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Patterns of Motivational Beliefs in the Science Learning of Total, High-, and Low-Achieving Students: Evidence of Taiwanese TIMSS 2011 Data

Cheng-Lung Wang[1] **· Pey-Yan Liou**[1,2]

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Abstract The purpose of this study was to examine the pattern of the relationships among motivational beliefs and science achievement of 8th grade Taiwanese students, given that the students in Taiwan have high science academic achievement but low motivational beliefs in science learning on a series of international large-scale assessments. Three motivational beliefs in science learning, including self-concept, intrinsic value, and utility value, were conceptualized based on the modern expectancy-value theory. Data are from the Taiwanese proportion of the Trends in International Mathematics and Science Study 2011 dataset. Three groups of students, namely, the total group, the high-achieving group (HAG), and the low-achieving group (LAG), were examined. Results showed that the patterns of the relative predictions of motivational beliefs to science achievement were distinct for each group. In the total group, all the motivational beliefs could positively predict science achievement ($R^2 = 20\%$). On the other hand, self-concept could positively and negatively predict science achievement for the HAG and LAG students, respectively, and intrinsic value could positively predict science achievement for the LAG students. In conclusion, this study, based on the Taiwanese representative sample, contributes to the discussion regarding national variation in students' motivational beliefs and provides empirical-based evidence of the motivational beliefs in science learning of students of different levels of ability.

Keywords High-achieving students · Low-achieving students · Motivational beliefs · Science achievement · TIMSS

✉ Pey-Yan Liou
lioupeyyan@gmail.com

[1] Graduate Institute of Learning and Instruction, National Central University, Taiwan, No. 300, Jhongda Rd., Jhongli Dist., Taoyuan City 32001 Taiwan, Republic of China

[2] Center of Teacher Education, National Central University, Taiwan, No. 300, Jhongda Rd., Jhongli Dist., Taoyuan City 32001 Taiwan, Republic of China

Introduction

Motivational beliefs in science learning have been confirmed as one of the key determinants of science achievement (e.g. Liou, 2017; Osborne, Simon, & Collins, 2003). However, in a series of the Trends in International Mathematics and Science Study (TIMSS), which has surveyed fourth and eighth grade students in the field of mathematics and science every 4 years since 1995, students from Taiwan usually have quite low motivational beliefs, despite having high academic achievement.

Moreover, the variation in Taiwanese eighth grade students' science achievement is larger than that for other Asian countries, except for Singapore (Martin, Mullis, Foy, & Stanco, 2012), indicating the issue of educational inequality in Taiwan. In 2002, the Ministry of Education in Taiwan launched the *White Paper on Science Education*, in which one of the targets was educational equality, to be achieved via several strategies such as adaptive teaching and properly distributing budgets to solve the problem of inequity. However, the problem seems not to have been solved yet.

Consequently, this study aims to examine the pattern of the relations among the motivational beliefs and science achievement of Taiwanese eighth grade students. Meanwhile, the issue of educational inequality is addressed by examining the roles motivational beliefs play, not only in all Taiwanese eighth grade students' but also in high- and low-achieving students' learning.

Expectancy-Value Theory for Conceptualizing Students' Motivational Beliefs in Science Learning

During the past several decades, achievement motivation theorists have been curious about the reason why individuals engage in or disengage from different activities. These theorists have been dedicated to developing an achievement motivation model which could properly explain individuals' achievement-related behaviors (Eccles & Wigfield, 2002; Pintrich & Schunk, 2002; Ryan & Deci, 2000). Although there are various theoretical framework perspectives, the expectancy-value theory (EVT), which is one of the influential theories in the field of motivation, is elaborated in this study to conceptualize motivational beliefs.

