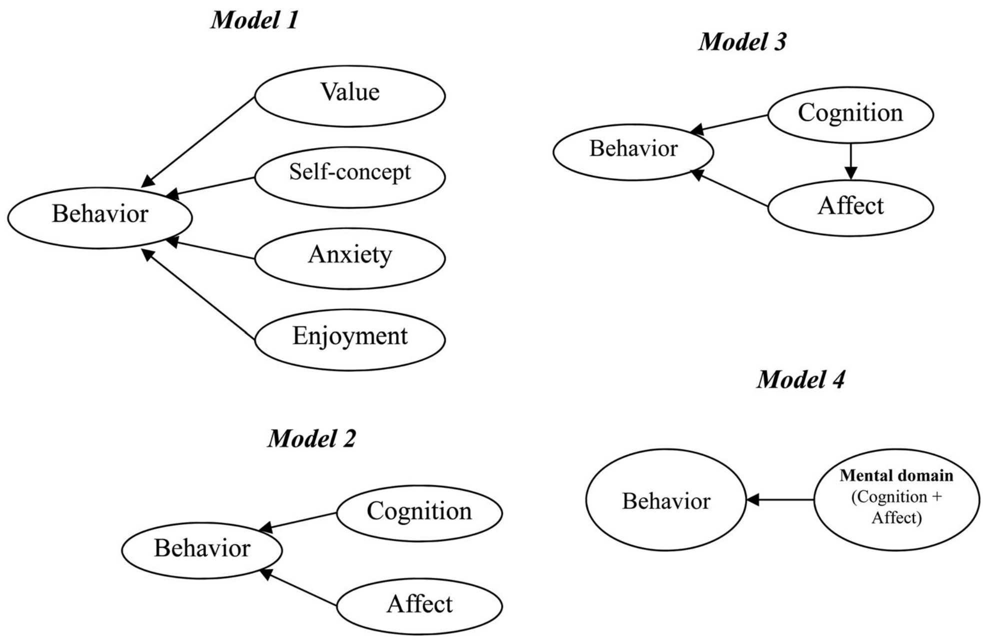

Figure 2. Four hypothetic models of the structure of students' attitudes towards science.

In order to examine the gender differences in students' attitudes towards science, *t*-tests were conducted for all the students and for the students in the three school bands. The two-way ANOVA (analysis of variance) (Kim, Kaye, & Wright, 2001; Ott & Longnecker, 2015) was conducted to explore the interaction effect between school bands and the gender differences in students' attitudes towards science. The SEM analysis was conducted using AMOS 21, whereas the *t*-tests and two-way ANOVA were performed using SPSS 21.

Results

Structural models for students' attitudes towards science

In the confirmatory factor analysis of the behavioural domain of attitudes towards science, the results of all the four indices consistently supported the three-factor structure (χ^2/df = 2.263; RMSEA = .059; PNFI = .689; CFI = .958). After validating the structure of behaviour, further analysis was conducted to compare the four structural models of students' attitudes towards science. As indicated in Table 4, Model 1 did not generate good fit statistics for two indices (RMSEA = .081; CFI = .853), implying that the data might not support this model. Model 2 had better four fit indices (χ^2/df = 2.741; RMSEA = .073;

Table 4. Fit statistics for the five hypothetical models of the structure of attitudes towards science.

Model	χ^2	df	χ^2/df	RMSEA	PNFI	CFI
1	2012	696	2.892	.081	.673	.853
2	1899	693	2.741	.073	.683	.867
3	1569	692	2.269	.059	.717	.912
4	1572	694	2.265	.059	.719	.912

PNFI = .683; CFI = .867) than Model 1, indicating that the integration of the four lower level factors into cognition and affect made the hypothetical model more fit to the data. However, CFI was still slightly below the marginal value. Thus, further improvement of the structure might be imperative. In Models 3 and 4, the connection between cognition and affect was added. The fit statistics for these two models were very similar, and they showed substantial improvement in terms of χ^2/df, RMSEA and CFI statistics compared with Model 2.

