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# Students' motivational beliefs in science learning, school motivational contexts, and science achievement in Taiwan

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**ABSTRACT**
Taiwanese students are featured as having high academic achievement but low motivational beliefs according to the serial results of the Trends in Mathematics and Science Study (TIMSS). Moreover, given that the role of context has become more important in the development of academic motivation theory, this study aimed to examine the relationship between motivational beliefs and science achievement at both the student and school levels. Based on the Expectancy-Value Theory, the three motivational beliefs, namely self-concept, intrinsic value, and utility value, were the focuses of this study. The two-level hierarchical linear model was used to analyse the Taiwanese TIMSS 2011 eighth-grade student data. The results indicated that each motivational belief had a positive predictive effect on science achievement. Additionally, a positive school contextual effect of self-concept on science achievement was identified. Furthermore, school-mean utility value had a negative moderating effect on the relationship between utility value and science achievement. In conclusion, this study sheds light on the functioning of motivational beliefs in science learning among Taiwanese adolescents with consideration of the school motivational contexts.

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**KEYWORDS**
Hierarchical linear modelling; motivational beliefs; science achievement; TIMSS

## Introduction

The role of students' motivational beliefs in science learning has been considered as a critical issue in science education over the years. Previous studies have theoretically and empirically demonstrated that motivational beliefs are associated with far-reaching positive learning consequences for students, such as high academic achievement, engagement in science learning, and self-regulated strategies (Denissen, Zarrett, & Eccles, 2007; Jack, Lin, & Yore, 2014; Pintrich, 1999; Wigfield & Eccles, 2000). However, the evidence, based on serial international results of the Trends in International Mathematics and Science Study (TIMSS), indicates that Taiwan as well as other Asian countries such as Korea, Japan, and Hong Kong, feature as having high science academic achievement

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but low motivational beliefs in science learning (Martin, Mullis, Foy, & Stanco, 2012). These contradictory findings from the different units of analysis (i.e. within-country and between-country analyses) imply that the multilevel nature of contexts matters in students' motivational beliefs in science learning as it relates to science achievement (Wilkins, 2004).

Although Taiwan has been regarded as one of the high-performing but low-motivation countries in terms of science learning within the global contexts, whether the role of motivational beliefs in science learning is important for Taiwanese students to learn science should be more exactly identified by within-country analysis. So far, numerous studies (e.g. Chang & Cheng, 2008; Liou, 2014a; Liou & Liu, 2015; Wang & Liou, 2017) have found that students' motivational beliefs in science learning are positively associated with their science achievement in Taiwan; however, little research has considered the context of the school as a unit to address in the relationship of school-mean motivational beliefs in science learning with science achievement (i.e. school contextual effect).

The importance of the school contextual effect of the motivational beliefs in science learning may be linked with the fact that the role of social contexts (e.g. educational contexts) has been shifted from a peripheral to a central position in psychological and educational research (Anderman & Maehr, 1994; Pintrich, 2003). Moreover, the development of students' motivational beliefs in science learning involves complex and hierarchical educational contexts. That is to say, individuals' science learning processes occur within a classroom, which in turn, is nested within a school under the current formal education system. Given the multilevel nature of learning environments and the increasing importance of social contexts for students' motivational beliefs in science learning, it is imperative to uncover the evidence of the school contextual effect of the motivational beliefs in science learning as a means of better understanding the influence of motivational beliefs in science learning on science achievement at different levels.

Consequently, this study aims to examine the predictive effect of motivational beliefs (i.e. self-concept, intrinsic value, and utility value) on science achievement at the student and school levels among Taiwanese eighth-grade students based on the Expectancy-Value Theory (EVT). Meanwhile, to extend the understanding of the multilevel nature of learning processes, the effect of school-mean motivational beliefs on the relationship between individual motivational beliefs in science learning and science achievement, referred to as cross-level interaction, was also examined. In sum, the results of this study shed some light on the current adolescents' motivational beliefs in science learning from the viewpoint of both individuals and schools, based on Taiwanese representative data. This is also a national study based on international large-scale assessment (ILSA) data to contribute to the body of motivational theories in the field of science education.

## Literature review

### *Conceptualising motivational beliefs in science learning based on the EVT*

Motivation theorists' focus on human behaviours has moved from investigating basic human needs or drives to examining how social environments where individuals are involved interact with one's perceptions of motivational beliefs (Eccles, Lord, &

Midgley, 1991; Eccles & Wigfield, 2002). One of the influential theoretical frameworks of academic motivation is the EVT (Eccles et al., 1983), which considers the role of social contexts and domain-specific academic tasks in students' academic motivation. The main hypothesis of the EVT is that an individual's academic learning behaviours, including choice, effort, persistence, and performance, are dependent on the two main constructs, expectancy for success and task value, which were conceptualised as the motivational beliefs in this study.

The expectancy-related belief is defined as the individual perceptions of how well he or she will do in a certain academic domain (Eccles et al., 1983). One of the prominent sources of individual expectation for success is students' perceptions of their ability (i.e. self-concept), which represents their broad perceptions of their current ability in a certain domain (Marsh & Shavelson, 1985). Wigfield and Eccles (2000) also confirmed that students' perceptions of their current ability and expectancy for success in a specific domain were indistinguishable, both conceptually and empirically. Thus, in line with previous empirical studies based on EVT in science education (e.g. Liou, 2017; Liou & Liu, 2015; Nagengast et al., 2011; Wang & Liou, 2017), science academic self-concept, was used to represent the expectancy for success, one type of motivational belief in science learning.