A modern EVT, which exerted a tremendous influence on the achievement motivation field, was proposed by Eccles and her colleagues (1983). The main hypothesis of the EVT is that the *expectancy for success* and *task values* are two prominent roles in explaining individuals' achievement-related choices, persistence, and performance (Wigfield & Eccles, 2000). According to the modern EVT, three constructs were conceptualized as motivational beliefs in this study, where *self-concept* is regarded as the individuals' judgment of their own self-beliefs and perceptions of task difficulty to represent expectancy. Meanwhile, the other two constructs which come from task values are *intrinsic value* and *utility value*. The former measures the individual's feeling of enjoyment when performing a task, or the subjective perception of interest in the task. On the other hand, the latter refers to how a task suits an individual's future goals or plans, involving more extrinsic reasons such as pleasing his/her parents.

Regarding the development of motivational beliefs in science learning, as students grow up, their motivational beliefs become more differentiated and domain-specific, meaning that these may reflect their authentic perception of science after experiencing science tasks (Guay, Marsh, & Boivin, 2003; Marsh & Shavelson, 1985; Wigfield & Eccles, 1992). Taiwanese eighth grade students, who already have experience of science learning through schooling, are assumed to be appropriate samples for research on motivational beliefs in science learning.

The relations of motivational beliefs in science learning and science achievement have been widely examined. Science academic self-concept is one domain-specific self-concept of the general academic self-concept (Marsh & Shavelson, 1985), referring to the perception or belief in one's ability to do well in science (Shavelson & Bolus, 1982). Numerous empirical studies have shown that science academic self-concept is significantly associated with science achievement (e.g. Kaya & Rice, 2010; Liou, 2014a, b, c, 2017). Moreover, in the study of Guay et al. (2003), they confirmed a reciprocal relationship between them, meaning that students' prior academic achievements would influence their subsequent academic self-concepts, while students' prior self-concepts would also influence their subsequent academic achievements.

Besides self-concept, the roles of intrinsic value of science and utility value of science in students' science learning are important. Wigfield and Eccles (1992) claimed that students may not persist in doing tasks without the support of interest or goals, in spite of having a high self-concept. The intrinsic value of science refers to individuals' feelings of enjoyment or subjective perceptions of interest in science tasks, and the utility value of science indicates that students perceive the science tasks as being valuable and useful for their future goals and plans. The bulk of the empirical studies have also confirmed the positive relationships between the two types of task values and science achievement (Lay, Ng, & Chong, 2015; Liou, 2014a, 2017; Mohammadpou, 2012; Ng, Lay, Areepattamannil, Treagust, & Chandrasegaran, 2012).

Pattern of the Relative Prediction of Motivational Beliefs to Science Achievement

With numerous studies on the relationships between motivational beliefs and science achievement, the positive relations for each motivational belief are well known. However, the extent to which the relative power of these motivational beliefs can predict science achievement remains somewhat unclear. Although there are generally consistent findings that self-concept is more predictive of science achievement than intrinsic and utility value (Areepattamannil & Kaur, 2013; Areepattamannil, Klinger, & Freeman, 2011; Liou, 2014a, 2017; Liou & Liu, 2015), Mohammadpour (2012) found that utility value yielded the strongest link to science achievement among the three motivational constructs for Malaysian students. It seems that there is no absolute pattern of the relative prediction of motivational beliefs to science achievement.

Furthermore, the results of the extent of the relative prediction of intrinsic and utility value to science achievement showed inconsistencies across countries. The results of other studies focusing on specific countries support the phenomenon of inconsistent results across countries. In Turkey, Ozel, Caglak, and Erdogan (2013) confirmed that the prediction of intrinsic value to science achievement was larger than that of utility value. This pattern was similar to 15-year-old students in Canada (Areepattamannil et al., 2011) and Saudi Arabian eighth grade students (Tighezza, 2014). In contrast, the opposite pattern was found, namely, that utility value had more predictive effect on science achievement than intrinsic value among Finnish 15-year-old students (Lavonen & Laaksonen, 2009) and among Malaysian eighth graders (Mohammadpour, 2012). Recently, the inconsistent pattern across countries was also supported by the study of Liou (2017), which examined the relative magnitude of the relations of the three motivational beliefs to science achievement across 26 countries using the same measures.

