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The suppression role of positive affect on students' science achievement in East Asia: the example of Taipei

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Abstract This study focuses on "high achievement but low motivation" phenomenon that is prevalent in East Asian countries and districts, and uses eighth graders in Taipei that participated in TIMSS 2007 as an example to examine the direct and indirect effects of academic motivation, positive affect, and instruction on science achievement. Confirmatory Factor Analysis and Structural Equation Modeling were employed to test measurement and structural models and indicated a good fit of the models to the data. The results showed that expectancy and value in science and inquiry-based instruction are three significant and positive predictors of students' positive affect toward science. In addition, expectancy, positive affect, and three types of instruction all significantly predicted students' science achievement after the number of books at home and mother's education were controlled. However, inquiry-based and practice-based instructions were negative predictors whereas traditional instruction was positive. The suppression role of the positive affect was partially supported between academic motivation and science achievement.

Keywords Academic motivation · Affect · Science achievement · Suppression effect · Taipei · TIMSS

1 Introduction

During the last two decades, international large-scale assessments, including the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA), have been constructed and administered to measure and compare students' performance all over the world.

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These assessments consistently reported that students in East Asia are ranked at the top in all of the subjects assessed. However, this is in stark contrast to the fact that the same group of students is also ranked the lowest in self-confidence, interest, and perceptions of value in learning science (Chang and Cheng 2008; Martin et al. 2004). Unfortunately, students in Chinese Taipei are no exception to this “high achievement but low motivation” phenomenon. The science achievement of eighth-grade students in Taipei was the highest in TIMSS 1999 and the second highest, behind only Singapore, between TIMSS 2003 and 2011. Although the average scores of their science achievement in TIMSS were always 80 points higher than the international average (National Center for Education Statistics 2010), in TIMSS 2003, only 28 % of the Taipei students were categorized in the group of high self-confidence in learning science, and only 26 % were categorized as viewing science with high value. The situation was even worse for the enjoyment in learning science: as few as 16 % of the students reported high enjoyment and 49 % reported low enjoyment (Martin et al. 2004).

Although a positive association has been well-established in the literature between students’ self-perceived attitudes and science achievement (Areepattamannil et al. 2011; Hassan 2008; Osborne et al. 2003; Papanastasiou and Zembylas 2004; Singh et al. 2002), the association has mostly been examined in Western cultures. There are vast variations in people’s self-perceptions between Western and Eastern cultures, and the relationship between individuals’ self-perceived attitudes and academic achievement in Eastern cultures might look different from that in Western cultures (Markus and Kitayama 1991; Nisbett and Masuda 2003; Schütte 2015). What adds to the complexity of this relationship is the fact that the self-perceived attitudes have often been treated as one variable in TIMSS and PISA. Yet this single construct includes eleven sub-constructs that refer to different aspects of the attitudes, thus, it fails to capture the differences between motivation and affect, two of the eleven sub-constructs (Osborne et al. 2003). In addition, the relationship between motivation and affect might be less straightforward than it appears, and affect might serve as a mediator between motivation and academic achievement (Pekrun 2006; Pekrun et al. 2007, 2009).

Furthermore, besides self-perceived motivation and affect, students’ science achievement is influenced by many other factors, such as instructional strategies (House 2005, 2008; Jiang and McComas 2015; Schroeder et al. 2007; Reynolds and Walberg 1991; Young et al. 1996). Despite the importance of instructional strategies, only a few studies have compared the effects of different instructions on students’ science achievement in Taiwan, and the results remained inconclusive (Chang 2001, 2002a, b, 2003; Chang and Mao 1999a, b). Additionally, compared with many studies on other East Asian countries, such as Singapore (Chinoh, and Fraser 2009; Ng et al. 2012; Tan et al. 2007) and Japan (House 2006, 2007, 2009; House and Telese 2008), there has been limited research on students’ science achievement in Taipei, the capital of Taiwan. Therefore, less is known regarding the interrelationships of motivation, instruction, positive affect, and science achievement among Taipei students.

In order to fill these gaps in the literature, this study focused on the relationship between students’ self-perceived motivation, affect, and academic achievement in

East Asia. It used Chinese Taipei as a representative case to explore how motivation, instruction, and positive affect influence students' science achievement and what role positive affect plays in this relationship. Because this study used the TIMSS dataset to analyze these relationships, it could provide a different picture than PISA regarding students' science achievement and contributing factors. The following three research questions were addressed in the current study.

Research question 1: How do achievement motivation and different types of instruction directly contribute to eighth-grade students' positive affect toward science in Taipei?

Research question 2: How do achievement motivation, different types of instruction, and positive affect directly contribute to eighth-grade students' science achievement in Taipei?

Research question 3: Does positive affect mediate the relationships between academic motivation, different types of instruction, and eighth-grade students' science achievement in Taipei?

2 Literature review

2.1 Motivation, affect, and science achievement

2.1.1 Motivation, affect, and science achievement in general

The construct of motivation has existed in the field for several decades. There are various ways of conceptualizing motivation in the literature, such as self-efficacy, intrinsic and extrinsic motivation, interest, and achievement motivation. Among the many theories on achievement motivation is expectancy-value theory that has been widely used to explain students' motivation (Murphy and Alexander 2000). According to this theory, two aspects are important in achievement motivation: one is individuals' expectancies or beliefs about how capable or competent they are when completing a task; the other is individuals' subjective task values, or the values that they view in completing the task. People who believe they are competent and see values in tasks are more likely to try harder and perform better, even when they face challenging tasks (Bandura 1997; Eccles and Wigfield 2002; Schunk 1991; Wigfield 1994; Wigfield and Eccles 2000, 2002). Expectancy and values are also significant predictors of students' science achievement (DeBacker and Nelson 1999; Ng et al. 2012). For instance, DeBacker and Nelson (1999) concluded that expectancy significantly predicted females' science achievement and persistence, while higher perceived values were related to male students' higher science achievement and more efforts that were put in learning science. However, fewer studies have applied expectancy-value theory to understand science achievement in Asian contexts. This is in contrast to many studies using the concepts of self-efficacy and intrinsic and extrinsic motivation (Pajares et al. 2000) as well as focusing on the relationship between academic motivation and mathematics achievement (Pajares and Graham 1999).

Affect, or emotion,[1] is another crucial variable in students' academic achievement (Alsop and Watts 2003; Linnenbrink 2007; Meyer and Turner 2006; Pekrun et al. 2009; Schweinle et al. 2006). In general, positive affect, such as enjoyment and pride, facilitates memory, self-regulation, creativity, and higher-order thinking. It also increases persistence and mastery-approach motivation goals. On the other hand, negative affect, such as anxiety, anger, and hopelessness, is detrimental to students' performance and attainment (Aspinwall 1998; Fiedler 2001; Meece et al. 1990). However, other positive affects, such as relief, are associated with a decrease in engagement, thus leading to reduced achievement (Feldman et al. 1999), whereas a small amount of frustration or anxiety can improve attention, thus, leading to better performance and engagement (Pekrun et al. 2007).

As two key predictors of students' science achievement, motivation and affect are often discussed as the same variable, attitudes toward science, particularly in TIMSS and PISA. Osborne et al. (2003) reviewed the literature and identified eleven frequently used components of attitudes toward science, including the perception of the science teacher, anxiety toward science, the value of science, self-esteem in science, motivation toward science, enjoyment of science, and attitudes of parents toward science. Each component covers a wide range of topics, therefore, the variable, attitudes toward science, does not represent a single construct. For this reason, conceptualizing motivation and affect by using the same construct of attitudes toward science does not yield reliable and meaningful results (Eklöf 2007; Gardner 1975; Osborne et al. 2003; Reiss 2005).

In addition, the relationship between motivation and affect is not as straightforward as it appears. Affect in science could be considered both a predictor and an outcome variable. On the one hand, overall, students who show more positive affect toward science will perform better than their peers who do not hold the same attitudes (Papanastasiou 2002). On the other hand, the better the students perform in science, the more positive affect they generate in their studies (Beaton et al. 1996). Recently, Pekrun and colleagues (Pekrun 2006; Pekrun et al. 2007, 2009) developed a new construct of achievement emotion, which was defined as "emotions tied directly to achievement activities or achievement outcomes" (Pekrun 2006, p. 317). They demonstrated that this construct functioned as a mediator between the achievement goals and performance attainment of 213 undergraduate students. This mediation effect still existed even after gender, social desirability, trait affectivity, and scholastic ability were controlled. Nevertheless, this mediation effect has never been tested in Eastern cultures.

2.1.2 Motivation, affect, and science achievement in Taiwan

The educational system of Taiwan spans over four levels before college: kindergarten (K), elementary school (Grades 1–6), junior high school (Grades 7–9), and senior high school or vocational school (Grades 10–12). Although junior

[1] Although affect can be defined as broadly as including interest, motivation, attitude, beliefs, self-confidence, and self-efficacy (Alsop and Watts 2003), it has a narrow meaning in this article, that is, it only focuses on feelings or emotions. At the same time, affect is used interchangeably with emotion here, but the author agrees with Pekrun et al. (2009) in that these two concepts are different.

high school students can either choose to take an academic (senior high schools) or vocational track (vocational schools or five-year junior college) in the higher level of education, many students and parents prefer the academic over the vocational track. If students wish to pursue an academic track, they should take a more difficult national standardized test, Basic Competency Test, in their third or last year of junior high school. The higher the scores they achieve in the test, the better the schools they will be admitted to. Because being admitted to a top-ranking senior high school significantly increases the likelihood of enrolling in a good college, the Basic Competency Test is a crucial part of students' academic life. In addition, the admission process of senior high schools is extremely competitive as only 44 % of junior high school students are able to follow an academic track in senior high schools (The Republic of China Government 2016). Therefore, junior high school students face great pressure to obtain a high score on the test, along with other academic responsibilities (Chang and Cheng 2008).