Gender differences in attitudes towards learning science

Table 5 shows the mean scores of the male students and female students in all seven dimensions of attitudes towards science (RQ2). As indicated in the results generated for all students, significant gender differences favour male students in five dimensions of attitudes towards science, including self-concept in science ($t = 22.505$, $p < .001$), enjoyment of science ($t = 8.287$, $p < .01$), learning science in the classroom ($t = 16.333$, $p < .001$), learning science outside the classroom ($t = 17.709$, $p < .001$) and future participation ($t = 25.334$, $p < .001$).

Table 5. Gender differences in students' attitudes towards science.

Attitudes towards science	School band	All		Male		Female		Difference (Male–Female)	*T*	*p*
		Mean	SD	Mean	SD	Mean	SD			
Cognition										
Value of science to society	1	3.156	.485	3.281	.501	3.084	.463	.198	5.493	.021*
	2	3.085	.405	3.090	.484	3.076	.215	.014	0.028	.866
	3	3.211	.373	3.221	.343	3.198	.414	.023	0.102	.751
	All	3.152	.430	3.189	.448	3.114	.408	.076	2.805	.095
Self-concept in science	1	2.580	.659	2.860	.688	2.423	.590	.438	15.602	.000***
	2	2.685	.436	2.749	.480	2.574	.325	.175	4.076	.046*
	3	2.602	.504	2.667	.528	2.514	.460	.152	2.610	.109
	All	2.618	.552	2.750	.563	2.481	.508	.268	22.505	.000***
Affect										
Anxiety towards science	1	2.053	.677	1.796	.611	2.198	.673	−.402	−12.189	.001**
	2	2.959	.547	2.940	.625	2.990	.381	−.049	0.200	.656
	3	3.050	.432	3.024	.432	3.086	.434	−.062	0.567	.453
	All	2.638	.735	2.658	.769	2.618	.700	.040	0.264	.608
Enjoyment of science	1	3.031	.621	3.277	.566	2.893	.611	.383	13.281	.000***
	2	3.127	.473	3.109	.536	3.158	.340	−.050	0.270	.604
	3	3.210	.434	3.220	.433	3.197	.441	.022	0.074	.786
	All	3.117	.528	3.195	.512	3.036	.534	.159	8.287	.004**
Behaviour										
Learning science in the classroom	1	2.851	.634	3.114	.621	2.703	.595	.411	14.834	.000***
	2	2.996	.437	2.993	.464	3.000	.391	−.007	0.006	.936
	3	3.088	.475	3.143	.448	3.015	.504	.128	2.059	.154
	All	2.969	.540	3.080	.508	2.855	.550	.225	16.333	.000***
Learning science outside the classroom	1	2.620	.667	2.868	.720	2.481	.595	.387	11.615	.001***
	2	2.766	.466	2.814	.500	2.682	.394	.132	2.000	.160
	3	2.875	.526	2.921	.517	2.812	.536	.109	1.212	.273
	All	2.744	.578	2.868	.572	2.617	.557	.251	17.709	.000***
Future participation	1	2.475	.833	2.870	.788	2.253	.777	.617	19.987	.000***
	2	2.901	.537	2.949	.567	2.821	.476	.129	1.419	.236
	3	2.960	.611	2.977	.644	2.937	.570	.040	0.121	.729
	All	2.756	.721	2.938	.659	2.567	.736	.370	25.334	.000***

*Cases with statistically significant difference at the .05 level.
**Cases with statistically significant difference at the .01 level.
***Cases with statistically significant difference at the .001 level.

When the students were further divided into school bands, school bands were found to play a prominent moderating role in the gender differences in students' attitudes towards science (RQ3). Significant differences favouring males were found for Band 1 students in all seven dimensions, that is, value of science to society ($t = 5.493$, $p < .05$), self-concept in science ($t = 15.602$, $p < .001$), anxiety towards science ($t = -12.189$, $p < .01$), enjoyment of science ($t = 13.281$, $p < .001$), learning science in the classroom ($t = 14.834$, $p < .001$), learning science outside the classroom ($t = 11.615$, $p < .001$) and future participation ($t = 19.987$, $p < .001$). For Band 2 and 3 students, a significant gender difference was only revealed in Band 2 students' self-concept in science ($t = 4.076$, $p < .05$). Therefore, all the significant gender differences in students' attitudes towards science for all the students were mainly caused by the variation between Band 1 male students and female students.