Such inconsistent patterns of the relative prediction of motivational beliefs to science achievement also exist between students with different levels of science ability (Jen, Lee, Chien, Hsu, & Chen, 2013). In their study, the TIMSS 2007 Taiwanese database was used to examine the issue. They defined high-/low-achieving students as those whose achievement was higher/lower than the weighted medium. Their results showed that when controlling for students' perceptions of teacher–student and peer relationships, both self-concept and intrinsic value were positively predictive of science achievement, in which self-concept was more predictive of science achievement than intrinsic value among high-achieving students when controlling for the students' perceptions of teacher–student and peer relationships. In contrast, the intrinsic value had a positively predictive effect on science achievement, but self-concept did not among low-achieving students.

Educational Context in Taiwan

A unique cultural context has shaped the education system in Taiwan. As an East Asian country, Taiwan inherited the traditional Confucian philosophy, which greatly influences the Taiwanese belief system regarding education. Through the Nine-Year Integrated Curriculum, which was fully implemented in 2004, it was the aim that students could develop according to their own interests (Ministry of Education, 2011). However, Jen, Lee, Chen, Lin, and Lo (2012) stated that students' parents and teachers still overemphasize academic achievement. Moreover, the education system of advancing to a higher school level (i.e. senior high school and college) is examination-oriented. Combining the high evaluation of academic achievement and the examination-oriented education system, students are expected and even forced to learn every subject well so as to enter better schools through the competitively selective process which exists from middle school through to college.

On the other hand, many Taiwanese middle and senior high school students attend cram school after school hours. They go there not only to strengthen their weaker subjects but also to enhance their better subjects so that they can raise their academic achievement. In Tsai and Kuo's (2008) research into cram school culture in Taiwan, they commented that most junior high teachers put more emphasis on students' academic achievements than on motivational outcomes in the content-oriented examination environment. To sum up, with its unique sociocultural context, such a screening system to the high school level may shape the competitive learning environment and further shape Taiwanese students' value of science learning.

Research Questions

The EVT was originally developed in the Western educational context. Although a few studies have examined motivational beliefs in science learning in Taiwan (e.g. Chang & Cheng, 2008; Jen et al., 2013; Liou & Liu, 2015), no study has simultaneously conducted a secondary analysis of self-concept, intrinsic value, and utility value or focused on the issue of differently achieving students. Therefore, this study aims to provide insight into the patterns of the relationship between the motivational beliefs and science achievements of Taiwanese eighth grade students in total, high-achieving, and low-achieving groups based on the Western-based EVT. The following questions are addressed:

1. Does any significant difference in each motivational belief appear between the high- and low-achieving group students in Taiwan?
2. What is the relationship among the self-concept, intrinsic value, utility value, and science achievement of Taiwanese eighth grade students in all groups?
3. What are the patterns of the relative predictive effect on the science achievement of the three motivational beliefs when controlling for the other motivational beliefs for Taiwanese eighth grade students in all groups?

Methods

Data Source and Samples

In this study, the Taiwanese TIMSS 2011 eighth grade student data were used. To produce the national representative samples, a stratified two-stage sampling design was used within a country. At the first sampling stage, schools were stratified by relevant variables and randomly sampled based on with probabilities proportional to their size. The second sampling stage was composed of the selection of one or more intact classes from the target grade of each sampled school (Martin & Mullis, 2012). The original total sample cases were 5042 in Taiwanese TIMSS 2011. In this study, listwise deletion was used when dealing with the problem of missing data, residuals, and influential cases, which will be discussed later. After excluding these data, the final correct sample size ($N = 4881$) is displayed in Table 1.

To elaborate on the students' science abilities corresponding to science achievements across countries, TIMSS provides an international benchmark to represent different levels of ability. Five proficiency levels were produced based on four international benchmarks, including low, intermediate, high, and advanced, with respective scores of 400, 475, 550, and 625. With these benchmarks, students' authentic science competencies could be defined more concretely based on scale anchoring analysis (see details in Martin & Mullis, 2012). In this study, the high-achieving group (HAG) and low-achieving group (LAG) students were defined as those whose science achievement was in the top and bottom 25% among all of the Taiwanese eighth grade students, respectively, after excluding missing data. In the HAG, a majority of students (95.8%) were at the highest proficiency level, meaning that almost all high performing students could communicate an understanding of the complex and abstract concepts in each content domain. Additionally, they could also combine information from several sources to solve problems, draw conclusions, and provide written explanations to communicate scientific knowledge (Martin et al., 2012).