Within this context, despite high achievement scores and performance, students in Taipei are among those who have the lowest positive attitudes toward learning science and the lowest self-confidence in science in TIMSS (Chang and Cheng 2008; Martin et al. 2004). Recently, a study (Chang and Cheng 2008) used a representative and large sample of eleventh-grade Taiwanese students ($N = 1044$) to examine their science achievement, self-confidence (similar to expectancy), and interest in science (similar to positive affect). It found that students' self-confidence and interest in science explained about 20 % of the variances in science achievement, knowledge, and reasoning skills, and all of the regression models had a large effect size (about .50). However, the average score of the students' self-confidence and interest in science was only 2.09 out of 4 (the highest possible score), which was lower than the midpoint (2.50), or the score that reflected a neutral attitude. Moreover, whereas the average score of the students' interest in learning science was 2.6, the average score of the students' self-confidence was as low as 1.86, which was only slightly higher than 1 (the lowest possible score). Even though the students in the high self-confidence and interest group had significantly higher science achievement, knowledge, and reasoning skills than the students in the low self-confidence and interest group, the former group of students' average score of self-confidence and interest in science was 2.98, which was still much lower than the highest possible value. Although this study (Chang and Cheng 2008) showed significant relationships between students' self-confidence, interest, and science achievement, no mediation analysis was performed. Therefore, it remains unknown whether positive affect functions as a mediator in the relationship and whether this effect is significant or has the same direction among Taipei students as among American students in previous studies (Pekrun 2006).

2.2 Instruction and science achievement

2.2.1 Instruction and science achievement in general

The way that teachers instruct students in classes has a direct impact on students' performance and attainment in science (Crosnoe 2010; Fogleman et al. 2011;

Lavonen and Laaksonen 2009; Reynolds and Walberg 1991). Instructions are conventionally categorized by two extremes: traditional versus inquiry-based. The former is often characterized by more teacher-led lectures, a focus on textbook contents, and rote memorization. The core characteristic of the latter is the employment of student-centered activities, such as making observations, planning investigations, and having group work (Anderson 2002; Chang and Mao 1999a, b; Gao 2014; Osborne 1996). The benefits of inquiry-based instruction on science achievement have been well documented in the literature (Anderson 2002; Chang and Mao 1999a, b; Jiang and McComas 2015; Schroeder et al. 2007). Yet science teachers use traditional instruction more routinely than inquiry-based instruction (Capps et al. 2012). Recently, science education researchers have dismissed the view that puts traditional and inquiry-based instruction at two extremes; instead, they perceive different types of instruction as a continuum (Osborne 1996). On the basis of this idea, Gao (2014) used the TIMSS 2007 science dataset of eighth graders in the U. S. and exploratory factor analysis to identify three types of instruction: more inquiry-oriented instruction (e.g., make observations, design or plan an experiment, and work in small groups), more didactic/traditional instruction (e.g., read science textbooks, memorize facts and principles), and more practice-based instruction (e.g., review homework, have a quiz or test).

The relationship between instruction and affect has also been discussed in the literature. Instructional practices, such as repetitive topic and practice toward national tests, contribute to students' negative attitudes toward science, thus, arousing negative affect (Murphy et al. 2006; Murphy and Beggs 2003). Osborne et al. (2003) have also noted that teaching is a significant determinant of students' attitudes and feelings. Students' positive attitudes toward science develop primarily from the science teaching they experience in classes. Although there is a significant body of studies focusing on the predictive power of inquiry-based instruction on students' science achievement (Areepattamannil 2012; Areepattamannil et al. 2011; Freedman 1997; House 2008; Jiang and McComas 2015), there is a dearth of research examining the effects of the three types of instruction on students' affect and science achievement.

2.2.2 Instruction and science achievement in Taiwan

Researchers in Taiwan have compared the effectiveness of traditional versus inquiry-based instructions in teaching earth science for high school students. These studies employed similar procedures and measures, however, the results presented a mixed picture. For instance, two studies (Chang and Mao 1999a, b) that used exactly the same instructional strategies (students formed six-member groups; gathered and interpreted data, explained; clarified, and presented their group work) reached contrasting conclusions. In one study (1999a), researchers found that students' overall achievement in earth science and their positive attitudes towards the subject were higher in the inquiry-based instruction group than those in the traditional instruction group. But no significant differences existed in students' achievement at the comprehension and application levels and their learning interest. In the other study (1999b), researchers found that there was significant difference in students' achievement at the application level between the control and treatment groups, but there were no significant differences in students' overall achievement and achievement at the knowledge and comprehension levels. A few studies (Chang 2001) have examined the effects of a problem-solving based computer-assisted tutorial that was similar to inquiry-based instruction and included five stages of problem-solving processes (presenting the problem, planning solutions, collecting necessary information, carrying out the plans, and evaluating results). The author consistently found that students taught by this approach showed more gains on overall achievement than those taught by a Lecture-Internet-Discussion approach that was similar to traditional instruction. However, no significant gains were noticed in the application test items in the problem-solving approach, and no change was found in students' attitudes in either approach. Two other studies (Chang 2002a, b, 2003) have investigated the differences in students' outcomes between a teacher-directed computer-assisted instruction approach that emphasized direct guidance, lectures, occasional demonstrations, and explanations of concepts and a student-controlled approach that emphasized learning based on students' own pace. Both studies even showed that students in the teacher-directed group had significantly higher achievement and more positive attitudes toward earth science than those in the student-controlled group.

Although the cited studies provided much insight into the relationships between instruction, students' attitudes, and achievement in science in Taiwan, there are several points that are worth noting. First, these studies only focused on one science subject and senior high school students. Therefore, some questions are unanswered. For example, what are the relationships among the same variables in other populations, such as junior high school students? Second, due to the mixed results obtained from the cited studies, it remains unclear which instructional approach produces better outcomes for Taiwanese students. This also implies that the relationship between instruction and students' achievement may be far more complex than it appears. Third, to date, the relationships among motivation, instruction, affect, and students' science achievement have seldom been examined among Taiwanese students in one single study. Thus, these relationships, particularly direct and indirect effects of these variables on students' achievement, warrant further examination. Fourth, most of the cited studies have small sample sizes, therefore, a study employing a large sample size is needed. Additionally, the use of more advanced statistical techniques, such as Structural Equation Modeling, can possibly test causality relationships among the variables, which is highly recommended by the researchers (Chang and Cheng 2008).

3 Methods

3.1 Sample

The sample used for this study was Chinese Taipei's eighth-grade students in TIMSS 2007, the fourth cycle of the assessment, where 241,613 students coming from 50 countries and seven benchmarking participants[2] participated. The TIMSS 2007 dataset was chosen because it was understudied compared to the datasets in other cycles. A total of 4046 students in Taipei were selected by using two-stage stratified cluster sampling, the uniform sampling design of the TIMSS. The design had two stages: at the first stage, schools were randomly selected with probability that was proportional to population size; at the second stage, one or more intact classes of students were selected. Five explicit stratifications, North, Middle, South, East, and Remote Islands, were also employed at the school level, which allowed to create smaller sampling frames (Foy and Olson 2009b). Participant students ranged from 13 to 17 years old ($M = 14.34$; $SD = .48$), and there were slightly more male students (52 %) than female students (48 %).

3.2 Measures

3.2.1 Science achievement

Student science achievement was an endogenous/outcome variable measured by items of science content and cognitive domains. There were four content domains in science assessment: biology (35 % of the assessment), chemistry (20 %), physics (25 %), and earth science (20 %), with each domain having several main topics. There were three cognitive domains: knowing that focuses on facts, procedures, and concepts; applying that focuses on applying knowledge and conceptual understanding in real-life problems; and reasoning that combines unfamiliar situations, complex context, and multi-step problems. Because students were asked to not complete all of the achievement booklets in the assessment, their individual performance score was estimated by using item response theory (IRT) that resulted in five plausible values (Mullis et al. 2005) (see Table 1).

3.2.2 Positive affect in learning science

Positive affect in learning science was both an endogenous and exogenous variable in the study. It was measured by four items (e.g., "I would like to take more science in school") on a 1–4 Likert scale with 1 being "Agree a lot" and 4 being "Disagree a lot" (see Table 1). All of the items were reverse coded except the negatively worded one. The reliability among the items was high (Cronbach's $\alpha = .88$).

3.2.3 Achievement motivation

Two components of achievement motivation were exogenous variables in the study. One component, expectancy in learning science, was measured by four items (e.g., "I usually do well in science"; Cronbach's $\alpha = .81$). The other component, value in learning science, was measured by four items (e.g., "I think learning science will

[2] Benchmarking participants in TIMSS are the American states and districts that participate in the TIMSS assessment in order to "provide them [American states and districts] with the opportunity to assess the comparative international standing of their students' achievement and to view their curriculum and instruction in an international context" (NCES 2016, 1st para).