In order to investigate the interaction effect between school bands and gender differences in students' attitudes towards science, the two-way ANOVA was conducted. As indicated in Table 6, gender differences favouring males were found in six dimensions, consisting of self-concept in science ($F = 19.035$, $p < .001$), anxiety towards science ($F = 7.838$, $p < .01$), enjoyment of science ($F = 4.477$, $p < .05$), learning science in the classroom ($F = 9.800$, $p < .01$), learning science outside the classroom ($F = 11.818$, $p < .001$) and future

Table 6. Two-way ANOVA of the effects of gender and school band on attitudes towards science.

Source	Dependent variable	Type III sum of squares	Mean square	*F*
Corrected model	Value of science to society	2.146	0.429	2.367*
	Self-concept in science	8.243	1.649	5.760***
	Anxiety towards science	83.314	16.663	53.351***
	Enjoyment of science	6.813	1.363	5.163***
	Learning science in the classroom	9.533	1.907	7.085***
	Learning science outside the classroom	9.710	1.942	6.244***
	Future participation	30.681	6.136	13.925***
Intercept	Value of science to society	3344.740	3344.740	18,441.209***
	Self-concept in science	2321.403	2321.403	8110.555***
	Anxiety towards science	2394.526	2394.526	7666.846***
	Enjoyment of science	3310.795	3310.795	12,545.929***
	Learning science in the classroom	3006.534	3006.534	11,171.997***
	Learning science outside the classroom	2560.025	2560.025	8230.714***
	Future participation	2630.952	2630.952	5970.672***
Gender	Value of science to society	0.509	0.509	2.808
	Self-concept in science	5.448	5.448	19.035***
	Anxiety towards science	2.448	2.448	7.838**
	Enjoyment of science	1.182	1.182	4.477*
	Learning science in the classroom	2.637	2.637	9.800**
	Learning science outside the classroom	3.676	3.676	11.818***
	Future participation	5.753	5.753	13.055***
School band	Value of science to society	0.918	0.459	2.531
	Self-concept in science	0.292	0.146	0.509
	Anxiety towards science	82.714	41.357	132.418***
	Enjoyment of science	0.920	0.460	1.743
	Learning science in the classroom	1.743	0.872	3.239*
	Learning science outside the classroom	2.232	1.116	3.589*
	Future participation	10.717	5.359	12.161***
School band*Gender	Value of science to society	0.640	0.320	1.763
	Self-concept in science	1.510	0.755	2.637
	Anxiety towards science	2.386	1.193	3.820*
	Enjoyment of science	3.172	1.586	6.010**
	Learning science in the classroom	2.631	1.316	4.889**
	Learning science outside the classroom	1.431	0.715	2.300
	Future participation	5.822	2.911	6.606**

participation ($F = 13.055$, $p < .001$). Amongst these six dimensions, the interaction between school band and gender difference was statistically significant in anxiety towards science ($F = 3.820$, $p < .05$), enjoyment of science ($F = 6.010$, $p < .01$), learning science in the classroom ($F = 4.889$, $p < .01$) and future participation ($F = 6.606$, $p < .01$).

Discussion and conclusions

This section initially discusses the findings on the two areas under study, that is, the structural models representing the students' attitudes towards science and the gender differences in these attitudes. Subsequently, the findings on Chinese students' attitudes towards science were compared with the findings of other relevant studies on Chinese science learners.

Structure of attitudes towards science

Generally, students' attitudes towards science form a complex structure, which consists of a large number of sub-constructs (Kennedy et al., 2016; Kind et al., 2007; Osborne et al., 2003). Above these sub-constructs higher level factors may exist, including cognition, affect and behaviour (Reid, 2006). Although Kind et al. (2007) and Fishbein and Ajzen (1975) held different views on whether to integrate the cognitive and affective domains into one domain, they both proposed the existence of a two-level structure of attitudes towards science. Such a two-level structure was also supported empirically by the findings of the current study. Firstly, the data supported the three-factor structure of the behavioural domain of the attitudes towards science, covering learning science in the classroom, learning science outside the classroom and future participation. As regards the four other dimensions (i.e. value of science to society, self-concept in science, anxiety towards science and enjoyment of science), the comparison between Models 1 and 2 indicates that these dimensions should be grouped into two higher level factors (i.e. cognition and affect). A further comparison between Model 2 and Models 3 and 4 shows that assuming the connection between the cognitive and affective domains is reasonable.