On the other hand, the LAG students were widely distributed across proficiency levels from level 1 to level 3, with only a few students (14.5%) in proficiency level 1.

Table 1 Proficiency level distribution of total, high-, and low-achieving group students

Groups		Proficiency levels (range of scores)					Total
		Level 1 (below 400)	Level 2 (400–475)	Level 3 (475–550)	Level 4 (550–625)	Level 5 (above 625)	
Total group	Surveyed cases	146	490	1267	1757	1221	4881
	Weighted cases	9327	30,964	77,711	105,619	70906	294,527
	Percentage	3.2	10.5	26.4	35.8	24.1	100
High-achieving group	Surveyed cases	0	0	0	112	1168	1280
	Weighted cases	0	0	0	3120	70,930	74,050
	Percentage	0	0	0	4.2	95.8	100
Low-achieving group	Surveyed cases	109	513	557	0	0	1179
	Weighted cases	10,649	31,405	31,571	0	0	73,625
	Percentage	14.5	42.7	42.8	0	0	100

The definition of proficiency level 3 refers to students who could recognize and apply their understanding of basic scientific knowledge in various contexts. However, compared with the HAG students, students in level 3 could just interpret information through brief descriptive responses according to their basic understanding. Students in proficiency level 2 could only recognize the basic scientific facts and interpret simple information through their basic knowledge from the practical situation (Martin et al., 2012). In brief, the HAG students not only understood more complex scientific knowledge and abstract concepts but also had better problem-solving skills than the LAG students.

Measures

Students' responses to items regarding motivational beliefs in the student questionnaire and their test scores of the science assessment were used to construct the three independent variables (i.e. self-concept, intrinsic value, and utility value) and the outcome variable (i.e. science achievement), respectively. All the measures in the study were constructed by TIMSS 2011 based on the item response theory (IRT) scaling method. More specifically, the constructs of motivational beliefs were created by the IRT Rasch partial credit model. On the other hand, the construct of science achievement was created by three distinct IRT models, namely, a three-parameter model, a two-parameter model, and a partial credit model, depending on the item types and scoring procedures (Martin & Mullis, 2012).

As for the constructs of motivational beliefs, items were originally scored on a four-point Likert scale ranging from 1 (agree a lot) to 4 (disagree a lot). After construction through the IRT Rasch partial credit model by TIMSS, students with higher scores tended to have a more positive perception of each motivational belief in science learning. *Self-concept* measures how students' beliefs and judgments influence their capability to learn science. *Intrinsic value* reflects students' interest in science learning and enjoyment of science. *Utility value* reflects that students consider science as valuable and useful for their future goals (Martin & Mullis, 2012). Table 2 shows the detailed descriptions of the items, Cronbach's alpha of the three motivational beliefs, and the factor loading of each item, which were derived from *Methods and procedures in TIMSS and PIRLS 2011* (Martin & Mullis, 2012).

For the validity of science assessment to cover the science curricula across TIMSS-participating countries, a matrix sampling approach was used. That is, the entire assessment pool of science items was packaged into a set of 14 booklets, with each student completing just one booklet to efficiently estimate population characteristics. However, this advantage is offset by the inability to make precise statements of science ability about individuals and might lead to biased estimates of population characteristics when aggregating individual student scores. This issue was addressed by TIMSS through using the plausible values methodology, in which five plausible values were generated to more consistently and precisely estimate students' general science ability (Martin & Mullis, 2012).