Table 1 Means and standard deviations of items

Variables	Items	Mean (SD)
Science achievement		562.77 (85.85)
Affect in learning science (α = .88)	I would like to take more science in school (Y_1)	2.41 (.93)
	I enjoy learning science (Y_2)	2.49 (.94)
	Science is boring (Y_3)	2.68 (.97)
	I like science (Y_4)	2.49 (.96)
Expectancy in learning science (α = .81)	I usually do well in science (Y_5)	2.51 (.85)
	Science is more difficult for me than for many of my classmates (Y_6)	2.38 (.94)
	Science is not one of my strengths (Y_7)	2.24 (1.01)
	I learn things quickly in science (Y_8)	2.27 (.85)
Value in learning science (α = .83)	I think learning science will help me in my daily life (Y_9)	3.02 (.84)
	I need science to learn other school subjects (Y_{10})	2.36 (.85)
	I need to do well in science to get into the school that I deem ideal in my heart (Y_{11})	2.51 (.85)
	I need to do well in science to get the job I want (Y_{12})	2.30 (.96)
Inquiry-based instruction (α = .86)	We make observations and describe what we see (Y_{13})	2.39 (.82)
	We watch the teacher demonstrate an experiment or investigation (Y_{14})	2.51 (.83)
	We design or plan an experiment or investigation (Y_{15})	2.21 (.78)
	We conduct an experiment or investigation (Y_{16})	2.31 (.73)
	We work in small groups on an experiment or investigation (Y_{17})	2.27 (.77)
Traditional instruction (α = .84)	We read science textbooks and other resource materials (Y_{18})	2.58 (1.01)
	We memorize science facts and principles (Y_{19})	2.63 (.95)
	We use scientific formulas and laws to solve problems (Y_{20})	2.70 (.95)
	We give explanations about what we are studying (Y_{21})	2.44 (.95)
	We review our homework (Y_{22})	2.48 (.94)
	We listen to the teacher give a lecture-style presentation (Y_{23})	3.43 (.86)
	We work problems on our own (Y_{24})	2.41 (.96)
Practice-based instruction (α = .44)	We begin our homework in class (Y_{25})	1.89 (.84)
	We have a quiz or test (Y_{26})	2.60 (.83)
	We use computers (Y_{27})	1.30 (.71)
Mother education		3.27 (1.52)
Books at home		2.96 (1.32)

$N = 4791$

help me in my daily life"; Cronbach's $\alpha = .83$) (see Table 1). Students were asked to indicate their degree of agreement on a 1–4 Likert scale with 1 being "Agree a lot" and 4 being "Disagree a lot". All of the items were reverse coded except negatively worded ones.

3.2.4 Instructional practices

Three types of instruction were exogenous variables in the study. Inquiry-based instruction was measured by five items (e.g., "We make observations and describe what we see"; Cronbach's $\alpha = .86$), traditional instruction was measured by seven items (e.g., "We read our science textbooks and other resource materials"; Cronbach's $\alpha = .84$), and practice-based instruction was measured by three items (e.g., "We begin our homework in class"; Cronbach's $\alpha = .44$) (see Table 1). Students were asked to indicate the frequency of each instructional activity in science classes on a 1–4 Likert scale, with 1 being "Every or almost every lesson" and 4 being "Never". All of the items were reverse coded.

3.2.5 Control variables

Mother education and the number of books at home were selected as control variables because a large body of research (Davis-Kean 2005; Martin et al. 2008; Rutkowski and Rutkowski 2013a, b) has shown that they were significant components of socioeconomic status (SES) and predictors of students' academic achievement. Mother education was measured on a 1–8 scale that was recoded from national options to fit international categories. They ranged from 1 "Some primary school or did not go to school/Elementary education" to 7 "Master's degree or higher" (see Table 1). Because 4 was "Option not administered or data not available" and 8 was "I don't know", the data based on these two categories were treated as missing data (Foy and Olson 2009a). The number of books at home was measured on a 1–5 scale with 1 being "None or very few (0–10 books)" and 5 being "Enough to fill three or more bookcases (more than 200 books)".

3.3 Data analysis

Structural Equation Modeling (SEM) was employed to analyze the data for the following reasons: (1) it can estimate measurement and structural models simultaneously; (2) it can provide an unbiased estimate of mediation effect (Cheung and Lau 2007); (3) because the data used in this study were all from students' self-reported information in the questionnaire, and no school or teachers' data were provided, a hierarchical linear modeling or multilevel modeling approach was considered unnecessary. Before a full SEM was performed, a Confirmatory Factor Analysis (CFA) was conducted to test the measurement model of positive affect, academic achievement, and instructional practices in order to ensure the validity of the measures (Anderson and Gerbing 1988).

Given that international large-scale datasets have complex sampling designs, several statistical techniques were employed to reduce the standard error of the variables (Rutkowski et al. 2010). First, all of the variables were weighted in IBM SPSS Statistics (Version 23) by total student weight provided in the TIMSS dataset. In spite of the differences among total, house, and senate weights in international large-scale datasets, these three types of weights result in the same point of estimate if the analysis is only conducted within a single country (Stapleton 2014). Later, all of the analyses were performed in Mplus 7.3, which is a powerful latent variable modeling program and can be used to analyze complex survey datasets with the function of TYPE = COMPLEX. The cluster and stratification were included in the analysis by using school id and explicit stratum code. Five plausible values provided in the TIMSS dataset were treated as observed variables of students' science achievement (Asparouhov and Muthen 2010). The valid sample size in the dataset was 3690, indicating 9 % missing data. Unlike the common methods of handling missing data (Little and Rubin 2014), Mplus does not impute missing values for the data. Instead, it uses all of the data available to estimate the modeling with full information maximum likelihood, and each parameter is estimated directly without first filling in missing data values for each individual (Muthen 1999).

Structural Equation Modeling (SEM) was used to answer the three research questions. Model fit indices in Mplus include Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Chi square test,[3] and Standardized Root Mean Square Residual (SRMR) (Muthen and Muthen 1998–2012). A model was considered a good fit to the data if RMSEA $< .06$, CFI $\geq .95$, TLI $\geq .95$, and SRMR $\leq .08$ (Hooper et al. 2008; Marsh et al. 2004; Schreiber et al. 2006). In order to answer the third research question, a mediation analysis was performed with the use of SEM.[4] When interpreting the results of the mediation analysis, the recommendations of Rucker et al. (2011) were followed. They argued that researchers' prediction of the mediation should be guided more by theories, and more attention should be paid to a suppression effect that refers to indirect effect having the opposite sign of the total effect. They also suggested that researchers should focus on two key points in reporting an indirect effect: whether the indirect effect is statistically significant and what the size of the effect is.

4 Results

4.1 Descriptive statistics and correlation

Table 1 presents weighted descriptive statistics of students' science achievement and their responses to each individual item in the questionnaire. It shows that the average score of the students' science achievement was 562.77 ($SD = 85.85$). The average scores of the four items measuring students' positive affect were all close to 2.50 (out of 4), and the students rated the item "Science is boring" higher than other

[3] Because the Chi-square test is sensitive to a large sample size, its result is not used in the current study as a model fit index (Schreiber et al. 2006).

[4] Mplus incorporates Bollen's (1987) method to test indirect effects and estimate standard errors.

items. The average score of one item measuring students' expectancy in learning science, "I usually do well in science", was also close to 2.50, while the average scores of the other three items, "Science is more difficult for me than for many of my classmates", "Science is not one of my strengths", and "I learn things quickly in science", were slightly lower than 2.50. The average scores of the two items measuring values in learning science, "I need science to learn other school subjects" and "I need to do well in science to get the job I want", were about 2.30. The average scores of the other two items, "I think learning science will help me in my daily life" and "I need to do well in science to get into the school that I deem ideal", were slightly higher (2.51 and 3.02). Of all the strategies used in the inquiry-based instruction, the item "We watch the teacher demonstrate an experiment or investigation" (Y_{14}) was reported with the highest frequency ($M = 2.15$). The item "We listen to the teacher give a lecture-style presentation" (Y_{23}) was reported with the highest frequency ($M = 3.43$) among all of the strategies used in the traditional instruction, and the item "We have a quiz or test" (Y_{26}) was reported with the highest frequency ($M = 2.60$) among all of the strategies used in the practice-based instruction.

Furthermore, for all of the 12 items that measured affect, expectancy, and value, between 9 and 30 % of the students showed the strongest degree of agreement, and most of the frequencies were around 10 %. For instance, only 9 % of the students strongly agreed that they can learn things quickly in science (Y_8), and 11 % of the students strongly agreed that learning science can help them to study other subjects (Y_{10}). In addition, 16 % of the students strongly agreed that they enjoy learning science (Y_2), and similar percentage of the students (17 %) strongly agreed that they like science (Y_4).

As shown in Table 2, most of the correlations among the observed variables were positive and significant at $p < .05$, and the magnitude of the correlations was between small and moderate. A few large correlations were from the relationship between "I enjoy learning science" (Y_2) and "I like science" (Y_4) ($r = .83$), "I need science to learn other school subjects" (Y_{10}) and "I need to do well in science to get the job I want" (Y_{12}) ($r = .74$), as well as "We conduct an experiment or investigation" (Y_{16}) and "We work in small groups on an experiment or investigation" (Y_{17}) ($r = .71$).[5]

4.2 Measurement model

CFA was first performed to test the measurement model in Mplus. The model created from the original conceptual framework indicated an adequate but not good fit with the data: RMSEA = .057 (90 % CI = [.055, .059]), CFI = .902, TLI = .889, and SRMR = .055. According to the model modification indices provided by Mplus, the model was revised by adding error variances for two sets of variables ("Science is not one of my strengths" and "Science is more difficult for

[5] The high correlations among the variables did not affect the final results of the measurement model because Mplus takes into consideration all of the correlations and intercorrelations among the observed and latent variables in estimation (Muthen and Muthen 1998–2012).