In the past four decades, a huge number of studies have been conducted to investigate students' attitudes towards science, and a considerable number of sub-constructs have been derived under such attitudes (Blalock et al., 2008). The prevailing approach to validate the structure of attitudes towards science is through an exploratory factor analysis (EFA) (e.g. Hong & Lin, 2011; Kind et al., 2007). Although EFA is efficient for a one-level structure, it has limitations in probing two-level structures. Firstly, it cannot provide information on whether the generated lower level factors can be further integrated into higher level factors. Secondly, when the higher level is more prominent than the lower level, EFA cannot just reveal the higher level factors and ignore the lower level factors. Since the two-level structure of attitudes towards science learning has been suggested by a number of scholars (e.g. Fishbein & Ajzen, 1975; Kind et al., 2007; Reid, 2006) and supported by the findings of this study, it may be necessary to combine EFA and SEM to explore such a two-level structure in future studies. Actually, if such a structure can be clarified and validated in the future, this structure can be a useful framework to synthesise and compare the findings generated by different studies on students' attitudes towards science.

Gender differences in attitudes towards science

The comparison between all male students and female students in the current study supports the conclusions drawn in previous reviews of the literature on the attitudes towards science (Becker, 1989; Osborne et al., 2003; Weinburgh, 1995): male students have more positive attitudes towards science than female students have. However, the previous finding that no significant gender difference exists in Chinese students' attitudes towards science (Collis & Williams, 1987; Lin, Tan, & Tsai, 2013; Wang & Berlin, 2010) is not generated in this study. Furthermore, the findings of the present study are opposite to those of two other Chinese studies (Boone, 1997; Hong & Lin, 2011), which found that Chinese female students showed more interest in science than male students did. Notably, although the conclusion that male students are more positive towards science is supported in the current study, such a gender difference was not found in some recent studies conducted in non-English-speaking regions (Akpinar, Yildiz, Tatar, & Ergin, 2009; Jerrim & Schoon, 2014; Manassero, Vázquez, Bennàssar-Roig, & García-Carmona, 2010; Navarro et al., 2016). Overall, the findings on gender differences in students' attitudes towards science are becoming increasingly inconsistent within the Chinese culture and worldwide.

This study also indicated that gender differences in students' attitudes towards science were moderated by school bands. Such a moderating effect may be attributed to student's ability. As introduced in the section of participants, different bands of schools indicated different average academic achievement of their students in the enrolment examination. In other words, the higher the band of a school, the greater the average academic ability its students have. With the increase in students' overall academic ability, more variation may appear in the domain-specific ability between male and female students, which in turn causes the moderating effect of students' ability on the gender differences in students' achievement in science as reported in Burkham et al. (1997), and such a moderating effect on students' attitudes towards science is reported in this study.

In addition to students' ability, other two contextual factors may also be the causes of the interaction effect between school bands and gender differences in Hong Kong students' attitudes towards science. One is the implemented science curriculum in the schools of different bands. As introduced in the preceding section on the Hong Kong education system, the university enrolment rate is very low in Hong Kong. Only 18% of DSE attendants can get enrolled into the government-funded Bachelor programmes. Given such a low rate, there is an extremely low possibility for Band 2 and 3 students to enter into university study. At the same time, Band 1 students also need to compete for the limited university enrolment quota and the competition will be more severe if they aim to enter higher rank local universities. Consequently, under the high pressure of competition, the implemented curriculum of Band 1 schools is usually rather examination-oriented. On the contrary, with much less pressure of competing for university enrolment, teachers in Band 2 and 3 schools have much room to reflect trends of curriculum reforms (such as scientific inquiry, nature of science and STSE) in their classroom, which in turn may reduce the gender difference in their students' attitudes towards science.

The other is the influence of family. As described in the preceding section on the Hong Kong education system, Hong Kong parents tend to influence their children's learning. Since parents always have the gender-related stereotypic impression that science is more important for boys and boys are more competent in learning science (Chang, Yeung, & Cheng, 2009), this stereotypic impression of their parents may contribute to the gender difference in students' attitudes towards science. As found by Chiu and Ho (2006), the higher social and economic status of the family indicated the greater influence exerted by the parents on students' learning. Comparatively speaking, Band 1 students are normally from families at higher social and economic status in Hong Kong. Therefore, under the influence of their parents, the gender difference in the attitudes towards science of Band 1 students was more prominent than that of Band 2 and 3 students.

