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Associations among attitudes, perceived difficulty of learning science, gender, parents' occupation and students' scientific competencies

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ABSTRACT

This study investigated the associations among students' attitudes towards science, students' perceived difficulty of learning science, gender, parents' occupations and their scientific competencies. A sample of 1591 (720 males and 871 females) ninth-grade students from 29 junior high schools in Shanghai completed a scientific competency test and a Likert scale questionnaire. Multiple regression analysis revealed that students' general interest of science, their parents' occupations and perceived difficulty of science significantly associated with their scientific competencies. However, there was no gender gap in terms of scientific competencies.

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Students' scientific competencies are central to science literacy. In order to help students to better prepare for the abilities needed in their future life and equip themselves with the basic science literacy necessary in modern society, developing students' scientific competencies has become one of the most essential objectives of science education (DeBoer, 2000; Kartal, Dogan, & Yildirim, 2017; Millar, 2006; Tsai, 2015). In 2006, science was the primary domain for the Programme for International Student Assessment (PISA) supported by the Organization for Economic Cooperation and Development (OECD). In contrast with other academic achievement-oriented international assessments, the objective of PISA focused on exploring how 15-year-old students apply knowledge of science and technology in daily life (Bybee, 2008; Bybee & McCrae, 2011; Olsen & Lie, 2011; Tsai, 2015). Especially, PISA 2006 science assessment gave priority to the students' scientific competencies, i.e. the ability to: (i) identify scientifically oriented issues; (ii) describe, explain or predict phenomena based on scientific knowledge; interpret evidence and conclusions; and (iii) use scientific evidence to make and communicate decisions (OECD, 2007, p. 29). PISA features these three key scientific competencies in terms of their associations with the practice of science and their connections to key abilities such as inductive and deductive reasoning, systems-based thinking, critical decision making, transformation of data to tables and graphs, construction of arguments and explanations based on data, thinking

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in terms of models and use of mathematics (Bybee, McCrae, & Laurie, 2009). However, PISA does not probe in depth student affective learning variables.

Research has found that students with positive attitudes towards science (such as the appreciation of the value of learning science) tend to perform better in related science subjects (Beaton et al., 1996; Freedman, 1997) and developing scientific literacy (Yaşar & Anagün, 2009). It has also found that student perception of difficulty in learning science is a major influence on students' choices of science subjects (Havard, 1996), their later career choices (Correll, 2001; Riegle-Crumb, Moore, & Ramos-Wada, 2011) and science achievement (Stankov, Morony, & Lee, 2014). In addition, gender differences have always been found in student performance (Osborne, Simon, & Collins, 2003) and parent social economic status including parent occupation plays a significant role in student learning (Johnson & Hull, 2014; OECD, 2014). However, it remains unclear how the above variables related to scientific competencies; there is a necessity for empirical studies to help elucidate these relationships so that better curriculum and instruction may be implemented to improve student affective constructs as both a learning outcome and factors affecting scientific competencies.

In order to fill the gap in the literature described earlier, this study empirically examined the associations among students' attitudes towards science, perceived difficulty of learning science and students' scientific competencies. Findings of this study will inform ongoing efforts to improve student development of scientific competences and attitude toward science.

Attitudes

In past decades, researchers have adopted different definitions of attitudes (Shah & Mahmood, 2011). Fishbein and Ajzen (1972) found more than 500 different operationalisations of the 'attitude-toward-object' concept in their review of attitude change research published over a 2-year period. Hogg and Vaughan (2005) defined attitude as 'a relatively enduring organisation of beliefs, feelings and behavioural tendencies towards socially significant objects, groups, events or symbols' (p. 150). Eagly and Chaiken (1993) proposed that attitudes are more malleable and temporary than a disposition; attitudes are tendencies rather than values, which serve as a guideline for a preferred state of existence. They also emphasise the evaluative nature of attitudes to distinguish from beliefs that are opinions about the nature of an object.

More and more researchers have adopted the ABC model of attitudes (Kind, Jones, & Barmby, 2007): 'A' for affective involves a person's feelings or emotions about the attitude object; 'B' for behavioural refers to the way attitude influences how we act or behave. For example: 'I will avoid cockroach and scream if I see one'. Finally, 'C' for cognitive involves a person's belief/knowledge about an attitude object. For example: 'I believe spiders are dangerous' (McLeod, 2009). Informed by the ABC model of attitudes, this study developed measures for the following attitude constructs: (i) Affective component: Interest in science-related topics, (ii) Behavioural component: Enjoyment of learning science and (iii) Cognitive component: General value of science.