Table 2 Zero-order correlations among variables

VA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Aff																													
Y_1	–																												
Y_2	.66	–																											
Y_3	.51	.62	–																										
Y_4	.66	.83	.66	–																									
Exp																													
Y_5	.54	.63	.45	.63	–																								
Y_6	.26	.38	.44	.39	.43	–																							
Y_7	.35	.48	.50	.47	.53	.58	–																						
Y_8	.52	.66	.48	.67	.67	.44	.50	–																					
Val																													
Y_9	.45	.49	.41	.50	.41	.19	.25	.41	–																				
Y_{10}	.45	.44	.33	.45	.36	.16	.23	.39	.55	–																			
Y_{11}	.45	.47	.35	.48	.40	.18	.25	.42	.46	.54	–																		
Y_{12}	.44	.46	.32	.46	.39	.18	.25	.40	.47	.54	.74	–																	
Inq																													
Y_{13}	.27	.27	.16	.26	.23	.08	.10	.21	.24	.25	.20	.21	–																
Y_{14}	.22	.23	.13	.22	.19	.05	.06	.17	.19	.19	.15	.17	.56	–															
Y_{15}	.23	.23	.11	.22	.22	.06	.10	.20	.20	.24	.17	.20	.54	.60	–														
Y_{16}	.19	.20	.09	.21	.19	.05	.07	.17	.15	.17	.15	.16	.48	.60	.63	–													
Y_{17}	.19	.19	.10	.20	.18	.05	.08	.17	.15	.17	.12	.15	.39	.49	.50	.71	–												
Tra																													
Y_{18}	.27	.30	.21	.29	.27	.09	.16	.27	.27	.24	.27	.23	.26	.23	.27	.23	.22	–											
Y_{19}	.25	.27	.16	.26	.24	.04	.09	.24	.25	.23	.26	.23	.28	.25	.29	.22	.20	.49	–										
Y_{20}	.27	.29	.21	.28	.26	.06	.12	.26	.28	.23	.29	.24	.28	.24	.27	.23	.20	.50	.71	–									
Y_{21}	.28	.30	.20	.29	.28	.10	.16	.28	.31	.29	.26	.26	.34	.29	.38	.31	.25	.43	.51	.59	–								

Table 2 continued

VA	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Y_{22}	.25	.25	.17	.25	.23	.05	.10	.21	.22	.22	.23	.20	.31	.28	.31	.27	.24	.34	.37	.41	.41	–							
Y_{23}	.28	.31	.25	.30	.27	.04	.10	.23	.30	.20	.29	.21	.26	.20	.17	.15	.12	.36	.36	.43	.33	.31	–						
Y_{24}	.32	.37	.26	.36	36	.17	.21	.34	.29	.26	.31	.26	.30	.25	.28	.25	.23	.39	.40	.42	.38	.44	.39	–					
Pra																													
Y_{25}	.16	.15	.07	.15	.16	.06	.09	.15	.11	.16	.12	.14	.21	.20	.24	.21	.20	.21	.22	.20	.24	.35	.08	.36	–				
Y_{26}	.17	.18	.10	.18	.18	**.02**	.05	.16	.14	.14	.13	.13	.22	.28	.25	.25	.23	.23	.31	.31	.27	.32	.25	.30	.25	–			
Y_{27}	.06	.05	−**.01**	.05	.06	**.01**	.02	.05	.03	.10	**.02**	.07	.10	.14	.18	.19	.21	.04	.04	**.03**	.08	.05	−.08	.08	.21	.15	–		
Con																													
ME	.10	.16	.11	.17	.15	.11	.13	.18	.14	.13	.17	.12	.04	.02	.04	.06	.06	.14	.12	.16	.14	.13	.10	.14	.18	.04	.05	–	
BK	.17	.22	.16	.22	.19	.09	.14	.21	.19	.16	.21	.16	.09	.06	.05	.06	.08	.23	.18	.23	.20	.20	.20	.18	.24	.07	.05	.38	–

VA variables, *Aff* positive affect, *Exp* expectancy, *Val* value, *Inq* inquiry-based instruction, *Tra* traditional instruction, *Pra* practice-based instruction, *Con* control variables, *ME* mother education, *BK* books at home

All correlations except the ones in bold were significant at $p < .001$

The specific item indicated by Y_n refers to Table 1 me than for many of my classmates", "I need to do well in science to get into the school that I deem ideal in my heart" and "I need to do well in science to get the job I want"). The final model showed a better fit: RMSEA = .042 (90 % CI = [.040, .044]), CFI = .948, TLI = .940, and SRMR = .042.

In the final measurement model, all of the factor loadings were statistically significant at $p < .001$ and ranged from .25 to .92 (see Fig. 1). The variables that had high factor loadings for positive affect were "I like science" ($\lambda = .92$) and "I enjoy learning science" ($\lambda = .90$). The items "I usually do well in science" ($\lambda = .82$) and "I learn things quickly in science" ($\lambda = .83$) had high factor loadings for expectancy, while "I think learning science will help me in my daily life ($\lambda = .73$) and "I need science to learn other school subjects" ($\lambda = .74$) had high factor loadings for value. The items "We design or plan an experiment or investigation" ($\lambda = .80$) and "We watch the teacher demonstrate an experiment or investigation" ($\lambda = .77$) had high factor loadings for inquiry-based instruction, while "We use scientific formulas and laws to solve problems" ($\lambda = .74$) and "We give explanations about what we are studying" ($\lambda = .70$) had high factor loadings for traditional instruction. The item "We have a quiz or test" ($\lambda = .58$) had a high factor loading for practice-based instruction.

4.3 SEM

The results of the final mediation SEM analysis showed that the RMSEA was .037 (90 % CI = [.035, .038]), the CFI was .965, the TLI was .960, and the SRMR was .043, indicating a good fit between the model and the data.

4.3.1 Relationships among academic motivation, instruction, and positive affect

In the final structural model (see Table 3; Fig. 2), expectancy, or perceived ability in completing science tasks ($\beta = .66$, $p < .001$), and value in science ($\beta = .28$, $p < .001$) were significant and positive predictors of positive affect in science. They were also the two strongest predictors of positive affect. This suggests that students who perceive themselves as more competent in learning science and see more values in science are more likely to have positive feelings toward science. Among the three types of instruction, only inquiry-based instruction ($\beta = .05$, $p < .05$) was significantly and positively related to positive affect, and it accounted for a much smaller variance than expectancy and value. Traditional instruction ($p = .09$) and practice-based instruction ($p = .06$) were nonsignificant. These results indicate that more inquiry-based instruction leads to higher positive affect in science learning. All of the variables together explained 79.4 % of the variance in positive affect in science.[6]

[6] Mplus only provides an overall R square for endogenous variables, rather than separate R square for control and exogenous variables, or direct and indirect effects.