The findings of the moderating role played by school band in the gender differences of students' attitudes towards science revealed in this study may provide a possible direction to probe the inconsistent results on gender differences in students' attitudes towards science as described in the first paragraph of this section. Since students from schools with different bands may exhibit different levels of gender difference, the inconsistent results on gender differences in students' attitudes towards science reported in different studies can be the result of the different distributions of school bands or students' abilities. Therefore, before making inference on the different patterns of gender difference as revealed in different studies, it is necessary to compare the samples of these studies in terms of school bands or students' abilities. Only when the influence of sample distribution can be excluded can the inferences situated in the broader cultural background be further made. Moreover, in future studies on students' attitudes towards science, attention should be also paid to the distribution of samples in terms of school bands or students' abilities. Information on such a distribution should be provided in the report and paper, so that the influence of school bands or students' ability on gender differences can be explored before performing intercultural or inter-subcultural comparisons.

Chinese students' attitudes towards science

Biggs (1994) called the conflict between the consistent outstanding science performance of Chinese students in large-scale international assessments and the negative stereotypical image of Chinese learners *the paradox of the Chinese learners*. The explanation for this paradox is important to educational researchers because it challenges the propositions in the Western literature regarding the relationships amongst classroom environment, learning process and learning outcome (Biggs, 1994; Cheng & Wan, 2016). Therefore, when appropriate, this section relates the findings of the current study of the status of Hong Kong students' attitudes towards science to this paradox.

Chinese students' low self-concept in science has been reported in a number of previous studies (e.g. Neber, He, Liu, & Schofield, 2008; Tuan, Chin, & Shieh, 2005). The findings of the current study ($M = 2.618$ out of 4, SD = .552) echo previous observations, but contradict Chinese learners' outstanding performance in science. However, a significant and positive correlation has been found between Chinese students' self-concept in science and their achievement (Chang & Cheng, 2008; Wang, Oliver, & Staver, 2008). Therefore, the inconsistency between Chinese science learners' self-concept in science and their high science achievement should not indicate a negative relation between these two variables for Chinese students. Instead, the inconsistency may be caused by the long-standing Chinese cultural trait of valuing modesty. As stated in an old Chinese saying, 'Beyond a high mountain there is always a higher mountain; beyond a capable person there is always a more capable person (山外有山，人外有人)'. As reflected in this saying, the spirit of being modest and restraining self-revelation is long accepted in Chinese communities (Zhan & Wan, 2016). Therefore, although Chinese science students demonstrate a high performance in science, they have rated the items on self-concept in science low in the current study.

The average score of value of science to society is relatively high in the current study ($M = 3.152$, SD = .430), which is consistent with the finding of Tuan et al.'s study (2005) of 1407 Taiwanese junior secondary students ($M = 18.76$ out of 25). On the contrary, the relatively high score of enjoyment of science in the current study ($M = 3.117$, SD = .552) is different from the relatively low scores reported in other studies on Chinese learners. This dimension had a score of 2.71 out of 4 in Boone's study (1997), 2.60 out of 4 in Chang and Cheng's study (2008) and 4.67 out of 7 in Cheung's study (2009). The relatively high score of enjoyment of science in the current study may reflect the effect of science curricular reforms (such as scientific inquiry, STSE and the nature of science) introduced in the preceding section. These efforts can contribute to enriching the activities and contents in science classes and consequently enhance the enjoyment of science. The findings on students' perception of the values of science to society and enjoyment of science challenge the traditional impression that Chinese learners are overwhelmingly exam driven. They consider the value of science to society high and experience enjoyment in the process of learning science; these favourable perception and experience are positively and significantly associated with their achievement in science (Lin et al., 2012; Tuan et al., 2005).