Students' interest, enjoyment of leaning subjects and perceived value of the subjects are all found to play important roles in students' academic achievement (Fortier, Vallerand, & Guay, 1995; Hacieminoglu, 2016; Häussler & Hoffmann, 2000; Ratelle, Guay, Vallerand, Larose, & Senécal, 2007; Schibeci & Riley, 1986; Siegel & Ranney, 2003; Tosto, Asbury, Mazzocco, Petrill, & Kovas, 2016; Vallerand, Fortier, & Guay, 1997) as well as their course and career choices (Dawson, 2000). Interest and enjoyment are often found to have significant and positive correlation with related academic achievement (Dev, 2016; Güzeller, Eser, & Aksu, 2016; Pinxten, Marsh, De Fraine, Van Den Noortgate, & Van Damme, 2014). For instance, high achieving students are found to show more interest in subject-related activities (Dierks, Höffler, Blankenburg, Peters, & Parchmann, 2016). Lately, Jansen, Lüdtke, and Schroeders (2016) analysed a nationally representative German dataset of 39,192 ninth-grade students and found a unique effect of academic interest over and above the other predictors across the five domains including the math, German, biology, chemistry and physics, both for class grades and standardised test scores. In terms of enjoyment of learning science, students who enjoy learning science tend to be emotionally attached to learning and perceive learning science as a meaningful activity (Glaser-Zikuda & Mayring, 2003). And in turn, students who have more enjoyment of learning some subjects are more likely to regulate their learning and to solve problems creatively (Pekrun, Goetz, Titz, & Perry, 2002). With regard to value, according to Taylor and Graham (2007), values are defined as the perceived importance, attractiveness and usefulness of achievement-related activities, which are more rooted in cultural experiences (e.g. what people find attractive is partly shaped by their cultural context) and subject to societal influences (p. 53). They are also important predictors of students' achievement. For instance, Cole, Bergin, and Whittaker (2008) findings showed that the students' perceptions of three task values (interest, usefulness and importance) significantly predicted test-taking effort and performance.

Perceived difficulty in learning science

Students hold beliefs about their capabilities for learning science, and these self-perceptions about personal abilities to manage engagement with science have been shown to causally influence success through motivation and the ability to do what is necessary in a given science learning situation (Evans, 2015). In student perceptions, science is more a 'love–hate' subject than other subjects (Hendley, Stables, & Stables, 1996). And previous findings showed that there is a reciprocal relation between academic performance and confidence in learning (Ganley & Lubienski, 2016). Students who expressed high levels of self-confidence of learning science have been found to have higher academic achievement (House, 2011; Mohammadpour, Shekarchizadeh, & Kalantarrashidi, 2015). On the contrary, students who lack confidence in their ability to learn what they judge to be important and to overcome difficulties may not find success, not only at school but also in their adult lives (OECD, 2007). For instance, House and Telese (2017) examined the relationship between confidence in science and achievement test scores for a national sample of fourth-grade students from Korea who participated in the TIMSS (Trends in International Mathematics and Science Study) 2011 assessment. They found that students who showed high achievement levels in science were more likely to report that they learned things quickly in science and did well in science; yet students who expressed negative comparisons of themselves to others tended to have lower science achievement.

Gender differences

Gender differences in interest, participation, career choices, performance in science are always the most controversial issues (Furnham, Reeves, & Budhani, 2002; Ganley & Lubienski, 2016; Gardner, 1974; Greenfield, 1996; Helgeson & Gollob, 1991; Hyde, Lindberg, Linn, Ellis, & Williams, 2008; Jones, Howe, & Rua, 2000; Keeves & Kotte, 1992; Kiefer & Sekaquaptewa, 2007; Osborne et al., 2003). Barrington and Hendricks (1988) conducted a survey regarding attitudes towards science and scientific knowledge to 143 third-, seventh- and eleventh-grade students, and they found gender as a separate variable did not have a significant main effect in any of the comparisons. Similarly, Greenfield (1996) also found no consistent gender differences in science achievement and very few in science attitudes and perceptions. In contrast, Jones et al. (2000) examined sixth-grade students' attitudes and experiences related to science. Their results showed that there continue to be significant gender differences in science experiences, attitudes, and perceptions of science courses and careers. Science achievement gender differences also have been observed in different countries (OECD, 2013), for instance, while girls do better in science in Caribbean Islands and India, the boys take more advantage in Canada and Hong Kong (Acar, Türkmen, & Bilgin, 2015). Analyses of ROSE (Relevance of Science Education) data indicate that there is a consistent gender differences in science-related affective variables, for instance, girls' and boys' interests are context dependent and growing with level of development; girls show more concerns for the environment than boys; there are fewer girls than boys who want to become scientists or want to get a job in technology (Sjøberg & Schreiner, 2010).