Table 2 Statistical descriptions and items of the independent variables

Independent variables	Cronbach's alpha	Factor loading	Items
Self-concept	0.92	0.85	I usually do well in science.[a]
		0.78	Science is more difficult for me than for many of my classmates.
		0.81	Science is not one of my strengths.
		0.84	I learn things quickly in science.[a]
		0.66	I am good at working out difficult science problems.[a]
		0.82	Science makes me confused and nervous.
		0.76	My teacher thinks I can do well in science <programs/classes/lessons> with difficult materials.[a]
		0.82	My teacher tells me I am good at science.[a]
		0.76	Science is harder for me than other subjects.
Intrinsic value	0.90	0.89	I enjoy learning science.[a]
		0.81	I wish I did not have to study science.
		0.83	Science is boring.
		0.83	I learn many interesting things in science.[a]
		0.90	I like science.[a]
Utility value	0.89	0.79	I think learning science will help me in my daily life.[a]
		0.78	I need science to learn other school subjects.[a]
		0.84	I need to do well in science to get into the <university> of my choice.[a]
		0.86	I need to do well in science to get the job I want.[a]
		0.78	I would like a job that involves using science.[a]
		0.77	It is important to do well in science.[a]

[a] Reverse-coded items

Data Analyses

To more precisely conduct a secondary analysis of the international large-scale assessment such as TIMSS, sampling weighting and design effect must be carefully considered due to the stratified two-stage sampling design for a national representative sample (Liou & Hung, 2015). Regarding weighting, a total student weight, which is the product of the final weighting components of schools, classes, and students, was used (Martin & Mullis, 2012). Moreover, five plausible values, which were used in TIMSS to represent student achievement due to a matrix sampling design, were taken into account in the analysis (Rutkowski, Gonzalez, Joncas, & von Davier, 2010). Although the five plausible values were generated for obtaining consistent and precise estimates of students' general science ability, these plausible values are not used for estimating individual science scores but rather are imputed scores for students with similar response patterns (Martin & Mullis, 2012). Consequently, International Database Analyzer software, which takes not only sampling design but multiple imputed achievement scores into account for calculating estimates of achievement scores and their standard errors, was used to conduct the statistical analyses (Foy, Arora, & Stanco, 2013).

Independent-samples *t* test, effect size *d*, zero-order correlation analysis, and multiple regression analysis were used to answer the questions. First, the independent-samples *t* test was used to examine whether there is a significant difference in each motivational belief between the HAG and LAG students. Second, Cohen's (1988) effect size *d* was used to identify the degree of differences in motivational beliefs in science learning between the high- and low-achieving group students. Moreover, zero-order correlation and multiple regression analysis were used to examine the relations of the three motivational beliefs to science achievement without and with controlling for the other motivational beliefs, respectively. Due to the large sample size, the significance of the results was defined as a *p* value below .01.

Several statistical assumptions were considered for avoiding the biased statistical results in each group. First, regarding the distributional properties, the assumption of normality and homogeneity matters less in a study with a large sample size. The tests of assumption are easily statistically violated, even for small and unimportant effects; rather, cases with a large residual and influential cases can bias the results more (Field, 2013). Therefore, data with standardized residuals in this multiple regression model larger than 3 were excluded. Moreover, the data for which the leverage value in the model was three times larger than the average leverage value, meaning that the data have undue influence over the parameter of model, were also excluded (Field, 2013).

On the other hand, the issue of multicollinearity should be considered in multiple regression analysis. According to the correlation matrix of the predictors (Table 4), there is no correlation coefficient larger than .80. Moreover, the variance inflation factor (VIF) was conducted. The results showed that VIFs ranging from 1.74 to 2.64 were far smaller than 10, meaning that the results do not have a potential problem of multicollinearity (Field, 2013).

Results

Characteristics of the Total, High-, and Low-Achieving Groups

Table 3 provides the descriptive statistics of motivational beliefs and science achievements in each group and the differences of each motivational belief and science achievement between the HAG and LAG. In terms of total group students, the mean values of self-concept, intrinsic value, and utility value were 8.32, 8.99, and 8.49, respectively. When comparing the differences of motivational beliefs between the HAG and LAG, the HAG students tended to have higher self-concept, intrinsic value, and utility value than the LAG students, in which the differences in self-concept, intrinsic value, and utility value (2.33, 1.99, and 1.86, respectively), were significant, with $t =$ 26.60, 21.77, and 24.03 and all $p < .01$. Furthermore, the differences in each self-concept, intrinsic value, and utility value showed a large effect size, $d = 1.21$, 1.11, and 1.07, respectively (Table 3).