Compared with students' tendency towards learning science in the classroom ($M = 2.969$, SD = .540), their enthusiasm to learn science outside the classroom ($M = 2.744$, SD = .578) and future participation ($M = 2.756$, SD = .721) are lower. Three studies investigated Chinese students' tendency towards learning science outside the classroom. It received the highest average score (3.05 out of 4) in Boone's study (1997) of 170 mainland Chinese junior secondary students. By contrast, it received the lowest score (2.07 out of 4) in Lin et al.'s study (2012), in which 8815 Taiwanese eighth graders were investigated. The score (20.38 out of 30) in Caleon and Subramaniam's study (2008) of 582 elementary Singaporean students was in the middle and similar to the result in the current study. Considerable differences are found amongst the results of the aforementioned studies on Chinese students' behaviour of learning science outside the classroom. Exploring the causes of such differences amongst Chinese learners in different regions is a meaningful direction for further research.

Although the recent science curricular reforms in Hong Kong may have contributed to the enhancement of Hong Kong overall students' enjoyment of science, significant gender differences still exist in the attitudes towards science of students in high-band schools. Previous studies have revealed some features of female students' science learning. They are more relational, cooperative and less competitive than their male counterparts (Alexopoulou & Driver, 1997). They benefit more from hands-on or inquiry-based learning (Cavallo & Laubach, 2001; Heard, Divall, & Johnson, 2000). Finally, they are more receptive to the visual depiction of scientific concepts or theories (Bunce & Gabel, 2002). Therefore, to reduce the gender difference amongst students in high-band schools, their science teachers should establish a more cooperative environment in their science classroom, provide sufficient opportunities for students to do hands-on activities and present abstract science contents through creative visual presentations.

Fouad (1995) reviewed research on the influence of extracurricular activities on students' learning in science and mathematics, identifying the positive effects of extracurricular activities on students' science performance. Moreover, as indicated in the study of junior high school students in Eastern Taiwan (Hong, Lin, & Lawrenz, 2008), female students improved more on their science performance than male students through extracurricular science intervention. One of the concerns of students being reluctant to participate in science extracurricular activities is that these activities occupy the time to be used to do academic works and so will negatively influence their science performance. Therefore, in order to enhance students' tendency of joining science extracurricular activities, teachers should show the beneficial effects of these activities on science achievement to students, which can to some extent relieve students' worry. Students' increased engagement in science extracurricular activities will not only enhance the science learning outcomes of all students as a whole, but also contribute to reducing the gender difference in their science performance.

As indicated in the findings of this study, the SEM fit indices for Models 3 and 4 were rather similar, so conclusions could not be made on the exact relationship between the cognitive and affective domains. One reason may be the sample size of the current study ($n = 360$) that was not very large and so might not be enough to detect the very fine variations in the tested models. Another reason may be the numbers of the sub-constructs under the cognitive and affective domains that were very small (each just has two), and so might not be able to generate enough variation for the compared models. Further study with a larger sample size and added sub-constructs in the cognitive and affective domains should be conducted to check if variations in the fit indices for these two models can be identified.

In this study, only quantitative method was adopted to explore the relationships amongst the three domains of attitudes towards science. Actually, in order to draw a more reliable inference into the causal relationships, both quantitative and qualitative studies are needed to generate both episodic knowledge (which is linked to concrete circumstances of specific events) and semantic knowledge (which is more abstract and decontextualised from specific situations) (Flick, 2009; Strube, 1989). Therefore, further efforts should also be made to adopt qualitative methods to reveal the detailed mechanism underlying the causal relationships amongst cognitive, affective and behavioural domains of attitudes towards science.

Note

1. Self-concept and self-efficacy are two related but different constructs in attitude area. Although both are related to one's competence perception, they reflect different time orientations. Self-concept tends to orient towards past accomplishments, while self-efficacy focuses on future expectation (Wigfield & Eccles, 2000). In addition, the assessment of self-concept is normally measured at more general levels, while self-efficacy is usually assessed at more specific levels (Bong & Skaalvik, 2003). For example, in Kind et al. (2007), only seven items were used to probe students' self-concept of science in a general sense. On the contrary, Lin et al. (2013) used a total of 32 items to investigate students' self-efficacy of five aspects of learning science. In this study, all the other six dimensions of attitudes towards science were assessed in a general sense and a limited number of items were adopted to assess each of them. In order to make all the dimensions of attitudes

towards science included in the same survey consistent and compatible, this study chose to include self-concept in science as one of the constructs covered in this research.

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