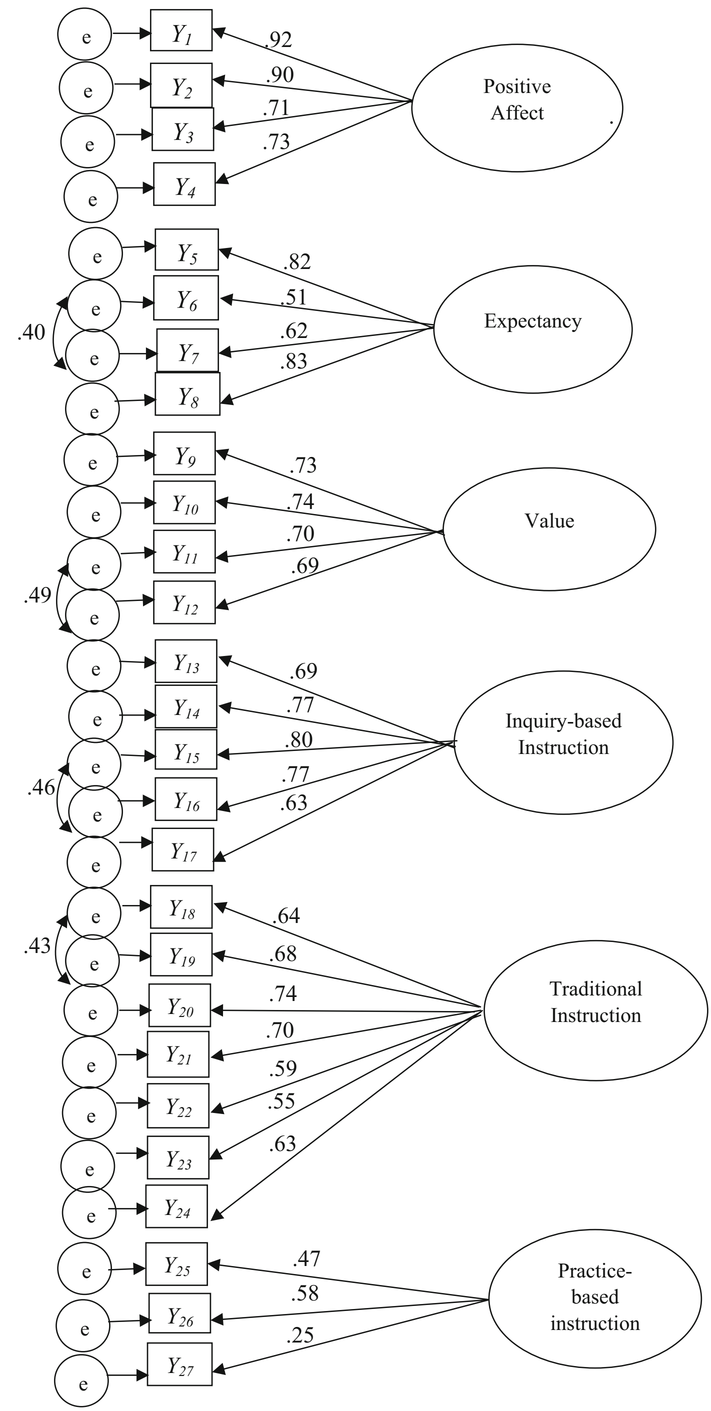

Fig. 1 Measurement model. All the factor loadings are *above* the *line*

Table 3 Parameter estimates, standard error, and *p* values

Hypothesized path		Direct effect	SE	Indirect effect	SE	Total effect	SE
Expectancy	Affect	.66**	.02	–	–	.66**	.02
Expectancy	SA	.35**	.05	−.07*	.03	.28**	.03
Value	Affect	.28**	.02	–	–	.24**	.02
Value	SA	.01	.04	−.03*	.01	−.02	.04
Inquiry	Affect	.05*	.02	–	–	.04*	.02
Inquiry	SA	−.17**	.03	−.01	.00	−.16**	.03
Traditional	Affect	.04	.03	–	–	.04**	.03
Traditional	SA	.75**	.06	−.01	.00	.74**	.06
Practice	Affect	−.05	.03	–	–	−.05	.03
Practice	SA	−.47**	.07	.01	.01	−.46**	.07
Affect	SA	−.11*	.05	–	–	−.11*	.05
Books	SA	.19**	.02	–	–	.19**	.02
Medu	SA	.01	.02	–	–	.01	.02

SA science achievement, *Inquiry* inquiry-based instruction, *Tradition* traditional instruction, *Practice* practice-based instruction, *Books* books at home, *Medu* mother's education

The dash indicates paths that were not specified in the model

** $p < .001$; * $p < .05$

4.3.2 Relationships among academic motivation, instruction, positive affect, and science achievement

In the final structural model (see Table 3; Fig. 2), one of the control variables, the number of books at home, was a significant and positive predictor ($\beta = .19$, $p < .001$), whereas mother's education was nonsignificant ($p = .50$). Of the two components of academic motivation, only expectancy in science ($\beta = .35$, $p < .001$) was a significant and positive predictor of science achievement after the number of books at home and mother education were controlled. In addition, all of the three types of instruction significantly predicted students' science achievement. However, inquiry-based instruction ($\beta = -.16$, $p < .001$) and practice-based instruction ($\beta = -.47$, $p < .001$) were two negative predictors whereas traditional instruction was positive ($\beta = .77$, $p < .001$). In the meantime, positive affect negatively predicted science achievement ($\beta = -.11$, $p < .05$). Among all of the significant and direct paths, traditional instruction accounted for most of the variance in science achievement, followed by practice-based instruction, expectancy in science, inquiry-based instruction, and positive affect. These mean that students who believe in their perceived ability to do science and are instructed more by traditional approach are more likely to have higher science achievement. On the other hand, students who have more positive affect in science, are instructed more by inquiry-based approach, and engaged in more practices are more likely to have lower science achievement. All of the variables together explained 55.5 % of the variance in science achievement.

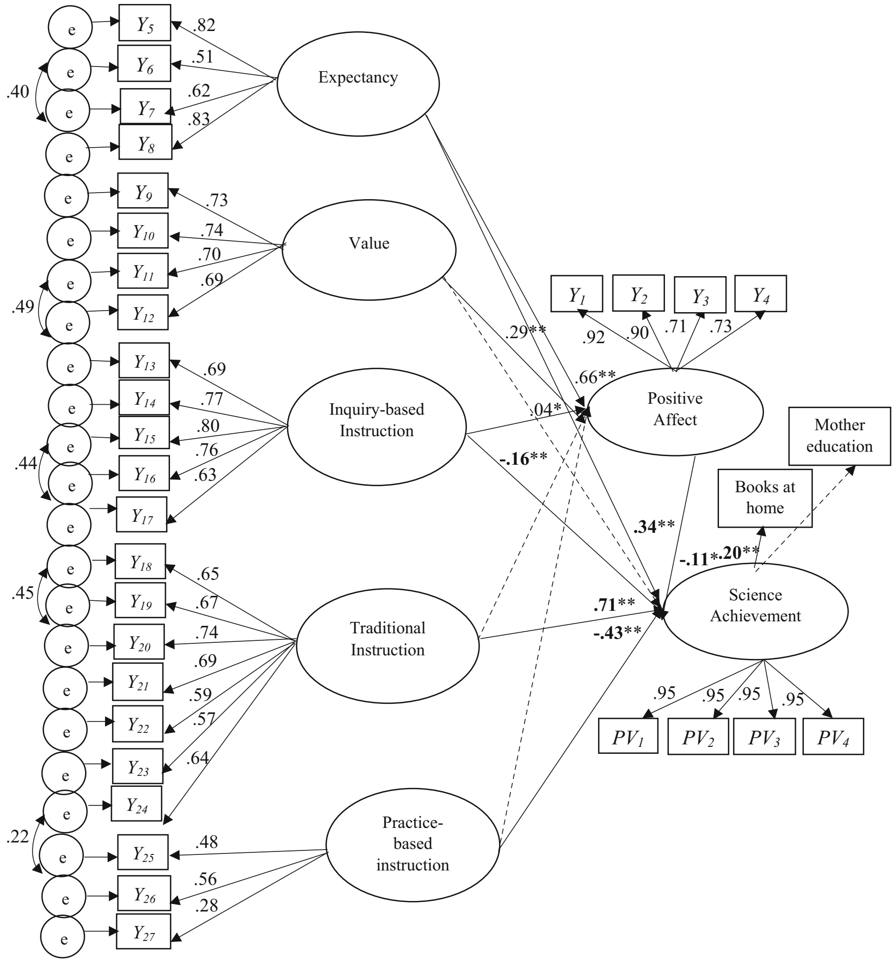

Fig. 2 Science achievement model tested by Structural Equation Modeling. *Solid lines* refer to significant paths (**$p < .001$; *$p < .05$). All the standardized coefficients are *above* the *line*. Standardized coefficients for science achievement are all in *bold*

4.3.3 Mediation of positive affect

In the mediation analysis (see Table 3; Fig. 2), only two components of academic motivation, expectancy and value in science, had statistically significant indirect effects on students' science achievement through positive affect. The indirect effect for expectancy was $-.07$ ($p < .05$; 95 % CI = [$-.13$, $-.01$]), which was about a fourth of the total effect ($\beta = .28$). The indirect effect for value was $-.03$ ($p < .05$; 95 % CI = [$-.05$, $-.01$]). Although the direct and total effects that were related to the indirect effect were not statistically significant, this indirect effect was still interpreted as significant based on Rucker et al.'s (2011) recommendations. Because both of the indirect effects had an opposite sign of the total effect, they were considered suppression effects. In addition, the three types of instruction did not have an indirect effect on science achievement through positive affect. Therefore, the mediation of the positive affect in the relationships of academic motivation, instruction, and science achievement was only partially supported.

5 Discussion

This study reports that the average science achievement of eighth-grade students in Taipei is about 560 and the average scores of their self-perceived affect toward science, expectancy and value of science are between 2.24 and 3.02. These results confirmed the existence of a "high achievement but low motivation" phenomenon in Chinese Taipei. They also corroborated previous findings. For instance, the average score of students' interest in learning science reported in the current study (2.50) is close to that reported in Chang and Cheng's (2008) study on senior high school students in Taiwan (2.60). Exactly the same percentage of the students (16 %) in Taipei reported high level of enjoyment in science in both TIMSS 2003 and the current study. However, the average scores of the four items measuring students' expectancy (from 2.24 to 2.51) were slightly higher than the average score of the senior high school students' self-confidence reported in Chang and Cheng's (2008) study (1.86). This difference may be because senior high school students in Taiwan are under more pressures than junior high school students, thus, showing a lower level of self-confidence.

This study concludes that the two components of achievement motivation, expectancy and value, significantly predict the positive affect of eighth graders in Taipei. This supports previous findings with regard to motivation in Western countries (DeBacker and Nelson 1999). It further suggests that in order to increase students' positive affect toward science, teachers should emphasize students' competencies in completing science tasks as well as the values of learning science. In addition, the study indicates that inquiry-based instruction is a positive predictor of students' positive affect toward science. This underlines the importance of class activities that reflect inquiry-based instruction, such as making observations, watching the teacher demonstrate, and group work, in increasing students' favorable feelings toward learning science. This finding has significant implications not only for the prevalent "high achievement but low motivation" phenomenon in Asian countries, but also for students' future selection of science-related college majors and future careers (Auger and Blackhurst 2005; Bandura et al. 2001; Tai et al. 2006).

However, it is also demonstrated in this study that traditional and practice-based instructions are both nonsignificant predictors of students' positive affect. Although learning activities in traditional instruction might be useful for knowledge comprehension, they are less interesting than inquiry-based activities. Practice-based instruction has seldom been addressed in the literature. But East Asian countries are notorious for their rigid test systems, and excessive high-stakes testing in these countries leads to extreme competition and anxiety, even maladaptation problems, among students (Leung 2002; Zhao 2005; Zhu and Leung 2010).

Furthermore, this study corroborates the significant and direct effects of expectancy, affect, and three types of instruction on science achievement of eighth graders in Taipei. However, this study fails to support the significant relationship between one component of academic motivation, value in learning science, and students' science achievement. Although both expectancy and value are reported to significantly predict students' achievement, expectancy is similar to intrinsic motivation, while value is similar to extrinsic motivation. Zhu and Leung (2010) examined the relationship between intrinsic and extrinsic motivation and mathematics achievement in five Asian and four Western educational systems. They noted that both types of motivation were positively associated with students' mathematics achievement, but intrinsic motivation was a much stronger predictor than extrinsic motivation. This pattern was demonstrated in eight of the nine countries examined.