On the other hand, despite the criterion of the high- and low-achieving selection with a similar range of distribution based on science performance (i.e. top and bottom 25% performing students), the standard deviation of science achievement in the LAG was 1.3 times that of the HAG.

Correlations among Motivational Beliefs and Science Achievement

Table 4 shows the correlation coefficients among motivational beliefs and science achievement, indicating that there were significantly positive correlations (all $p < .01$) among the three motivational beliefs for the total, HAG, and LAG students. Additionally, in each group, the highest correlation was between self-concept and intrinsic value.

With regard to the correlations among the three motivational beliefs and science achievement, the pattern of the total group was similar to that of the HAG, where self-concept was positively correlated to science achievement among total group/HAG students ($r = .41/.28$), intrinsic value was positively related to science achievement among total group/HAG students ($r = .39/.22$), and utility value was positively related to science achievement among total group/HAG students ($r = .39/.21$, all $p < .01$). In contrast, there is no significant relationship between motivational beliefs and science achievement in the LAG.

Relative Prediction of Motivational Beliefs to Science Achievement

Table 5 indicates the relative prediction of each of the three motivational beliefs to science achievement when controlling for other variables in each group. The patterns of relative prediction of motivational beliefs to science achievement in each group vary.

Table 3 Descriptive statistics for the total, high-, and low-achieving group students

Variables	Total students		HAG students		LAG students		$t_{(HAG, LAG)}$	Cohen's *d*
	M	SD	*M*	SD	*M*	SD		
Self-concept	8.32	2.04	9.67	1.96	7.34	1.88	26.60*	1.21
Intrinsic value	8.99	1.92	10.14	1.84	8.15	1.73	21.77*	1.11
Utility value	8.49	1.82	9.53	1.64	7.67	1.84	24.03*	1.07
Science achievement	565.70	81.05	653.93	40.74	461.40	53.27	19.46*	4.06

M mean of scores, *SD* standard deviation

*$p < .01$

Table 4 Correlation coefficients among self-concept, intrinsic value, utility value, and science achievement for the total, high-, and low-achieving group students

Variables	Total group students			HAG students			LAG students		
	IV	UV	SA	IV	UV	SA	IV	UV	SA
Self-concept	.75*	.61*	.41*	.69*	.55*	.28*	.67*	.50*	–.05
Intrinsic value	–	.71*	.39*	–	.66*	.22*	–	.63*	.07
Utility value		–	.39*		–	.21*		–	.06

SC self-concept, *IV* intrinsic value, *UV* utility value, *SA* science achievement

*$p < .01$

Moreover, the regression model of the three motivational beliefs accounted for 20, 9, and 2% variance for the total group, HAG, and LAG, respectively. The following parameter estimates are reported in one standard deviation increments as a means of facilitating interpretation.

The results indicate that, for the total sample, when controlling for the other variables, the standardized coefficient of self-concept was .23, meaning that when self-concept in science increases one standard deviation, the science achievement changes by .23 standard deviation, followed by utility value ($\beta = .19$ with $p < .01$) and intrinsic value ($\beta = .08$ with $p < .01$).

On the other hand, the patterns of relative prediction of motivational beliefs to science achievement among both the HAG and LAG students were also unique. In the HAG, after controlling for the other two motivational beliefs, self-concept was still the strongest positive predictor of science achievement among the motivational beliefs ($\beta = .23$, with $p < .01$), and no other motivational beliefs could predict science achievement in the HAG. On the contrary, among the LAG students, self-concept ($\beta = -.18$, with $p < .01$) and intrinsic value ($\beta = .15$, with $p < .01$) had a significant negative and positive predictive effect on science achievement, respectively.