As for task-value beliefs, it addresses the question of why individuals engage or are involved in a certain academic task. As described in the EVT (Eccles et al., 1983), two components of task values were discussed in our study, namely intrinsic value, and utility value. Intrinsic value represents that the individual gets enjoyment from engaging in a specific task or is subjectively interested in a specific domain. Students who are intrinsically motivated are usually characterised as having a preference for heading a challenging task and being driven by interest and curiosity (Eccles & Wigfield, 2002). On the other hand, utility value indicates individuals' perceptions of how the tasks would benefit their future plans. In contrast to intrinsic value, utility value seems to capture more extrinsic reasons for engaging in an academic task rather than for its own sake.

### *School as a context of the development of students' motivational beliefs in science learning*

Although students' motivational beliefs in science learning represent their own perceptions of their science competence and their own value of the science task, social contexts are regarded as playing an important role in developing individuals' motivational beliefs in the EVT model (Eccles et al., 1991, 1993; Roeser, Eccles, & Sameroff, 2000; Tighezza, 2014). The hypothesis is that students' motivational beliefs are assumed to be influenced by students' perceived socialisers' beliefs or expectations and their previous learning experiences (Eccles et al., 1983; Eccles & Wigfield, 2002).

Given the current formal education system, schools where students spend much of their time learning, play a prominent role in students' motivational beliefs (Eccles et al., 1991). The effect of school on students' motivational beliefs might be not only through socialisers' beliefs or attitudes (i.e. teachers and peers), but also through providing quality instruction, which in turn, influences the students' learning experiences. Moreover, based on the framework of EVT, Eccles et al. (1993) considered whether a proper learning environment, which a school provided to fulfil the basic human needs of competence, autonomy, and the quality of interpersonal relationships, is important for students to develop their motivational beliefs. A proper learning environment is characterised as where students can perceive themselves as being successful (the needs of competence), gain opportunities for self-expression and decision making (the needs of autonomy), and feel cared for by teachers and peers (the need for quality interpersonal relationships).

An earlier motivation-related review paper in the field of science education (Osborne, Simon, & Collins, 2003) also highlighted that a growing body of literature had examined the role of school learning and teaching contexts in students' motivational beliefs in science learning. Recently, several studies have examined classroom- or school-level factors in students' motivational beliefs in science learning based on the theoretical framework of academic motivation. Chen, Lin, Wang, Lin, and Kao (2012) confirmed that positive school climate, which was measured by teacher–student interaction in a school, significantly predicted students' intrinsic value of science tasks. Positive interaction was also able to indirectly predict students' intrinsic value through their learning participation in science class activities. Jen, Lee, Chien, Hsu, and Chen (2013) also found that students' perceptions of teacher–student relationships in their school yielded positive effects not only on students' intrinsic value of science but also on their science academic self-concept. Additionally, peers' relationships served as the other important factor for students to develop their motivational beliefs in science learning. Ng, Liu, and Wang (2016) uncovered evidence that students who perceived that the teacher built an autonomously supportive learning environment tended to have a high perception of motivational beliefs in science learning.

### *The relationships between motivational beliefs in science learning and science achievement at the student and school levels*

As motivation theorists have uncovered the structure and functioning of each motivational belief in students' learning (Eccles & Wigfield, 2002), science educators have been widely examining the relationship of motivational beliefs in science learning with science achievement through conducting various types of research such as cross-sectional and longitudinal research and doing a review paper (e.g. Chang, 2015; Denissen et al., 2007; Lay, Ng, & Chong, 2015; Liou, 2014a, 2014b, 2017; Osborne et al., 2003; Sun, Bradley, & Akers, 2012). Generally, the evidence of these findings supports the theoretical hypothesis that students with a higher perception of the three motivational beliefs in science learning (i.e. science academic self-concept, the intrinsic value of science, and the utility value of science) tended to have higher performance on science tasks. Moreover, these results support the previous evidence that expectancy-related beliefs serve as a much stronger predictor of students' academic achievement than task-value beliefs, drawing on the EVT literature (Wigfield & Eccles, 1992, 2000).

Given that previous studies have found that school learning and teaching contexts played a role in developing students' motivational beliefs in science learning (e.g. Chen et al., 2012; Roeser et al., 2000; Tighezza, 2014), school motivational contexts, which were represented as an aggregation of individual motivational beliefs in a school (i.e. school-mean motivational beliefs) might differ from one school to another due to the various educational contexts as well as the school composition of the student body.

However, little is known about the relation of school motivational contexts with science achievement, which was labelled as the school contextual effect of motivational beliefs in science learning on science achievement.

According to Hox (2002), the school contextual effect refers to the effects of the social contexts which are shaped by the student bodies in a school. Taking a positive school contextual effect of science academic self-concept on science achievement as an example, a student with a low level of science academic self-concept who attends a school where the school-mean science academic self-concept is high may have higher science achievement than a student with the same level of science academic self-concept who attends a school where the school-mean science academic self-concept is low. In brief, the school-mean science academic self-concept influences students' science achievement above and beyond the effect of the individual level.

Although several studies have examined the contextual effect of motivational beliefs in science learning on science achievement, previous findings from the few studies that have been carried out are inconsistent in terms of various types of motivational beliefs in science learning or different nations. Mohammadpour (2013) found that the school contextual effect of the intrinsic value of science on Singaporean eighth-grade students' science achievement is significantly positive, but that of science academic self-concept was insignificant based on the TIMSS 2007 data. On the other hand, in Kaya and Rice's (2010) study, the results showed that the pattern of the relations of classroom-mean science academic self-concept with students' science achievement in each country was inconsistent, as Scotland and the U.S. had a positive contextual effect, but Singapore, Japan, and Australia did not, based on the TIMSS 2003 data.