Parents' occupation

Parents have been regarded as important sociocultural agents (Dunkley, Wertheim, & Paxton, 2001; Rodgers, Faure, & Chabrol, 2009; van den Berg, Thompson, Obremski-Brandon, & Coovert, 2002). Parental factors including parents' socioeconomic status (Johnson & Hull, 2014) and parents' occupations (OECD, 2014) have positive relationships with their children's school performance (Breakwell & Beardsell, 1992; George & Kaplan, 1998; Hanson & Ginsburg, 1988; Lareau, 1987; Osborne et al., 2003; Papanastasiou, 2002; Shoraka, Arnold, Kim, Salinitri, & Kromrey, 2015). For example, PISA 2012 asked participating students about their parents' occupations. The results showed that students whose parents work in professional occupations generally outperform other students in mathematics, while students whose parents work in elementary occupations tend to underachieve compared to their peers, and it also found that the gap in performance between the children of professionals and other students tend to be widest in mathematics and narrower in reading (OECD, 2014).

One of the central goals of school science education is to develop students' competencies such as creating or using conceptual models to make predictions or give explanations, analysing scientific investigations, relating data as evidence, evaluating alternative explanations of the same phenomena and communicating explanations with precision (Bybee, 2008; Nentwig, Roennebeck, Schoeps, Rumann, & Carstensen, 2009; Tsai, 2015). Although earlier studies showed that above factors such as students' attitudes towards science, perceive difficulty of learning science, gender and parents' occupation have played important roles in students' academic achievement, unfortunately, few reports in the literature examined their associations with students' scientific competencies. Exploring potential factors of attitude towards science, student perceived difficulty of learning science as well as gender and parent occupation associated with students' scientific competencies will make contributions to new knowledge and inform improving students' science literacy and facilitating them to build solid abilities for lifelong learning. Accordingly, the main purpose of this study is to examine the associations between the aforementioned factors and students' scientific competencies. This study will answer the following research questions:

(1) Are students' attitudes towards science including general interest in science-related topics, enjoyment of learning science and general value of science associated with students' science competencies?
(2) Is students' perceived difficulty of learning science associated with students' science competencies?
(3) Is there a gender gap in terms of students' science competencies?
(4) Are parents' occupations associated with students' science competencies?

Method

Samples and procedures

The population of this study is all ninth-grade students in Shanghai, China. Shanghai as an advanced economically developed city in China achieved best overall scientific competences in 2009 and 2012 PISA assessment (OCDE & OECD, 2014; OECD, 2010). We randomly selected one district consisted of 29 junior high school from 19 districts in Shanghai. Two paper–pencil tests were conducted in this study: a scientific competencies test and a Likert scale questionnaire to examine students' interest in school science-related topics, enjoyment of learning science, general value of science, parents' occupations and perceived difficulty of science. Note that the questionnaire was conducted 1 month after the scientific competencies test, although we assumed that the factors measured from the questionnaire such as students' attitudes towards science and parents' occupation should not change within 1 month, yet caution is still needed in the interpretation of the results. A total of 2617 ninth graders participated in each of the two paper–pencil tests. Because 1026 students who did not provide the personal information either in the scientific competencies test or the Likert scale questionnaire, only 1591 students (720 males and 871 females) were successfully matched for the test and questionnaire. Independent sample *t*-tests showed that, on average, there was no significant difference between the 1591-sample and the 1026-sample in terms of scientific competencies and Likert scale questionnaire. Thus the sample of 1591 (720 males and 871 females) ninth-grade students was used for the final analysis.

Measures

Scientific competencies test

Scientific competencies as dependent variable measured in the current study followed the PISA 2006 assessment framework including (i) identify scientifically oriented issues; (ii) describe, explain or predict phenomena based on scientific knowledge; interpret evidence and conclusions; (iii) and use scientific evidence to make and communicate decisions. The scientific competencies test was composed of 24 items derived from a shortened version of the released test questions from PISA 2006. Selection of the 24 items was based on the consideration of the coverage of all the three PISA scientific competence dimensions and the variation of item difficulties. Item formats included selected response and constructed response. Selected response items included either standard multiple choice with four responses from which students were required to select the best answer or complex multiple choice presenting several statements for each of which students were required to choose one of two possible responses (yes/no, true/false, correct/incorrect, etc.). Open-ended constructed response items required a response to be generated by the student, with a range of possible partial and full-credit answers (OECD, 2007). In this study, the scientific competencies test consisted of 10 multiple choice items, 4 complex multiple choice items and 10 open-ended constructed response items.