In addition, this study shows that inquiry-based instruction and practice-based instruction are negative predictors of science achievement whereas traditional instruction is a positive and the strongest predictor. Chang (2002a, b, 2003) found that students' science achievement was higher in a teacher-directed computer-assisted teaching approach than in a student-centered approach. Jiang and McComas (2015) demonstrated a negative relationship between the amount of guidance provided to students in inquiry-based instruction (or openness of the instruction) and students' science achievement in 26 countries in PISA 2006. Their findings suggested that the quality of the instruction might be more important than the type or the time of the instruction. Additionally, researchers questioned the effectiveness of inquiry-based instruction, especially when it was implemented with little guidance (Bell et al. 2010; Kirschner et al. 2006). They also contended that traditional instruction had some degree of effectiveness in explaining difficult concepts and teaching complex procedures (Brown and Campione 1994; Klahr and Nigam 2004; Moreno 2004; Tuovinen and Sweller 1999). It might also lead to more knowledge acquisition, less misconception, deeper understanding, and better transfer of knowledge (Brown and Campione 1994; Kirschner et al. 2006; Klahr and Nigam 2004). These strengths of traditional instruction might be even more prominent in Asian cultures where teachers' role as a knowledge dispenser and the importance of fundamental skills are emphasized (if not overemphasized) (Gao 1998; Tsai 2004). Students also reported high levels of happiness, albeit less involvement and flow experience, when they were taught with highly conceptual and challenging materials, a situation that most Chinese students experience in their daily academic life (Csikszentmihalyi et al. 1993; Meyer and Turner 2006).

Another interesting finding in this study is the negative relationship between positive affect toward science and science achievement. On the one hand, the same negative relationship was found in studies on American students. For instance, Yu (2012) examined the relationships among academic self-concept, instrumental motivation, and science achievement in five Asian countries and America based on TIMSS 2007 data. The results revealed that the positive affect toward science was a significant but negative predictor of American students' science achievement. On the other hand, this finding echoes the comments from Osborne et al. (2003) that feelings and emotions toward science only reflected subjects' own perceptions of preferences toward a subject, but these perceptions might be inconsistent with the behaviors.

The mediation effect of the positive affect between academic motivation and science achievement (Pekrun et al. 2009) was partially confirmed in the current study. This could be because of several differences that exist between Pekrun et al.'s (2009) study and the current study. First, the construct, definition, and measure of positive affect in the current study and achievement emotions in Pekrun et al.'s (2009) study are different. Second, the motivation variable used in Pekrun et al.'s (2009) study is achievement goals, which are different from achievement motivation in this study. Third, the populations in the two studies are different: Pekrun et al.'s study used undergraduate students as participants, whereas the current study used eighth graders as participants. Fourth, the endogenous variable in Pekrun et al.'s study was students' performance attainment measured by their midterm exam scores, whereas the endogenous variable in the current study was students' science achievement in TIMSS assessment.

What's more, the mediation effect of positive affect between academic motivation and science achievement in the current study was essentially a suppression effect, which was opposite to the findings of Pekrun et al.'s (2009) study. This might be relevant to the cultural differences between the East and the West. The culture that individuals live in shapes their self-perceptions and attitudes (Markus and Kitayama 1991; Nisbett and Masuda 2003; Schütte 2015). Because Western cultures emphasize the importance of individualism and independence, whereas Eastern cultures emphasize the importance of collectivism and interdependence, individuals in the two cultural contexts show different values. To be more specific, individuals in the Western cultures make reference to their own feelings, thoughts, and actions when making decisions, whereas individuals in the Eastern cultures make reference to others' feelings, thoughts, and actions, especially their family's preferences. When there is dissonance between the values placed on an academic domain and the individuals' own ability in that domain, individuals in Western cultures become disengaged from the domain whereas individuals in East Asian cultures study even harder in order to fulfill others' expectations. In other words, individuals' attitudes and feelings are not viewed as primary considerations in East Asian cultures, and individuals' identity is mainly pertinent to the relationships with significant others and social roles (Schütte 2015).

Although the suppression effect was partially established in this study, the indirect effects of expectancy and value were small. According to Rucker et al. (2011), the results of mediation depend on many factors, such as sample size and size of the total effect in the model. It is more likely to observe a full mediation in a smaller sample size because it is easier to find an insignificant direct effect between independent and dependent variables after controlling the mediator. When the total effect is highly significant in the model, it is easier to find a partial mediation with smaller effect size even though the mediator has a smaller measurement error and the model is based on a solid theory. They also noted that a suppression effect often occurs when there are opposite signs between the direct and mediated effects. Maassen and Bakker (2001) also contended that suppression effect occurs more frequently in path analyses or models using latent variables, where the suppressed variable is corrected for errors in measurement.

6 Limitations of the study

There are several limitations in the current study. First, the present study only includes data that were collected from students' self-report information in the student questionnaire. Students' self-reports have long been used as a way of collecting information regarding their feelings and perceptions. However, the reliability of self-reports was called into question because these perceptions are personal, and they might be different from what is happening in students' real lives (Lüdtke et al. 2009). In order to avoid this problem in the future, data from teachers and schools could be utilized to examine multilevel effects of school factors together with student factors. Second, the structural model proposed in the current study explained 55.5 % of variances in science achievement. However, this also suggests that factors other than motivation, instruction, and affect should be taken into account in the future. Third, although this study only focuses on one single country, the understanding of the scales of Taipei students might be different from that of American students. It is noteworthy that being moderate and conservation is a value in Chinese culture, and individuals are not always encouraged to express their strong feelings (Chang and Mao 1999a, b; Tsai 2004). Fourth, because TIMSS is just a cross-sectional and observational study, causal inferences could be interpreted with caution. Given the large sample size in the study, any statistical significance should be interpreted in the context of practical significance (Rutkowski et al. 2010; Kline 2009). Fifth, although the current study supports partial mediation of affect between academic motivation and science achievement, the effects were rather small. Besides, the mediation effects between instructional practices and achievement were not found in this study, suggesting that instructional practices might take other paths. More studies are needed in the future with regard to the mediation effect or moderation effect of other variables in the educational context.

7 Conclusion

The current study employed the sample of eighth-grade students in Taipei that participated in TIMSS 2007 assessment and examined the interrelationships among academic motivation, instruction, positive affect toward science, and science achievement, as well as the mediation effect of positive affect. Consistent with previous findings, the results showed that students in Taipei had high achievement but low self-confidence and enjoyment of learning science. Although expectancy, positive affect, and traditional instruction were significant and positive predictors of science achievement, inquiry-based and practice-based instructions were significant and negative predictors, and value was nonsignificant. The suppression role of positive affect was supported for the relationship between the two components of academic motivation and science achievement. The findings of the current study provided an in-depth understanding of the "high achievement but low motivation" phenomenon that is prevalent in East Asian countries. These results also demonstrated that the motivation exerted a negative effect on students' science achievement through the suppression role of positive affect toward science.

References

Alsop, S., & Watts, M. (2003). Science education and affect. *International Journal of Science Education, 25*, 1043–1047. doi:10.1080/0950069032000052180.

Anderson, R. D. (2002). Reforming science teaching: What research says about inquiry? *Journal of Science Teacher Education, 13*, 1–12.

Anderson, J. C., & Gerbing, D. W. (1988). Structural equational modeling in practice: A review and recommended two-step approach. *Psychological Bulletin, 103*, 411–423. doi:10.1037/0033-2909.103.3.411.

Areepattamannil, S. (2012). Effects of inquiry-based science instruction on science achievement and interest in science: Evidence from Qatar. *The Journal of Educational Research, 105*, 134–146. doi:10.1080/00220671.2010.533717.

Areepattamannil, S., Freeman, J. G., & Klinger, D. A. (2011). Influence of motivation, self-beliefs, and instructional practices on science achievement of adolescents in Canada. *Social Psychology of Education, 14*, 233–259. doi:10.1007/s11218-010-9144-9.

Asparouhov, T., & Muthen, B. (2010). *Plausible values for latent variables using Mplus*. Technical Report. Retrieved from http://www.statmodel.com/download/Plausible.pdf.

Aspinwall, L. G. (1998). Rethinking the role of positive affect in self-regulation. *Motivation and Emotion, 22*, 1–32. doi:10.1023/A:1023080224401.

Auger, R. W., & Blackhurst, A. E. (2005). The development of elementary-aged children's career aspirations and expectations. *American School Counselor Association Journal, 8*, 322–329.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York, NY: Freeman.

Bandura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (2001). Self-efficacy beliefs as shapers of children's aspirations and career trajectories. *Child Development, 72*, 187–206.

Beaton, A., Martin, M. O., Mullis, I., Gonzalez, E. J., Smith, T. A., & Kelley, D. L. (1996). *Science achievement in the middle school years: IEA's third international mathematics and science study*. Chestnut Hill, MA: Boston College.

Bell, T., Urhahne, D., Schanze, S., & Ploetzner, R. (2010). Collaborative inquiry learning: Models, tools, and challenges. *International Journal of Science Education, 32*, 349–377. doi:10.1080/09500690802582241.

Bollen, K. A. (1987). Total, direct, and indirect effects in structural equation models. *Sociological Methodology, 17*, 37–69.

Brown, A., & Campione, J. (1994). Guided discovery in a community of learners. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 229–270). Cambridge, MA: MIT Press.