Despite the well-known positive relationship between motivational beliefs and science achievement, which has been proved based on multilevel analysis (Areepattamannil, Freeman, & Klinger, 2011; Kaya & Rice, 2010; Lam & Lau, 2014), all of these studies assumed that the slope of each motivational belief with respect to science achievement is the same across schools. However, the nested learning environment indicated that individuals in a group (i.e. a school) are usually interdependent. Additionally, the educational contexts across schools might vary in that the school characteristics such as the school composition of the student body or teacher body, school resources, and school location differ (Ker, 2016). With the different educational contexts in a school, the relationships between individual motivational beliefs in science learning and science achievement may not always be consistent across schools.

Given the multilevel nature of learning environments and the increasing importance of school learning and teaching contexts for students' motivational beliefs in science learning, this study proposes a model of multilevel motivational beliefs regarding science achievement comprised of two major components (Figure 1). One is to examine the relations of motivational beliefs in science learning to science achievement at the student and school levels (i.e. school contextual effect). On the other hand, a cross-level moderation effect was included in the model as a means of further examining whether each school-mean motivational belief can serve a moderator role in the variability in its own relationship between individual motivational beliefs and science achievement if there is a significant variety in the slopes for each motivational belief with respect to science achievement.

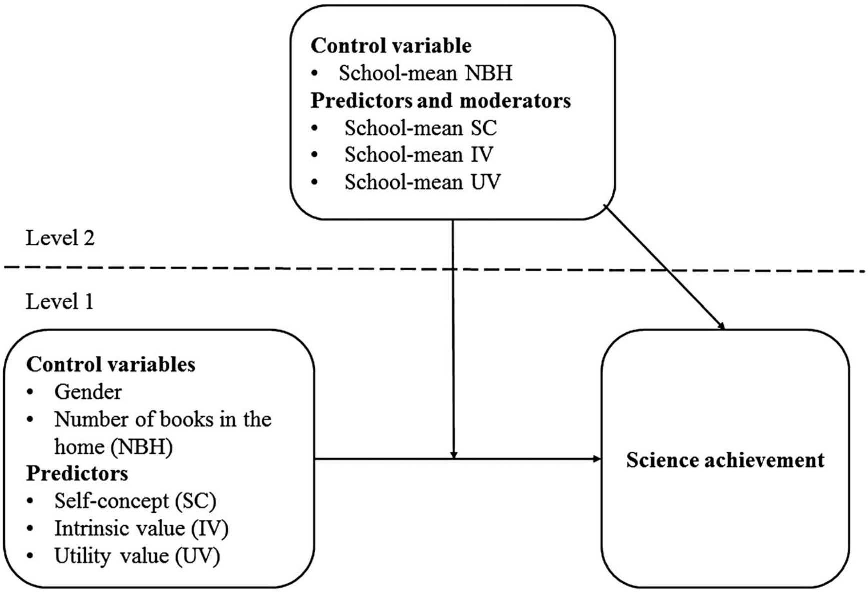


**Figure 1.** The model of multilevel motivational beliefs on science achievement.

## *The educational context of Taiwan*

A unique phenomenon, in Taiwan, is the formation of an examination culture which is aligned with the current education system and traditional Confucian culture. Given that getting high scores on the national examination plays a critical role for students in gaining social respect and acquiring social resources and success in their future life, Taiwanese students, parents, and even teachers overemphasise academic achievement (Huang, 2012). Huang (2012) also argued that as the benefits or losses from a real society were embedded in the high-stakes national examination, the learning environment in Taiwan is competitive. As a consequence, an examination-oriented teaching method is extensively adopted by teachers, which in turn, causes Taiwanese students to do many tests and exercises in their school years as a means to prepare for the high-stakes examination (Chang & Cheng, 2008). Liou and Ho (2016) also showed that Taiwanese students perceive teacher-oriented instructional practices (e.g. we listen to the teacher who gives a lecture-style presentation) as being more frequently used than student-oriented practices (e.g. we design and plan an experiment or investigation).

Moreover, Chang and Cheng (2008) argued that the competitively selective learning environment somehow diminishes students' motivational beliefs within the social context that overemphasises the value of academic achievement. This phenomenon also seems to correspond with the results of Taiwan in the serial results of TIMSS (Martin, Mullis, Foy, & Stanco, 2012) which indicate that, although Taiwanese students perform well in the science domain, relatively low motivation is reported in comparison with other countries. On the other hand, Lin, Deng, Chai, and Tsai (2013) argued that the pressure coming from the examination-based activities and national examinations might cause Taiwanese students to feel high test anxiety. Consequently, with the unique examinational culture and education system, Taiwanese students' motivational beliefs in the academic domain might develop in a different way from those of students in other countries.

### Research purposes and questions

Given the lack of research on the relationship between school motivational contexts and students' science achievement in Taiwan, this study aims to examine the model of multilevel motivational beliefs regarding science achievement (Figure 1) as a means of better understanding the various functions of science learning motivational beliefs in science achievement. In this model, the predictive effects of motivational beliefs on science achievement at not only student level but also school level are examined. Moreover, a cross-level moderation effect is also taken into account. Therefore, the following questions are proposed.

(1) How is the variation in science achievement distributed at the student and school levels?
(2) Does each student-level and school-level motivational belief in science learning have a significant predictive effect on science achievement?
(3) Do the school-mean motivational beliefs explain the variance in the slopes of each motivational belief with respect to science achievement at the student level (i.e. cross-level interaction effects)?

## Methods

### Data source and sample

In this study, Taiwanese TIMSS 2011 eighth-grade student data were used. TIMSS is one of the ILSA, and has surveyed fourth- and eighth-grade students in mathematics and science once every four years since 1995. Regarding the sampling in TIMSS, a stratified two-stage cluster sample design is used for sampling national representative data within a country. As for the procedure, schools are treated as the unit of the sample with probabilities proportional to their size after a stratification at the first sampling stage. Then, an intact class, which means all of the students in the class, is randomly selected from those sampled schools (Joncas & Foy, 2012).