Using the scoring rubric provided by PISA, six research assistants participated in the scoring, one item was required to be scored by two assistants. All of the research assistants were trained for scoring over 6 hours and were asked to score randomly on the open-ended constructed response items independently with the rubric. An inter-rater reliability analysis using the Kappa statistics was performed to determine consistency between raters. The inter-rater reliability for the raters was found to be Kappa = .98 ($p < .001$), indicating almost perfect agreement (Landis & Koch, 1977).

In the past 30 years, Rasch measurement has been increasingly used in a wide variety of disciplines (Liu & Boone, 2006) and is becoming the convention of developing quality measurement instruments for many well-known assessment programs such as PISA, TIMSS and PIRLS (Progress in International Reading Study) data (Boone, Townsend, & Staver, 2016; Royal, Ellis, Ensslen, & Homan, 2010). The Rasch model provides evidence of construct validity by fit statistic (Royal et al., 2010). When there is a good model data fit, measures produced by the instrument are interval, the interval scale measures have precise measurement errors for both individual items and subjects, allowing for inferential statistical analyses to be conducted with more power. Compared with classical test theory (CTT), Rasch model has several advantages (Sussman, Beaujean, Worrell, & Watson, 2013), i.e. while CTT analyses attach less importance to the functioning of specific items (McDonald, 1999), Rasch analyses can identify poor response patterns of items and person performance, informing how well the data fit the model, and detecting weak, biased and redundant items (Hula, Doyle, McNeil, & Mikolic, 2006; Thissen & Steinberg, 1988).

In this current study, Rasch measurement was used to investigate the quality of the instrument of scientific competencies. Specifically, we used person separation index and item separation index provided by Winsteps (Linacre & Wright, 2000) to evaluate the reliability of the instrument. The person separation index is an estimate of the adjusted person standard deviation divided by the average measurement error, indicating how well the instrument can discriminate persons on the measured variable. The item separation index indicates an estimate in standard error units of the spread of separation of items along the measurement construct (Kim, Wang, & Ng, 2010). The reliability separation index greater than two is considered adequate (Bond & Fox, 2013).

With regard to the substantive aspect of validity, our evaluation of the instrument focused on item quality proposed by Liu and Boone's (2006) framework of validity evidence. According to Liu and Boone (2006), 'if assessment data fit the Rasch model well, then there is evidence to claim that the originally hypothesised dimension or construct exists, and is assessed by the instrument, thus providing evidence for content and construct validity' (Liu & Boone, 2006, p. 6). We examined item quality indices (i.e. the mean square residual (MNSQ), the standardised mean square residual (ZSTD)) for each item from the rating scale model as implemented in Winsteps computer program (Linacre, 2011). MNSQ and ZSTD are typically used as the fit indicators to examine how well each item accords with the Rasch unidimensional model. Item MNSQ has an expected value of 1.0 and a range from zero to infinity. MNSQ values greater than 1.0 indicate the data are less predictable than the model expects (underfit), e.g. an MNSQ of 1.4 indicates that there is 40% more randomness in the data than modelled. MNSQ values less than 1.0 indicate fits better than expected (overfit), e.g. an MNSQ of .6 indicates a 40% deficiency in Rasch model-predicted randomness. Based on Linacre's suggestion (Linacre, 2011), items fit the model when their MNSQs fall within the range of .6–1.4 and ZSTD values within the range of −2 to +2; a positive ZSTD indicates that responses are worse than expected; a negative ZSTD indicates that responses are better than expected (Bradley, Peabody, & Mensah, 2016). Item-measure correlations (point-measure correlation (PTMEA)) were also examined in this study; zero or negative PTMEA indicates a rating scale with reversed direction (Nam, Yang, Lee, Lee, & Seol, 2011).