Capps, D. K., Crawford, B., & Constas, M. A. (2012). A review of empirical literature on inquiry professional development: Alignment with best practices and a critique of the findings. *Journal of Science Teacher Education, 23*, 291–318. doi:10.1007/s10972-012-9275-2.

Chang, C.-Y. (2001). A problem-solving based computer-assisted tutorial for the earth science. *Journal of Computer Assisted learning, 17*, 263–274. doi:10.1046/j.0266-4909.2001.00181.x.

Chang, C.-Y. (2002a). Does computer-assisted instruction + problem solving = improved science outcomes? A pioneer study. *The Journal of Educational Research, 95*, 143–150. doi:10.1080/00220670209596584.

Chang, C.-Y. (2002b). The impact of different forms of multimedia CAI on students' science achievement. *Innovations in Education and Teaching International, 39*, 280–288. doi:10.1080/13558000210161052.

Chang, C.-Y. (2003). Teaching earth sciences: Should we implement teacher-directed or student-controlled CAI in the secondary classroom? *International Journal of Science Education, 25*, 427–438. doi:10.1080/09500690210145701.

Chang, C.-Y., & Cheng, W.-Y. (2008). Science achievement and students' self-confidence and interest in science: A Taiwanese representative sample study. *International Journal of Science Education, 30*, 1183–1200. doi:10.1080/09500690701435384.

Chang, C.-Y., & Mao, S.-L. (1999a). Comparison of Taiwan science students' outcomes with inquiry-group versus traditional instruction. *The Journal of Educational Research, 92*, 340–346.

Chang, C.-Y., & Mao, S.-L. (1999b). The effects on students' cognitive achievement when using the cooperative learning method in earth science classrooms. *School Science and Mathematics, 99*, 374–379.

Cheung, G. W., & Lau, R. S. (2007). Testing mediation and suppression effects of latent variables: Bootstrapping with structural equation modeling. *Organizational Research Methods, 11*, 296–325. doi:10.1177/1094428107300343.

Chinoh, Y. H., & Fraser, B. J. (2009). Classroom environment, achievement, attitudes and self-esteem in geography and mathematics in Singapore. *International Research in Geographical and Environmental Education, 18*, 29–44. doi:10.1080/10382040802591530.

Crosnoe, R. (2010). Instruction, teacher-student relations, and math achievement trajectories in elementary school. *Journal of Educational Psychology, 102*, 407–417. doi:10.1037/a0017762.

Csikszentmihalyi, M., Rathunde, K., & Whalen, S. (1993). *Talented teenagers: The roots of success and failure*. Cambridge, UK: Cambridge University Press.

Davis-Kean, P. E. (2005). The influence of parent education and family income on child achievement: The indirect role of parental expectations and the home environment. *Journal of Family Psychology, 19*, 294–304. doi:10.1037/0893-3200.19.2.294.

DeBacker, T. K., & Nelson, R. M. (1999). Variations on an expectancy-value model of motivation in science. *Contemporary Educational Psychology, 24*, 71–94. doi:10.1006/ceps.1998.0984.

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*, 109–132.

Eklöf, H. (2007). Test-taking motivation and mathematics performance in TIMSS 2003. *International Journal of Testing*, *7*(3), 311–326.

Feldman Barrett, L., & Russell, J. A. (1999). The structure of current affect: Controversies and emerging consensus. *Current Directions in Psychological Science, 8*, 10–14.

Fiedler, K. (2001). Affective influences on social information processing. In J. P. Forgas (Ed.), *Handbook of affect and social cognition* (pp. 163–185). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Fogleman, J., McNeill, K. L., & Krajcik, J. (2011). Examining the effect of teachers' adaptations of a middle school science inquiry-oriented curriculum unit on student learning. *Journal of Research in Science Teaching, 48*, 149–169. doi:10.1002/tea.20399.

Foy, P., & Olson, J. F. (Eds.). (2009a). *Supplement 2: National adaptations of international background questionnaires*. Boston, MA: TIMSS and PIRLS International Study Center.

Foy, P., & Olson, J. F. (Eds.). (2009b). *Supplement 4: TIMSS 2007 sampling stratification information*. Chestnut Hill, MA: Boston College.

Freedman, M. P. (1997). Relationship among laboratory instruction, attitude toward science, and achievement in science knowledge. *Journal of Research in Science Teaching, 34*, 343–357. doi:10.1002/(SICI)1098-2736(199704)34:4<343:AID-TEA5>3.0.CO;2-R.

Gao, L. (1998). Cultural context of school science teaching and learning in the People's Republic of China. *Science Education, 82*, 1–13. doi:10.1002/(SICI)1098-237X(199801)82:1<1:AID-SCE1>3.0.CO;2-L.

Gao, S. (2014). *The relationship between teaching approaches and student science achievement for four racial groups in U.S. eighth grade classes*. University of Nevada, Las Vegas Theses/Dissertations/Professional Papers/Capstones. Paper 2180.

Gardner, P. L. (1975). Attitudes to science: A review. *Studies in Science Education*, *2*(1), 1–41.

Hassan, G. (2008). Attitudes toward science among Australian tertiary and secondary school students. *Research in Science and Technological Education, 2008*, 129–147. doi:10.1080/02635140802034762.

Hooper, D., Coughlan, J., & Mullen, M. (2008). *Structural equation modeling: Guidelines for determining model fit*. Retrieved from online www.dit.ie.

House, J. D. (2005). Classroom instruction and science achievement in Japan, Hong Kong, and Chinese Taipei: Results from the TIMSS 1999 assessment. *International Journal of Instructional Media, 32*, 295–311.
House, J. D. (2006). Mathematics beliefs and achievement of elementary school students in Japan and the United States: Results from the Third International Mathematics and Science Study. *The Journal of Genetic Psychology, 167*, 31–45. doi:10.3200/GNTP.167.1.31-45.
House, J. D. (2007). Mathematics beliefs and instructional strategies in achievement of elementary-school students in Japan: Results from the TIMSS 2003 assessment. *Psychological Reports, 100*, 476–482. doi:10.2466/pr0.100.2.476-482.
House, J. D. (2008). Effects of classroom instructional strategies and self-beliefs on science achievement of elementary-school students in Japan: Results from the TIMSS 2003 assessment. *Education, 129*, 259–266.
House, J. D. (2009). Elementary-school mathematics instruction and achievement of fourth-grade students in Japan: Findings from the TIMSS 2007 assessment. *Education, 130*, 301–307.
House, J. D., & Telese, J. A. (2008). Relationships between student and instructional factors and algebra achievement of students in the United States and Japan: An analysis of TIMSS 2003 data. *Educational Research and Evaluation, 14*, 101–112. doi:10.1080/13803610801896679.
Jiang, F., & McComas, W. F. (2015). The effects of inquiry teaching on student science achievement and attitudes: Evidence from propensity analysis of PISA data. *International Journal of Science Education, 37*, 554–576. doi:10.1080/09500693.2014.1000426.
Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*, 75–86. doi:10.1207/s15326985ep4102_1.
Klahr, D., & Nigam, M. (2004). The equivalence of learning paths in early science instruction: Effects of direct instruction and discovery learning. *Psychological Science, 15*, 661–667.
Kline, R. B. (2009). *Principals and practice of structural equation modeling*. New York: Guilford.
Lavonen, J., & Laaksonen, S. (2009). Context of teaching and learning school science in Finland: Reflections on PISA 2006 results. *Journal of Research in Science Teaching, 46*, 922–944. doi:10.1002/tea.20339.
Leung, F. K. S. (2002). Behind the high achievement of East Asian students. *Educational Research and Evaluation, 8*, 87–108. doi:10.1076/edre.8.1.87.6920.
Linnenbrink, E. A. (2007). The role of affect in student learning: A multi-dimensional approach to considering the interaction of affect, motivation, and engagement. In P. A. Schutz, R. Pekrun (Eds.), *Emotion in education*. Educational psychology series (pp. 107–124). San Diego, CA: Elsevier Academic Press.
Little, R. J. A., & Rubin, D. B. (2014). *Statistical analysis with missing data*. Hoboken, New Jersey: Wiley.
Lüdtke, O., Robitzsch, A., Trautwein, U., & Kunter, M. (2009). Assessing the impact of learning environments: How to use student ratings of classroom or school characteristics in multilevel modeling. *Contemporary Educational Psychology, 34*, 120–131. doi:10.1016/j.cedpsych.2008.12.
Maassen, G. H., & Bakker, A. B. (2001). Suppressor variables in path models. *Sociological Methods and Research, 30*, 241–270.
Markus, H. R., & Kitayama, S. (1991). Culture and the self: Implications for cognition, emotion, and motivation. *Psychological Review, 98*, 224–253. doi:10.1037/0033-295X.98.2.224.
Marsh, H. W., Hau, K.-T., & Wen, Z. (2004). In search of golden rules: Comment on hypothesis-testing approaches to setting cutoff values for fit indices and dangers in overgeneralizing Hu and Bentler's 1999 findings. *Structural Equation Modeling, 11*, 320–341. doi:10.1207/s15328007sem1103_2.
Martin, M. O., Mullis, I. V. S., & Foy, P. (2008). *TIMSS 2007 international science report: Findings from IEA's trends in international mathematics and science study at the eighth and fourth grades*. Chestnut Hill, MA: Boston College.
Martin, M. O., Mullis, I. V. S., Gonzalez, E. J., & Chrostowski, S. J. (2004). *TIMSS 2003 international science report.* Boston, MA: TIMSS & PIRLS International Study Center, Lynch School of Education, Boston College.
Meece, J. L., Wigfield, A., & Eccles, J. S. (1990). Predictors of math anxiety and its consequences for young adolescents' course enrollment intentions and performance in mathematics. *Journal of Educational Psychology, 82*, 60–70.
Meyer, D. K., & Turner, J. C. (2006). Re-conceptualizing emotion and motivation to learn in classroom contexts. *Educational Psychology Review, 18*, 377–390. doi:10.1007/s10648-006-9032-1.