The original total number of sampled students and schools is 5042/150, representing 304,037/918 weighted cases of students and schools, respectively. Moreover, within the 5042 sampled students, the number of boys ($N = 2594$) constituted 51.4% in total, while 48.6% of total students were girls ($N = 2448$). Moreover, among the 150 Taiwanese sampled schools, the number of sampled students per school ranged from 14 to 56.

### Measures

All the variables, including an outcome variable, predictors, moderators, and control variables, are described as follows. In terms of an outcome variable, science achievement was measured by students' performance on the TIMSS 2011 science assessment. In TIMSS 2011, the entire assessment pool of science items is packaged into a set of 14 booklets, and each student completes just one booklet in which only a small sample of total items were contained. Given that, to estimate how a student might have performed if he or she had been administered the total number of items, TIMSS created five plausible values based on Item Response Theory (IRT) as a computational approximation to obtain consistent and precise estimates of students' general science ability (Foy, Brossman, & Galia, 2012). In this study, all five plausible values were used as a proxy for science achievement.

Regarding the student-level factors of motivational beliefs in science learning, self-concept measures students' perceptions of their current capability to learn science (e.g. I usually do well in science). Intrinsic value represents students' interest in learning science and enjoyment of science (e.g. I enjoy learning science). Lastly, utility value reflects students' judgment of the value and usefulness of science for their future goals (e.g. I need science to learn other school subjects). These motivational-related items, in Table 1, were originally scored on a four-point Likert scale ranging from 1 (agree a lot) to 4 (disagree a lot) in the student questionnaire. After recording and transforming through IRT scaling by TIMSS, students with a higher value for each motivational construct were shown to hold a higher motivational belief. Table 1 shows that the Cronbach's $\alpha$ ranged from .89 to .92 for the three motivational beliefs, representing that the scale of each motivational belief has internal consistency and the scores of the scale are reliable (Field, 2013). On the other hand, the factor loadings of each item from the principle components analysis are positive and substantial (Martin, Mullis, Foy, & Arora, 2012), indicating a strong correlation between each item within a specific construct.

Gender and the number of books in the home (NBH), which is associated with students' socioeconomic status (SES), were regarded as the control variables because these two background variables have been proved to link with students' science achievement in the prior literature (Areepattamannil et al., 2011; Liou & Ho, 2016) at the student level. On the other hand, as for the school-level factors, all student-level factors except for gender were further aggregated to school-level variables to represent school-level

**Table 1.** The descriptions of the scale of each motivational belief.

| Factor | Cronbach's $\alpha$ | Factor loadings | Items |
|---|---|---|---|
| Self-concept | .92 | .85 | *I usually do well in science |
| | | .78 | Science is more difficult for me than for many of my classmates |
| | | .81 | Science is not one of my strengths |
| | | .84 | *I learn things quickly in science |
| | | .66 | *I am good at working out difficult science problems |
| | | .82 | Science makes me confused and nervous |
| | | .76 | *My teacher thinks I can do well in science with difficult materials |
| | | .82 | *My teacher tells me I am good at science |
| | | .76 | Science is harder for me than other subjects |
| Intrinsic value | .90 | .89 | *I enjoy learning science |
| | | .81 | I wish I did not have to study science |
| | | .83 | Science is boring |
| | | .83 | *I learn many interesting things in science |
| | | .90 | *I like science |
| Utility value | .89 | .79 | *I think learning science will help me in my daily life |
| | | .78 | *I need science to learn other school subjects |
| | | .84 | *I need to do well in science to get into the <university> of my choice |
| | | .86 | *I need to do well in science to get the job I want |
| | | .78 | *I would like a job that involves using science |
| | | .77 | *It is important to do well in science |

Notes: *Reverse coded item. The Cronbach's $\alpha$ and factor loadings were derived from *Methods and procedures in TIMSS and PIRLS* 2011 (Martin, Mullis, Foy, & Stanco, 2012b).

control variables as well as predictors, and cross-level moderators (Figure 1). In the previous literature, the school contextual effect of family background such as NBH on science achievement has been confirmed by Mohammadpour (2012). Consequently, the school-mean NBH was regarded as a control variable at the school level.

### *Data analysis and consideration*

When using ILSA data such as TIMSS, two important issues should be taken into account, namely weighting and design effect (Liou & Hung, 2015). Otherwise, the parameter estimate would be biased. Given that, to ensure the estimation of parameters and standard error, the following analyses, including descriptive statistics, correlation analysis, and two-level hierarchical linear modelling (HLM), take these two issues into account.

First, the descriptive statistics and correlation matrix, including mean, standard deviation, and correlation coefficient, were conducted to indicate the profile of students' motivational beliefs and demographics at both the student and school levels among Taiwanese eighth-grade students (Table 2). IEA international database (IDB) analyser was used in this study. In accordance with Foy, Arora, and Stanco (2013), IDB analyser can deal with the weighting and design effect by using an appropriate sampling weight and the jackknife repeated replication method to deal with sampling errors.

Furthermore, HLM analysis was proper to deal with TIMSS data which are hierarchy structured (Raudenbush & Bryk, 2002). Therefore, HLM was used to examine the relationship between motivational beliefs and science achievement at the student level, school level, and the cross-level interactions. It should be noted that, in the cross-level analysis, each school-mean motivational belief was assumed to be treated as a moderator in the relationships between its own motivational belief and science achievement at student level in our test model. For example, the hypothesis is that school-mean self-concept would moderate the relationship between individual self-concept and science achievement.