Based on the analysis of the instrument, the person separation index was 2.00, with an equivalent Cronbach's reliability coefficient (α-value) of .80. Item separation index was 24.04, and its corresponding Cronbach's α-value was 1.00, indicating reliable item and person estimation. Having inspected the fit statistics for all 24 items, we found the mean of the item infit mean squares (MNSQs) at .99 and the outfit mean squares (MNSQs) at 1.00, which were very close to the expected value of 1. The mean infit ZSTD at .0 and outfit ZSTD at .0 were both inside the conventionally acceptable range of −2 to +2. The inspection of the fit statistics for all 24 items (seen in Table 1) showed that all the 24 items had infit and outfit MNSQs within the acceptable range of .6–1.4 (Linacre, 2006). Given the large sample size, we placed more emphasis on non-standardised MNSQs. None of the items had a zero or negative PTMEA; all of the PTMEA had positive values ranging from .21 to .66, which indicated that all of the 24 items contributed to the measurement of students' scientific competencies. To sum up, those results have revealed that the measures from this instrument are reasonably valid and reliable.

Further, a good measurement instrument should be able to show that a distribution of item measure is approximately equivalent to a distribution of person measure. The Wright map showed the distributions of item difficulties and person ability measures along the same linear scale in logit units (Liu, 2010). From Figure 1, we can see that the left-hand column located the person ability measures along the scale, and the persons had a normal distribution and the range of variation of students' scientific competencies were covered by the items. The item difficulty measures were almost as wide as the range of person ability measures, indicating that this instrument had the items that could target subjects with high variations in terms of scientific competencies.

Table 1. Fit statistics for items.

Items		Measure	S.E.	IN.MNSQ	IN.ZSTD	OUT.MNSQ	OUT.ZSTD	PTMEA
1	E6	2.21	.05	1.11	4.65	1.24	4.78	.030
2	U6	2.08	.04	.95	1.83	.90	3.00	.55
3	U4	1.45	.03	.87	5.30	1.07	1.46	.62
4	I62	1.43	.04	1.01	.57	1.02	.84	.50
5	I61	1.23	.04	.90	3.63	.89	3.77	.56
6	I43	1.20	.04	.91	5.09	.93	2.41	.50
7	E4	.99	.04	.97	1.98	.94	2.07	.47
8	U5	.93	.03	.84	7.34	.80	7.49	.66
9	I42	.70	.04	1.03	1.50	1.04	1.77	.42
10	I31	.27	.05	1.28	9.90	1.40	9.90	.21
11	E33	.12	.05	1.13	6.21	1.20	5.60	.33
12	I41	.10	.05	.96	1.87	.94	1.69	.46
13	I32	.07	.05	.92	3.61	.85	3.82	.49
14	E32	.08	.03	1.18	5.70	1.26	3.59	.51
15	U3	.24	.05	.86	6.08	.83	4.27	.52
16	E21	.38	.05	1.07	2.56	1.09	2.01	.36
17	E24	.47	.05	1.17	6.24	1.39	7.36	.25
18	E23	.82	.05	1.06	1.97	1.02	.38	.35
19	U2	1.20	.06	.85	4.23	.74	3.76	.47
20	E31	1.49	.06	.95	1.19	.88	1.38	.38
21	E11	1.54	.07	1.06	1.31	1.09	1.10	.28
22	I2	1.77	.07	.98	.29	.94	.48	.32
23	E22	2.10	.08	.91	1.51	.79	1.84	.35
24	E12	2.55	.09	.86	1.95	.67	3.42	.36

Likert scale questionnaire

This study aimed to explore the potential factors affecting the students' scientific competencies, specifically, Interest in school science-related topics (Interest), Enjoyment of learning science (Enjoyment), General value of science (Evaluation), Parents' occupations (PC), gender, Students' perceived difficulty of science (Difficulty) were examined as independent variables. Except for the information of the parents' occupation, this study adopted those variables from the ROSE questionnaire (Sjøberg & Schreiner, 2010). Different from PISA and TIMSS, the ROSE Survey focuses on student affective constructs as both learning outcomes and factors affecting learning; it is an international assessment and has been conducted in over 40 countries. The ROSE Survey is a 250 item questionnaire covering 15-year-old students' interests, perceptions, experiences, attitudes, plans and priorities relevant to the learning of science and technology (Jenkins & Nelson, 2005); the validity, reliability and credibility of the ROSE questionnaire were well documented (Chang, Yeung, & Cheng, 2009). In this study, students were required to finish the whole ROSE questionnaire, but the data analysed and presented in this paper were a total of 122 items extracted from 4 out of 9 sections (Sections A, C, E and F) of ROSE questionnaire, which were categorised into 4 dimensions of Interest (108 items: sections A, C, E, Cronbach's $\alpha = .98$), Enjoyment (4 items: F2, F5, F6, F15, Cronbach's $\alpha = .77$), Evaluation (8 items: F4, F7-F13, Cronbach's $\alpha = .89$), Difficulty (2 items: F1 and F3, Cronbach's $\alpha = .67$). Each item was composed of a statement and a 4-point Likert response from not interested/disagree/ to very interested/agree (seen in Table 2). Note that in the original ROSE questionnaire: Sections A, C and E consists of 108 items to probe what possible topics students are interested in learning. Because it is rather lengthy with totally 108 items, the items were grouped into 3 sections to avoid fatigue from the students. Section F originally consists of 16 items that are designed to provide