Discussion and Implications

Through testing the Western-based EVT in the context of Taiwan, this study highlights unique patterns of relations of the three motivational beliefs and science achievement

Table 5 Multiple regression analysis predicting science achievement for total, high-, and low-achieving group students

	Total group students				HAG students				LAG students			
	B	SE	*t*	*β*	*B*	SE	*t*	*β*	*B*	SE	*t*	*β*
Self-concept	9.23*	0.91	10.11	.23*	4.74*	1.25	3.79	.23*	−5.14*	1.18	-4.37	−.18*
Intrinsic value	3.45*	1.25	2.77	.08*	0.33	1.19	0.28	.01	4.60*	1.57	2.93	.15*
Utility value	8.41*	1.00	8.43	.19*	1.97	1.18	1.67	.08	1.67	1.34	1.25	.06
Adjusted R^2 (SE)	0.20 (0.01)				0.09 (0.02)				0.02 (0.01)			

*$p < .01$

for Taiwanese eighth grade students. Three groups, namely, the total group, HAG, and LAG, were also considered. In general, the results comply with the theoretical framework, the EVT, that the three motivational beliefs are predictors of science achievement. Additionally, the various patterns or functions of motivational beliefs in students' science learning may appear between differently achieving students. In the following, more detailed interpretations of the relationships among motivational beliefs and science achievement are discussed.

Roles of Motivational Beliefs in Taiwanese Students' Science Learning

The results of the correlation analysis showed that all motivational beliefs are significantly moderately correlated with science achievement, consistent with previous literature (Kaya & Rice, 2010; Lay et al., 2015; Liou, 2014a, 2017). Moreover, according to the results of the relative magnitude of the relations of motivational beliefs to science achievement based on multiple regression analysis, in line with previous literature (e.g. Areepattamannil & Kaur, 2013; Lavonen & Laaksonen, 2009; Liou, 2017; Liou & Liu, 2015), self-concept was the strongest predictor among these motivational beliefs after controlling for one another. This reveals that self-concept is one of the determinants of science achievement for Taiwanese eighth grade students. Although the study may not confirm a causal relationship based on cross-sectional data, previous studies (e.g. Guay et al., 2003) have confirmed that students' prior self-concepts can predict their subsequent achievements.

On the other hand, besides self-concept, intrinsic and utility values are important for Taiwanese eighth grade students to learn science. The results indicate that, consistent with previous studies (Lay et al., 2015; Liou, 2017; Mohammadpour, 2012), intrinsic and utility values were significantly associated with science achievement after controlling for other motivational beliefs. Based on the above results, it is suggested that motivational beliefs should be regarded as having an important role in the design of instructional practice for science teachers or the goal of science curricula for schools. Eccles et al. (1993) also stressed that it is imperative to consider the effect of motivational beliefs when designing school-wide approaches to facilitate students' learning in school.

Localized Phenomenon of Taiwanese Students' Motivational Beliefs in Science Learning

According to the results of the multiple regression analysis, utility value was more predictive of science achievement than intrinsic value for Taiwanese eighth grade students after controlling for the other motivational beliefs. This pattern is inconsistent with that in Canada where intrinsic value had a higher prediction to science achievement than did utility value (Areepattamannil et al., 2011).

The phenomenon of this inconsistent pattern may relate to potential cultural differences between students from Western and Eastern cultures. In the Western literature, intrinsic value seems to be a more important ingredient in learning because researchers have stated that it results in high-quality or high-level learning (Eccles & Wigfied, 2002; Ryan & Deci, 2000). However, Taiwan is one of the Asian countries which are influenced by the historical Confucian culture. Therefore, this cultural context may lead to students, parents, and even teachers overemphasizing utility value rather than intrinsic value due to the extraordinary value placed on academic achievement, which is considered as a prominent index of students' future college admittance and/or career paths in Taiwan.

In the sociocultural context, the relatively lower prediction of intrinsic value to science achievement may be interpreted as being the result of the competitive education system. The study of Liou (2014c) elaborated that Taiwanese eighth graders are about to face their first high-stakes examinations, and the design of the curriculum for secondary schools is more knowledge-based rather than motivating students in learning in comparison with elementary schools. Therefore, when facing the new competitive learning environment, the role of intrinsic value in science achievement for eighth graders may be indirectly influenced by self-concept in that students who feel themselves to have low ability in science may feel disengaged from participating in science tasks (Ryan & Deci, 2000).