To assess the model of multilevel motivational beliefs regarding science achievement (Figure 1), the five-step approach for multilevel modelling was performed, following the

**Table 2.** Descriptive statistics and zero-order correlation matrix for the student- and school-level scales.

| Taiwan | Correlation | | | | | |
|---|---|---|---|---|---|---|
| Student-level variables | 1 | 2 | 3 | 4 | 5 | 6 |
| 1. Gender | – | −.03* | .20** | .19** | .12** | .02 |
| 2. NBH | .02 | – | .21** | .21** | .23** | .42** |
| 3. Self-concept | .01 | .02 | – | .72** | .58** | .40** |
| 4. Intrinsic value | .02 | .02 | .01 | – | .68** | .37** |
| 5. Utility value | .02 | .02 | .01 | .01 | – | .37** |
| 6. Science achievement | .02 | .01 | .01. | .02 | .02 | – |
| School-level variables | 1 | 2 | 3 | 4 | 5 | |
| 1. School-mean NBH | – | .20** | .21** | .34** | .78** | |
| 2. School-mean self-concept | .14 | – | .85** | .70** | .42** | |
| 3. School-mean intrinsic value | .13 | .03 | – | .80** | .36** | |
| 4. School-mean utility value | .11 | .05 | .03 | – | .42** | |
| 5. School-mean science achievement | .06 | .12 | .08 | .07 | – | |

Notes: The value within the top-right matrix indicates the correlation coefficient and its standard error shown within the bottom-left matrix. NBH represents the number of books in the home.

$^{**}p < .01$.

$^{*}p < .05$.

guidance of examining the main and moderation effects (Aguinis, Gottfredson, & Culpepper, 2013). First, an unconditional model (null model) was presented to interpret the extent to which the total outcome variance was distributed at the student and school levels without putting any predictor into the model. Second, a random intercept and fixed slope model (Model 1) was used, which assumed that the intercept of gender and NBH varied among schools, and the relations of gender and NBH with science achievement remained consistent across schools.

Third, in terms of motivational beliefs, a random-coefficient regression model was used at the student level (Model 2), assuming that both intercept and slope are random across schools. This model was used to ensure the existence of variant slopes across schools. Then, it would be reasonable to test a cross-level moderation effect. Fourth, the intercepts-as-outcomes model was used to examine the extent of the variance in science achievement that were explained by the school-level factors (Models 3 and 4). Finally, the final model was to examine whether the variance of the slope of each motivational belief with respect to science achievement could be explained by the moderators (i.e. school-mean motivational beliefs). Hence, the cross-level interaction model (Model 5) was built.

With regard to centring, grand mean centring is more appropriate than group means centring when assessing the predictive effect at a higher level under control for specific variables at level 1; on the other hand, group means centring is preferable for examining cross-level interaction (Field, 2013). Hence, grand mean centring was used for NBH (control variable), while group mean centring was used for motivational beliefs (predictors) at the student level. Restricted maximum likehood was used to estimate the parameters. Given the above description, the equation of the final model is as follows:

Level-1 Model:

$$\begin{aligned}\text{Sience achievement}_{ij} = \beta_{0j} + \beta_{1j} \times (\text{Gender}_{ij}) + \beta_{2j} \times (\text{NBH}_{ij}) + \beta_{3j} \times (\text{Self-concept}_{ij}) \\ + \beta_{4j} \times (\text{Intrinsic value}_{ij}) + \beta_{5j} + (\text{Utility value}_{ij}) + r_{ij}.\end{aligned} \tag{1}$$

Level-2 Model:

$$\begin{aligned}\beta_{0j} = \gamma_{00} + \gamma_{01} \times (\text{School-mean NBH}_j) + \gamma_{02} \times (\text{School-mean self-concept}_j) + \gamma_{03} \\ \times (\text{School-mean intrinsic value}_j) + \gamma_{04} \times (\text{School-mean utility value}_j) + u_{0j},\end{aligned} \tag{2}$$

$$\beta_{1j} = \gamma_{10}, \tag{3}$$

$$\beta_{2j} = \gamma_{20}, \tag{4}$$

$$\beta_{3j} = \gamma_{30} + \gamma_{31} \times (\text{School-mean self-concept}_j) + u_{3j}, \tag{5}$$

$$\beta_{4j} = \gamma_{40} + \gamma_{41} \times (\text{School-mean intrinsic value}_j) + u_{4j}, \tag{6}$$

$$\beta_{5j} = \gamma_{50} + \gamma_{51} \times (\text{School-mean utility value}_j) + u_{5j}, \tag{7}$$

Moreover, several important statistical considerations of HLM, including missing data, outliers, and multicollinearity were pondered in the study. First of all, missing data may lead to problematic parameter estimates, especially at the group or upper levels (Gibson & Olejnik, 2003). In this study, listwise deletion was used for eliminating missing data due to the small fraction of missing data (Tabachnik & Fidell, 2007). Concerning the outliers, the existence of outliers would affect a sum of squared errors and go further to cause the standard deviation and the standard error to be biased (Field, 2013). To solve this problem, any standard scores of all five plausible variables (outcome variables) not located within three standard deviations of the mean were regarded as outliers and were excluded. In this study, 55 outliers were excluded from the data. Thus, after deletion, the final number of the student sample was 4968, representing 299,334 weighted eighth-grade students.