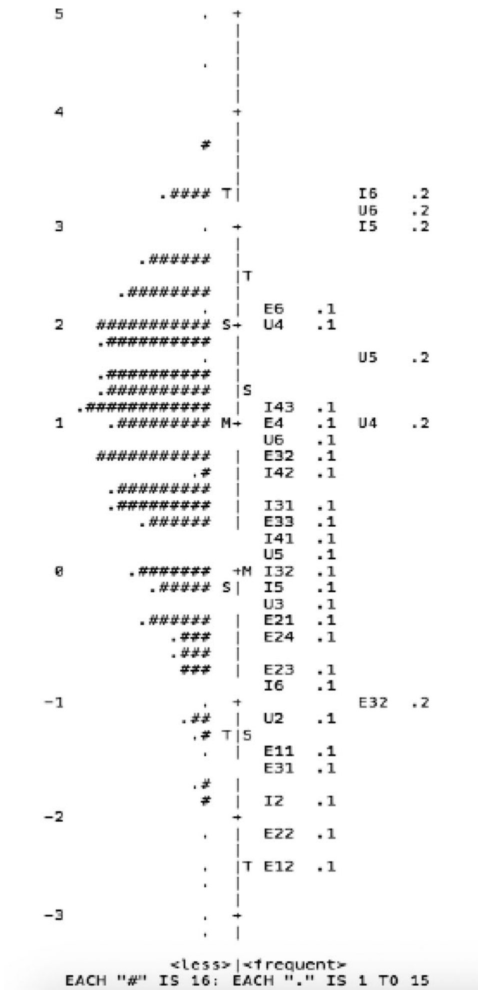

Figure 1. Wright map for the distributions of item difficulties and person abilities.

information about different aspects of the students' perception of their science learning, such as their self-confidence in their own abilities in science at school, their perceptions of the necessity of science education, etc. (Schreiner & Sjøberg, 2004). We selected items from those 16 items relevant to 3 dimensions: Enjoyment, Evaluation and Difficulty. Three experts reviewed those items; all of the experts are university professors with advanced education in science education (i.e. Ph.D.).

Data analysis

The study's main statistical analysis was hierarchical multiple regression analysis using IBM SPSS Statistics 22.0 to test whether there are associations between the aforementioned factors and students' science competencies. Originally, the responses of Interest, Enjoyment, Evaluation and Difficulty were scored from '1' to '4'; higher scores indicated higher degrees of interest or agreement. Considering that the original design of the

Table 2. The illustration of the independent variables.

	Variables	Total number of items	Examples
Attitude toward science	Affective component: Interest in science-related topics	108	***From Not interested to very interested:*** A1. Stars, planets and the universe C7. How computers work
	Behavioural component: Enjoyment of learning science	4	***From disagree to agree:*** F2. School science is interesting F5. I like school science better than most other subjects F6. I think everybody should learn science at school F15. I would like to have as much science as possible at school
	Cognitive component: General value of science	8	***From disagree to agree:*** F4. School science has opened my eyes to new and exciting jobs F13. School science has taught me how to take better care of my health
Parents' occupation		1	1. Clerical support workers 2. Skilled workers 3. Craft and related trades 4. Professionals 5. Managers
Gender		1	Female/male
Perceived difficulty of learning science		2	***From disagree to agree:*** F1. School science is a difficult subject F3. It is easy to learn science (reverse coding)