Moreno, R. (2004). Decreasing cognitive load in novice students: Effects of explanatory versus corrective feedback in discovery-based multimedia. *Instructional Science, 32*, 99–113. doi:10.1023/B:TRUC.0000021811.66966.1d.

Mullis, I. V. S., Martin, M. O., Ruddock, G. J., O'Sullivan, C. Y., Arora, A., & Erberber, E. (2005). *TIMSS 2007 assessment framework*. Chestnut Hill, MA: Boston College.

Murphy, P. K., & Alexander, P. A. (2000). A motivated exploration of motivation terminology. *Contemporary Educational Psychology, 25*, 3–53. doi:10.1006/ceps.1999.1019.

Murphy, C., Ambusaidi, A., & Beggs, J. (2006). Middle East meets West: Comparing children's attitudes to school science. *International Journal of Science Education, 28*, 405–422. doi:10.1080/09500690500339696.

Murphy, C., & Beggs, J. (2003). Children's perceptions of school science. *School Science Review, 84*, 109–116.

Muthen, L. (1999). Missing data [Msg 2]. Message posted to http://www.statmodel.com/discussion/messages/22/24.html?1429060790.

Muthen, L. K., & Muthen, B. O. (1998–2012). *Mplus User's Guide* (7th Ed.). Los Angeles: Muthen and Muthen.

National Center for Education Statistics. (2010). *TIMSS 2003 table*. Retrieved from http://nces.ed.gov/timss/TIMSS03Tables.asp?Quest=4andFigure=8.

National Center for Education Statistics (NCES). (2016). *State and district participation in TIMSS*. Retrieved from https://nces.ed.gov/timss/benchmark.asp.

Ng, K. T., Lay, Y. F., Areepattamannil, S., Treagust, D. F., & Chandrasegaran, A. L. (2012). Relationship between affect and achievement in science and mathematics in Malaysia and Singapore. *Research in Science and Technological Education, 30*, 225–237. doi:10.1080/02635143.2012.708655.

Nisbett, R. E., & Masuda, T. (2003). Culture and point of view. *Proceedings of the National Academy of Science of the United States of America, 100*, 11163–11170. doi:10.1073/pnas.1934527100.

Osborne, J. F. (1996). Beyond constructivism. *Science Education, 80*, 53–82. doi:10.1002/(SICI)1098-237X(199601)80:1<53:AID-SCE4>3.0.CO;2-1.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*, 1049–1079. doi:10.1080/0950069032000032199.

Pajares, F., Britner, S. L., & Valiante, G. (2000). Relation between achievement goals and self-beliefs of middle school students in writing and science. *Contemporary Educational Psychology, 25*, 406–422. doi:10.1006/ceps.1999.1027.

Pajares, F., & Graham, L. (1999). Self-efficacy, motivation constructs, and mathematics performance of entering middle school students. *Contemporary Educational Psychology, 24*, 124–139. doi:10.1006/ceps.1998.0991.

Papanastasiou, E. C. (2002). School, teaching, and family influence on student attitudes toward science: Based on TIMSS data for Cyprus. *Studies in Educational Evaluation, 28*, 71–86. doi:10.1016/S0191-491X(02)00013-5.

Papanastasiou, E. C., & Zembylas, M. (2004). Differential effects of science attitudes and science achievement in Australia, Cyprus, and the USA. *International Journal of Science Education, 26*(3), 259–280. doi:10.1080/0950069022000038277.

Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implementations for educational research and practice. *Educational Psychology Review, 18*, 315–341. doi:10.1007/s10648-006-9029-9.

Pekrun, R., Elliot, A. J., & Maier, M. A. (2009). Achievement goals and achievement emotions: Testing a model of their joint relations with academic performance. *Journal of Educational Psychology, 101*, 115–135. doi:10.1037/a0013383.

Pekrun, R., Frenzel, A., Goetz, T., & Perry, R. P. (2007). The control–value theory of achievement emotions: An integrative approach to emotions in education. In P. A. Schutz & R. Pekrun (Eds.), *Emotion in education* (pp. 13–36). San Diego, CA: Academic Press.

Reiss, S. S. (2005). Extrinsic and intrinsic motivation at 30: Unresolved scientific issues. *The Behavior Analyst*, *28*, 1–14.

Reynolds, A. J., & Walberg, H. J. (1991). A structural model of science achievement. *Journal of Educational Psychology, 83*, 97–107. doi:10.1037/0022-0663.83.1.97.

Rucker, D. D., Preacher, K. J., Tormala, Z. L., & Petty, R. E. (2011). Mediation analysis in social psychology: Current practices and new recommendations. *Social and Personality Psychology Compass, 5*, 359–371. doi:10.1111/j.1751-9004.2011.00355.x.

Rutkowski, L., Gonzalez, E., Joncas, M., & von Davier, M. (2010). International large-scale assessment data: Issues in secondary analysis and reporting. *Educational Researcher, 39*, 142–151. doi:10.3102/0013189X10363170.

Rutkowski, D., & Rutkowski, L. (2013a). Measuring socioeconomic background in PISA: One size might not fit all. *Research in Comparative and International Education, 8*, 259–278. doi:10.2304/rcie.2013.8.3.259.

Rutkowski, L., & Rutkowski, D. (2013b). Getting it 'better': The importance of improving background questionnaires in international large-scale assessment. *Journal of Curriculum Studies, 42*, 411–430. doi:10.1080/00220272.2010.487546.

Schreiber, J. B., Nora, A., Stage, F. K., Barlow, E. A., & King, J. (2006). Reporting Structural Equation Modeling and Confirmatory Factor Analysis results: A review. *The Journal of Educational Research, 99*, 323–338. doi:10.3200/JOER.99.6.323-338.

Schroeder, C. M., Scott, T. P., Tolson, H., Huang, T.-Y., & Lee, Y.-H. (2007). A meta-analysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching, 44*, 1436–1460. doi:10.1002/tea.20212.

Schunk, D. H. (1991). Self-efficacy and academic achievement. *Educational Psychologist, 26*, 207–231. doi:10.1080/00461520.1991.9653133.

Schütte, K. (2015). Science self-concept and valuing science: A cross-cultural analysis of their relation among students from Western and East Asian countries. *Social Psychology of Education, 18*, 635–652. doi:10.1007/s11218-015-9311-0.

Schweinle, A., Meyer, D. K., & Turner, J. C. (2006). Striking the right balance: Students' motivation and affect in elementary mathematics. *The Journal of Educational Research, 99*, 271–294. doi:10.3200/JOER.99.5.271-294.

Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievement: Effects of motivation, interest, and academic engagement. *The Journal of Educational Research, 95*, 323–332. doi:10.1080/00220670209596607.

Stapleton, L. M. (2014). Incorporating sampling weights into single- and multi-level analyses. In L. Rutkowski, M. von Davier, & D. Rutkowski (Eds.), *Handbook of International Large-Scale Assessment: Background, technical issues, and methods of data analysis* (pp. 363–388). New York, NY: CRC Press Taylor and Francis Group.

Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Science, 312*, 1143–1144.

Taiwan Government. (2016). *Education*. Retrieved from http://www.taiwan.gov.tw/ct.asp?xItem=126577&CtNode=3773&mp=1.

Tan, I. G. C., Sharan, S., & Lee, C. K. E. (2007). Group investigation effects on achievement, motivation, and perceptions of students in Singapore. *The Journal of Educational Research, 100*, 142–154. doi:10.3200/JOER.100.3.142-154.

Tsai, C.-C. (2004). Conceptions of learning science among high school students in Taiwan: A phenomenographic analysis. *International Journal of Science Education, 26*, 1733–1750. doi:10.1080/0950069042000230776.

Tuovinen, J. E., & Sweller, J. (1999). A comparison of cognitive load associated with discovery learning and worked examples. *Journal of Educational Psychology, 91*, 334–341. doi:10.1037/0022-0663.91.2.334.

Wigfield, A. (1994). Expectancy-value theory of achievement motivation: A developmental perspective. *Educational Psychology Review*, *6*(1), 49–78.

Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology, 25*, 68–81.

Wigfield, A., & Eccles, J. S. (2002). The development of competence beliefs, expectancies for success, and achievement values from childhood through adolescence. In A. Wigfield & J. Eccles (Eds.), *Development of achievement motivation* (pp. 91–120). San Diego, CA: Academic Press.

Young, D. J., Reynolds, A. J., & Walberg, H. J. (1996). Science achievement and educational productivity: A hierarchical linear model. *The Journal of Educational Research*, *89*(5), 272–278.

Yu, C. H. (2012). Examining the relationships among academic self-concept, instrumental motivation, and TIMSS 2007 science scores: A cross-cultural comparison of five East Asian countries/regions and the United States. *Educational Research and Evaluation, 18*, 713–731. doi:10.1080/13803611.2012.718511.

Zhao, Y. (2005). Increasing math and science achievement: The best and worst of the East and West. *Phi Delta Kappan, 87*, 219–222.

Zhu, Y., & Leung, F. K. S. (2010). Motivation and achievement: Is there an East Asian model? *International Journal of Science and Mathematics Education, 9*, 1189–1212. doi:10.1007/s10763-010-9255-y.

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