As for multicollinearity, it may cause untrustworthy parameter estimates due to the strong relationship between predictors, thus limiting the correlation between the predictors and the outcome variable (Field, 2013). Field (2013) suggested a general guideline that if there is any Variance Inflation Factor (VIF) of predictors larger than 10, it would be considered problematic. In this study, the values of VIF ranged from 1.054 to 2.563 for the student-level variables, whereas for the school variables, the values of VIF ranged from 1.046 to 4.578. On the other hand, there is no correlation coefficient over .90 in the study (Table 2). Any correlation coefficient between predictors over .90 would be regarded as a multicollinearity problem (Tabachnik & Fidell, 2007). Consequently, this study did not have the problem of multicollinearity.

## Results

According to the results of HLM analysis (Table 3), the null model provided information about the within-school variance ($\sigma^2$) and between-school variance ($\tau$). The intra-class correlation (ICC), which refers to the proportion of the variance in science achievement within schools and between schools, was computed as the equation ($\rho = \tau_{00}/\tau_{00} + \sigma^2$). Thus, in response to the first research question, the value of ICC was .20 = 1293.65/(1293.65 + 5118.15), meaning that 20% of the total variance in science achievement was between schools.

By adding the motivational constructs (Model 2), an additional 14% of the student-level variance was explained. The results indicated that self-concept (+5.83; $p < .01$), intrinsic value (+5.23; $p < .01$), and utility value (+3.06; $p < .05$) had a positively predictive effect on science achievement with an increase of one-scale point after accounting for student background. Moreover, based on the model of random slopes for each motivational belief, the results showed that the residual of the slope of each motivational belief was significant. This means that although the predictive effect of motivational beliefs on science achievement was positive to a certain average degree, the degree of predictive effect differs by school.

In terms of the intercept-as-outcomes models (Models 3 and 4), after controlling the school-mean NBH variable, the school-mean motivational beliefs accounted for another 7% of the between-school variance. However, among the three school-mean motivational beliefs, only school-mean self-concept (+21.63; $p < .01$) was significantly positively predictive of science achievement with a one-scale point increase, meaning that there is a positive school contextual effect of self-concept on science achievement.

**Table 3.** Results from the two-level HLM predicting student science achievement.

| Parameter | Null model | Model 1 | Model 2 | Model 3 | Model 4 | Model 5 |
|---|---|---|---|---|---|---|
| Fixed effect | | | | | | |
| Intercept | 555.46 (5.05) | 558.37 (4.19) | 557.93 (4.30) | 563.16 (3.27) | 563.68 (2.83) | 563.67 (2.83) |
| Student level | | | | | | |
| Gender | | 3.58 (2.95) | −4.21 (3.19) | −4.49 (3.23) | −4.64 (3.16) | −4.57 (3.22) |
| NBH | | 19.34** (1.25) | 15.26** (1.43) | 14.31** (1.41) | 14.42** (1.43) | 14.34** (1.44) |
| Self-concept | | | 5.83** (1.36) | 5.96** (1.37) | 5.99** (1.34) | 6.25** (1.35) |
| Intrinsic value | | | 5.23** (1.66) | 5.23** (1.68) | 5.27** (1.66) | 5.31** (1.65) |
| Utility value | | | 3.06* (1.34) | 3.20* (1.34) | 3.13* (1.31) | 2.94* (1.29) |
| School level | | | 0.024 | | | |
| School-mean NBH | | | | 43.48** (5.68) | 37.89** (5.64) | 38.07** (5.67) |
| School-mean self-concept | | | | | 21.63** (7.01) | 23.16** (7.41) |
| School-mean intrinsic value | | | | | −7.39 (8.60) | −7.75 (8.63) |
| School-mean utility value | | | | | 4.61 (7.83) | 1.25 (7.92) |
| Cross-level interaction | | | | | | |
| Self-concept × School-mean self-concept | | | | | | 2.32 (1.54) |
| Intrinsic value × School-mean intrinsic value | | | | | | 1.89 (1.72) |
| Utility value × School-mean utility value | | | | | | −4.89** (1.73) |
| Random effect | | | | | | |
| Within-school (Level 1) variance ($\sigma^2$) | 5118.15 | 4592.28 | 3905.73 | 3907.13 | 3910.33 | 3896.45 |
| Between-schools (Intercept) variance | 1293.65 | 817.59 | 923.46 | 406.54 | 323.10 | 322.00 |
| Self-concept slope variance | | | 21.21** (4.61) | 22.30** (4.72) | 20.47** (4.52) | 22.24** (4.71) |
| Intrinsic value slope variance | | | 48.51** (6.96) | 50.57** (7.11) | 48.73** (6.98) | 48.04** (6.93) |
| Utility value slope variance | | | 29.75** (5.45) | 29.20** (5.40) | 28.10** (5.30) | 23.43** (4.84) |
| Variance within schools explained (%) | | 0.10 | 0.24 | 0.24 | 0.24 | 0.24 |
| Variance between schools explained (%) | | 36.80 | 28.62 | 68.57 | 75.02 | 75.11 |

Notes: The parameter estimates represent that the degree of the outcome measure increased with a one-point increase in the independent variables. The value inside the parentheses represents the standard errors of the parameter estimate. NBH represents number of books in the home.

**$p < .01$.

*$p < .05$.