ROSE survey might violate some assumptions of the Rasch model analysis (i.e. unidimensionality and local independence), we did not use Rasch measurement for the ROSE items. Instead, given that ROSE variables are ordinal variables rather than numerical variables, we converted the responses into dummy variables respectively for analysis: Interest (Interested = 1, original mean scores of 108 items are no less than 2.5; Non-interest = 0, original mean scores of 108 items are below 2.5); Enjoyment (Enjoyment = 1, original mean scores of 4 items are no less than 2.5 and Non-enjoyment = 0, original mean scores of 4 items are below 2.5); Evaluation (Appreciation = 1, original mean scores of 8 items are no less than 2.5 and Non-appreciation = 0, original mean scores of 4 items are below 2.5); Difficulty (Difficulty = 1, original mean scores of 2 items are above 2.5 and Non-difficulty = 0, original mean scores of 2 items are below 2.5). We also converted parents' occupation into eight dummy variables: father/mother_CSW (clerical support workers = 1, professionals = 0); father/mother_SW (skilled workers = 1, professionals = 0); father/mother_CRT (craft and related trades = 1, professionals = 0); father/mother_managers (managers = 1, professionals = 0) and dummy gender variable (Male = 0; Female = 1).

Results

Descriptive statistics and correlation

Table 3 presented descriptive statistics and correlations of the variables. The mean scientific competencies Rasch measures of students who are interested (mean = 1.08 logits, SD = 1.14) are higher than those who are not (mean = .83 logits, SD = 1.10); students who prefer science (mean = 1.04 logits, SD = 1.14) have higher mean scientific competencies

Table 3. Correlation and descriptive statistics.

Variables	1	2	3	4	5	*M*	SD
1. Scientific competencies						.98	1.13
2. Interest	.107**					Non: .83 Interest: 1.08	Non: 1.10 Interest: 1.14
3. Enjoyment	.082**	.327**				Non: .84 Enjoyment: 1.04	Non: 1.09 Enjoyment: 1.14
4. Evaluation	.073**	.364**	.568**			Non: .82 Appreciation: 1.03	Non: 1.17 Appreciation: 1.12
5. Difficulty	−.078**	−.061*	−.242**	−.146**		Non: 1.09 Difficulty: .91	Non: 1.14 Difficulty: 1.12
6. Gender	.024	.040	.010	.030	.077**	Male: .95 Female: 1.01	Male: 1.16 Female: 1.10
7. F_csw	−.037	−.005	−.012	−.018	.017	.89	1.09
8. F_sw	−.129**	−.045	.024	−.008	−.008	.81	1.09
9. F_crt	−.055	−.026	−.007	.031	.052	.76	.98
10. F_manager	.052	−.016	−.024	.023	.004	1.14	1.09
11. M_csw	−.020	.004	.023	.020	.051*	1.02	1.06
12. M_sw	−.142**	−.020	−.010	−.018	−.005	.73	1.00
13. M_crt	−.125**	−.015	−.010	−.010	−.018	.67	1.09
14. M_manager	.042	−.034	−.037	−.012	.009	1.11	1.08

Note: M = mean score of science competencies.
**$p < .01$.
*$p < .05$.

Rasch measures than those who do not prefer science (mean = .84 logits, SD = 1.09); students who appreciate science (mean = 1.03 logits, SD = 1.12) also have higher mean scientific competencies Rasch measures than those who do not appreciate science (mean = .82 logits, SD = 1.17); yet students who perceive difficulty of learning science (mean = .91 logits, SD = 1.12) have lower mean scientific competencies Rasch measures than those who do not (mean = 1.09 logits, SD = 1.14). The results also showed that females have higher mean scientific competencies Rasch measures (mean = 1.01 logits, SD = 1.10) than males (mean = .95 logits, SD = 1.16). Students with fathers (mean = 1.42 logits, SD = 1.10) or mothers (mean = 1.40 logits, SD = 1.10) working in professional occupations outperform other students in terms of science competencies, while students with fathers (mean = .76 logits, SD = .98) or mothers (mean = .67 logits, SD = 1.09) working in craft and related trades tend to underachieve compared to their peers.

Except six variables (gender, F_CSW, F_CRT, F_manager, M_CSW, M_manager), all the other seven variables were significantly associated with scientific competencies. The correlation results revealed that all the three attitudes variables were not only significantly associated with scientific competencies but also had significant relationships with each other. The perceived difficulty of learning science had significantly negative relationships with scientific competencies ($r = -.078$, $p < .01$) and significantly positive correlations with gender ($r = .077$, $p < .01$).

Regression analysis

Regression results indicated a statistically significant effect; approximately 4.5% of the total variance was explained by these factors ($p < .01$). As observed in Table 4, attitudes ($R^2 = .014$, $p < .01$), perceived difficulty of learning science ($R^2 = .004$, $p < .05$) and

Table 4. Regression results.