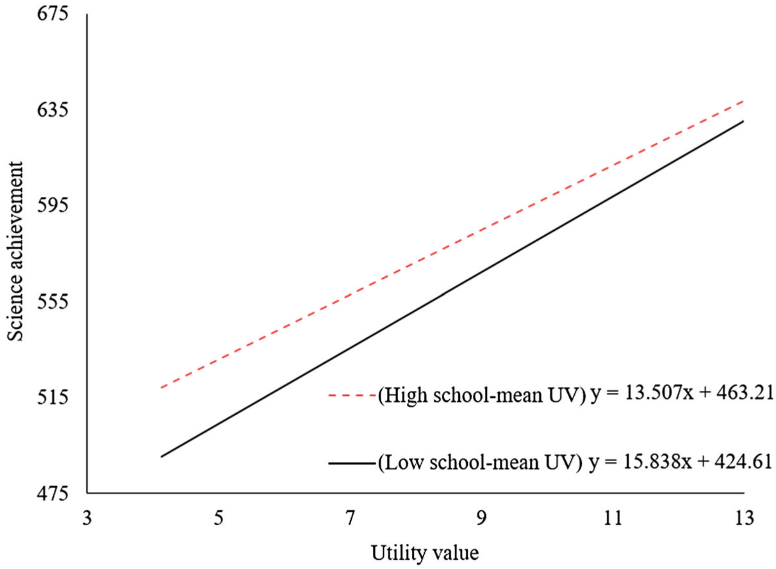


**Figure 2.** The relationship between utility value (UV) and science achievement with consideration of school-mean UV.

Finally, a cross-level interaction model (Model 5) concerns the cross-level moderation effect on the relationship between each motivational belief and science achievement. The results showed that only school-mean utility value had a significantly negative moderation effect on the relationship between utility value and science achievement, meaning that the relationship between individuals' utility value and their science achievement become weaker, by $\gamma_{51} = -4.89$ units, as the school-mean utility value increases by one unit (Figure 2).

Figure 2 depicts the slopes of utility value with regard to science achievement between schools with high and low school-level utility value in an explanation of the negative cross-level moderation effect. It should be noted that there was a positive but insignificant school contextual effect of utility value on science achievement. Therefore, a tiny separation, ideally, was expected between the solid black line (for schools with a low average utility value) and the dashed red line (for schools with a high average utility value). However, a large divergence in science achievement appeared between schools with high school-mean utility value and schools with low school-mean utility value. It therefore explained a part of the variance in the slope of utility value with respect to science achievement.

## Discussion and implications

Taiwanese students have been identified as having lower motivational beliefs from an international perspective (Liou, 2017; Martin, Mullis, Foy, & Stanco, 2012). Although numerous studies have found that Taiwanese students' motivational beliefs positively correlate with their science achievement (Chang, 2015; Liou, 2014a, 2014b; Tsai, Yang, & Chang, 2015; Wang & Liou, 2017), little is known about the school contextual effect of motivational beliefs on science achievement, meaning the relationship between school-mean motivational beliefs and science achievement. Therefore, this study aimed to examine the relationships between the three motivational beliefs, including self-concept, intrinsic value, and utility value and science achievement, not only at the student level but also at the school level simultaneously. Moreover, the cross-level interaction between individuals' motivational beliefs and school-mean motivational beliefs was examined. Further discussion of the results, and suggestions for future studies are provided in the following sections.

### *Relationship between motivational beliefs and science achievement*

On the basis of EVT, self-concept, intrinsic value, and utility value were hypothesised as influencing individual performance (Eccles et al., 1983; Eccles & Wigfield, 2002). Our results, in line with previous empirical studies (Jen et al., 2013; Liou, 2017; Liou & Liu, 2015 ; Tsai et al., 2015; Wang & Liou, 2017), provide further empirical evidence that each motivational belief has a positively predictive effect on science achievement in Taiwan. Moreover, the strength of the relationship between science academic self-concept and science achievement is slightly larger than that of intrinsic and utility values, which somewhat follows the general trends that expectancy-related beliefs are a stronger predictor of academic achievement than task-value beliefs, both empirically and theoretically (e.g. Chang, 2015; Eccles et al., 1983; Liou, 2017; Wigfield & Eccles, 2000). It thus seems that the main hypothesis of EVT could be generalised to the science domain within the Taiwanese educational contexts.

However, the degree of relationships between various task values (i.e. intrinsic value and utility value) and science achievement remain open to further debate. The results of this study are similar to those of Tsai et al.'s (2015) study, in which the predictive effect of intrinsic value was larger than utility value after considering parents' educational level in Taiwan. However, the pattern was inconsistent with the results of previous studies based on Taiwanese data (i.e. Liou, 2017; Wang & Liou, 2017) in which only the three motivational beliefs were included in their statistical model and treated as the predictors of science achievement. However, Liou (2017) also commented that it is possible that other covariates might play a moderating role in the relationships between students' motivational beliefs and science achievement. In this study, student backgrounds such as gender and the NBS were included in our test model, which might be a reason why the results of this study differed from those of the two previous studies. Future studies could make a deeper investigation into the functioning of student backgrounds, especially as it relates to students' motivational beliefs.

Although science academic self-concept yielded the largest predictive effect on science achievement among the three motivational beliefs when controlling for the other factors, the importance of task-value beliefs in science achievement could not be undervalued. With a high correlation among each other, it is possible that the three motivational beliefs could interact with each other to influence students' engagement in a certain science task, which in turn, may influence their science achievement. Papanastasiou and Zembylas (2012) found that science academic self-concept had indirectly predictive effects on the students' achievement through their perceptions of both the intrinsic and utility values of science tasks. On the other hand, Nagengast et al. (2011) suggested that the predictive effect of motivational beliefs on students' engagement in science would be more substantial when students had both high perceptions of their self-concept and task value in a science domain. They suggested that when researchers or educators attempt to facilitate students' science learning from the perspective of motivational beliefs, neither the science academic self-concept nor task values of science could be neglected.

As motivational beliefs are gaining importance for students' science learning, in Taiwan, classroom activities in middle school generally feature more teacher control and discipline rather than teacher–student or peer interactions, and more standard quizzes rather than diverse tasks. Taiwanese eighth-grade students also perceive the instruction in the classroom as being more teacher-oriented rather than student-oriented (Liou & Ho, 2016). This general pattern may be caused by the competitive examination culture which causes students to suffer more pressure from tests and competition, and leads to teachers frequently adopting more examination-oriented instruction (Chang & Cheng, 2008; Chen et al., 2012; Huang, 2012). However, such learning and teaching contexts may not fit the learning environment proposed by Eccles et al. (1993) which allows students to fulfil their basic needs of competence, autonomy, and quality interpersonal relationships. For example, students would not feel autonomous in their learning behaviours or cared for by teachers or peers under the rigid teacher control and discipline and teacher-directed instruction. On the other hand, the overemphasis on standard quizzes may play a role in facilitating social comparison or learning competition, which is harmful to the need to experience a feeling of competence for most students (Eccles et al., 1993; Pintrich, 2003).

Given the current educational context in Taiwan, designing classroom activities which allow for proper autonomy of students' participation and high quality interaction between teachers and students as suggested by Eccles et al. (1993) seems to be imperative and constructive. Several empirical studies (Chen et al., 2012; Jen et al., 2013) have also highlighted the importance of learning and teaching contexts in students' science learning in Taiwan. In Jen et al.'s (2013) study, they demonstrated that quality interpersonal relationships (i.e. peer relationships and teacher–student relationships) was one of the important determinants of students' motivational beliefs, which in turn, had a positive prediction of science achievement in Taiwan.

### *The school contextual effect of motivational beliefs on science achievement*

In the literature on school contextual effects, most studies (Kaya & Rice, 2010; Lam & Lau, 2014; McConney & Perry, 2010; Sun et al., 2012) examining the variables of school composition of the study body have focused on students' SES-related factors such as the NBH, and parents' educational and occupational levels. The main causes of the variant school SES composition of the student body between schools are not dependent its own learning environments but on the geographical variables, such as the location of the school. In contrast, the variance in school motivational contexts may not only result from the student body in a school but also from the school learning and teaching environments which were created by all school teaching staff members and students.

Previous theoretical and empirical studies have suggested that different school learning contexts might influence or be linked to students' motivational beliefs (Chen et al., 2012; Eccles et al., 1991, 1993). However, research has hardly examined the school contextual effect of motivational beliefs in science learning on science achievement. To uncover the role of school motivational contexts in students' science achievement, the results of this study indicated that there is a positive school contextual effect of science academic self-concept on science achievement after controlling student-level factors and school-mean NBH in Taiwan. This means that despite students having similar degrees of science academic self-concept, those attending a school with a high mean science academic self-concept for the whole student body performed better than those attending a school with a low mean science academic self-concept for the whole student body.

One possible explanation of the positive school contextual effect of science academic self-concept is that when a student is confronted with a difficult science problem within the teaching time constraints, he or she can probably seek help from peers who feel competent to deal with the difficult science tasks easily, which in turn, can help them to solve the problem. This phenomenon may be caused by the fact that middle-school teachers in Taiwan are specific and professional in a certain subject and they have to take more responsibility for more classes. That is to say, the teachers may not have enough time to care for every single student and respond to all individuals' questions within the constraints of teaching time in a class. Thus, the role of peers becomes important for individuals' science learning.

This finding suggested that science academic self-concept might be an important factor in students' science learning, not only through students' perceptions of their own science academic ability, but also through positive social interactions. However, in a real situation, the school learning setting in Taiwan is more competitive through an overemphasis on public reference to normative evaluation standards and strict grading systems. These school-based policies or learning settings are likely to encourage the use of social comparison in an evaluation of one's ability, which in turn, would undermine most students' self-concept (Eccles et al., 1993). Thus, future studies could deeply investigate how school-based reform plays a role in school motivational contexts, which is related to students' science achievement in terms of their self-concept.

Moreover, regarding the contextual effect of motivational beliefs, the results of this study did not show a similar pattern in comparison with previous studies. There was a school contextual effect of intrinsic value on science achievement in Malaysia (Mohammadpour, 2012) and in Singapore (Mohammadpour, 2013) rather than science academic self-concept. This difference provided researchers with a clue that the school contextual effect of motivational beliefs may be caused by various cultural or national schooling contexts (Kaya & Rice, 2010).

### *The cross-level moderation effect of motivational beliefs on science achievement*

Although each motivational belief has been confirmed to be positively related to science achievement, most of the studies hypothesised that this positive relationship had the same pattern across schools (e.g. Areepattamannil et al., 2011; Kaya & Rice, 2010; Lam & Lau, 2014; Sun et al., 2012). However, the nature of students' learning processes in the current schooling system is complex and multilevel, and the findings of the study indicate that the relationship between each motivational belief and science achievement, in fact, varied across schools.

Moreover, a cross-level moderation effect indicated that the relation of individuals' utility value with science achievement becomes slighter as school-mean utility value gets higher. A further interpretation based on Figure 2 is that Taiwanese students who perceived low utility value of science did not perform well in science, especially those attending a school with low school-mean utility value. It should be noted that the results of this study based on Taiwanese TIMSS 2011 eighth-grade student science data, a cross-sectional study, did not offer any causal relationship and may not be generalised to other countries, grades, or subjects.

In conclusion, although this study provides a snapshot of the relationships between motivational beliefs at the different levels and the cross-level moderation effect of motivational beliefs, the results of this study contribute extending empirical evidence to the body of science education literature from the perspective of academic motivation based on EVT. The results indicate that each motivational belief has a positively predictive effect on science achievement when controlling student backgrounds such as gender and NBH at the student level. Additionally, after controlling student-level factors and school-mean NBH, only school-mean self-concept has a positively school contextual effect on science achievement. Regarding the cross-level moderation effect on the individual relationship between motivational beliefs and science achievement, only school-mean utility value has a negative moderation effect on the relationship between individual utility value and science achievement.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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