Variables		B	SE	β	R^2	
Attitudes	Interest	.186**	.063	.079	.011**	.014*
	Enjoyment	.089	.078	.036	.002*	
	Evaluation	.052	.086	.019	.000	
Difficulty		−.146*	.059	−.063	.004*	
Gender		.048	.056	.021	.001	
Parents' occupation	F_CSW	−.174**	.121	−.039	.017*	.027*
	F_SW	−.197*	.078	−.082		
	F_CRT	−.165	.130	−.036		
	F_manager	−.030	.078	.012		
	M_CSW	−.004	.080	.001	.010*	
	M_SW	−.236**	.091	−.076		
	M_CRT	−.324**	.109	−.083		
	M_manager	−.031	.087	.010		

Note: Total explained variance = .045*; father/mother_CSW refers to clerical support workers; father/mother_SW refers to skilled worker; father/mother_CRT refers to craft and related trades; father/mother_managers refers to managers; reference group: professionals.
**$p < .01$.
*$p < .05$.

parents' occupation ($R^2 = .027$, $p < .01$) significantly predicted students' scientific competencies.

In terms of attitudes, after controlling all the other variables, only interest significantly predicted scientific competencies ($b = .186$, $p < .01$), students who had more general interest in science-related topics had significant higher scientific competencies Rasch measures than those who were less interested. Students who perceived science to be difficult to learn had significantly lower scientific competencies Rasch measures than those who perceived learning science as being easy ($b = -.146$, $p < .05$). On average, taking into account other variables, there was no significant gender difference in terms of scientific competencies Rasch measures ($b = .048$, $p > .05$). Both father's ($R^2 = .017$, $p < .01$) and mother's ($R^2 = .010$, $p < .01$) occupation had significant correlations with students' scientific competencies. Students with fathers working in professional occupations significantly outperformed the students with fathers who were skilled workers ($b = -.197$, $p < .05$) or clerical support workers ($b = -.174$, $p < .05$). Similarly, students with mothers working in professional occupations significantly outperformed the students with mothers who were skilled workers ($b = -.236$, $p < .01$) or craft and related trades ($b = -.324$, $p < .01$).

Discussion

This study aimed to explore the associations among attitudes including interest, enjoyment, evaluation of science; perceived difficulty in learning science; gender and parents' occupation and ninth-grade students' scientific competencies. Although numerous studies reported that positive attitudes towards science are critical in science learning with increased enrolment in science courses, science achievement and interest in scientific careers (e.g. Blalock et al., 2008; Cannon & Simpson, 1985; Gauld & Hukins, 1980; Germann, 1988; Hill, Atwater, & Wiggins, 1995; Hough & Piper, 1982; Rennie & Punch, 1991; Simpson, 1978; Wyer, 2003), none of them examined the direct effects on students' scientific competencies. The results showed that taking into account other variables, only students' general interest in science significantly predicted students' scientific competencies. In this regard, the current study brings about a new addition to the knowledge base of research regarding the direct effects of attitudes towards science on students' science academic success.

Until now, females still continue to be less likely to pursue science, technology, engineering and mathematics careers than their counterparts (Ceci & Williams, 2007; National Science Foundation, 2011; Wang, Eccles, & Kenny, 2013). Females are often taught such ideas as that science is a male domain (Nosek et al., 2009). In the current study, aligned with the previous studies (e.g. Greenfield, 1996), we found that holding constant other variables, there was no gender gap in terms of ninth-grade students' scientific competencies. Yet the results indicated that the perceived difficulty in learning science was significantly associated with students' scientific competencies and more female students agreed that school science is a difficult subject than their male peers, which was significant.

In addition, this study found that, on average, students with parents working in professional occupations significantly outperformed the students with fathers who were skilled workers or clerical support workers, and students with mothers who were skilled workers or craft and related trades in terms of scientific competencies.

Overall, this study confirmed that students' general interest in science, perceived difficulty of science and parents' occupation are significantly associated with ninth-grade students' scientific competencies. However, this study has some limitations. First, despite accounting for many statistically significant factors associated with scientific competencies, our regression model only explained a small portion of variance (4.5%), suggesting that many other important contributors have not been taken into consideration. Second, we only provided students five choices of parents' occupation; future research may give more choices for students. Third, having been limited by the original ROSE questionnaire, the numbers of items for measuring the potential factors were unequal and limited, insufficient to produce scale scores. As the result, we only coded student responses to those variables as dummy variables. Fourth, this study only examined the main effect; future research can also explore the interaction effect of those factors.

Disclosure statement

No potential conflict of interest was reported by the authors.

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