Characteristics of HAG and LAG Students in Taiwan

Examining the differences in the characteristics of high- and low-achieving students based on empirical-based investigations may be practical for the government or educational stakeholders to reveal the current problem of educational inequality (Gilleece, Cosgrove, & Sofroniou, 2010). The results of this study, in agreement with previous studies (e.g. Ceylan & Akerson, 2014), indicated that all the three motivational beliefs of the HAG and LAG students showed a significant difference whereby the students' motivational beliefs in the HAG were greater than those of the students in the LAG after controlling for one another. This may shed light on the fact that educational inequality, within the context of education in Taiwan, may not merely appear in students' science performance but may also be reflected in students' motivational beliefs in science learning.

Before discussing the issue of high- and low-achieving students, Gilleece et al. (2010) mentioned that the criteria or definitions of being high- and low-achieving should be clearly described. According to the criteria of this study, students whose science achievement was in the top and bottom 25% in TIMSS 2011 science assessment were categorized into HAG and LAG, respectively. Moreover, the results of the descriptive statistics (i.e. standard deviation) and science proficiency level proposed by TIMSS revealed that the science academic ability of students in the LAG in this study was more heterogeneous, in spite of falling within a similar interquartile range. This gave us the insight to interpret the results more carefully regarding the nature of the population of the HAG and LAG students selected for this study.

Pattern of Relative Relations between Motivational Beliefs and Science Achievement in the HAG and LAG

The results of the correlation analysis demonstrated that the patterns of relations between motivational beliefs and science achievement in the HAG were similar to the pattern of the total group, in that all three motivational beliefs are significantly associated with science achievement, but the relations are weaker than those in the total group. On the contrary, the LAG pattern with no significant relationships existing between each motivational belief and science achievement was different from the general pattern of the total group.

These weaker relationships in the HAG and the non-significant relationships in the LAG also reflect on the coefficient of determination of the multiple regression models. The R^2 values for the HAG (9%) and LAG (2%) were lower than that for the total group (20%). It cannot be directly interpreted that the total group complied with the EVT much better than the HAG and LAG because the subsamples were operationally chosen by the criterion of their science performance rather than randomly. This leads to the standard deviation being condensed, which in turn influences the degree of variance that could be explained. Although the groups cannot be compared directly, it still offers us a glance of the pattern in each group.

Regarding the patterns of the relative relationships between the three motivational beliefs and science achievement after controlling for the other motivational beliefs in both the HAG and LAG, the results are somewhat different from those of Jen's (2013) study in both HAG and LAG. However, it should be noted that the potential difference in the definition of HAG and LAG and the various controlling variables might be the reason for this inconsistency.

In our study, after controlling for the other motivational beliefs, self-concept was still significantly positively and negatively associated with science achievement in the HAG and LAG, respectively. Intrinsic value was positively associated with science achievement in the LAG rather than in the HAG. It is interesting that after controlling for the other motivational beliefs, the opposite results of self-concept and specific results of intrinsic value in various ability groups might reveal the existence of the distinct phenomenon behind it.

In terms of the HAG students, it should be noted that a high percentage of nearly 95.8% attained the highest proficiency level (Table 3), which means that they had similar authentic high-level science ability. However, only self-concept was significantly associated with science achievement. This indicates that these HAG students may judge their own science ability comparatively instead of from an objective perspective (i.e. their authentic science ability). In Taiwan, quizzes are used by teachers to evaluate whether the students have learned the content of the lessons taught. Most importantly, the scores of not only the midterm and final examinations but also of quizzes are generally posted on the bulletin board in the classroom and are sent back to their parents. This may make students consider a score a comparative standard. Within such a "score-based" learning environment, the connection between self-concept and science achievement among the HAG students may be strengthened by students over-judging their science ability through comparing with their peers' performance; that is to say, this context which facilitates a social comparison process may well be the cause of this phenomenon.

In contrast, the results in LAG are counterintuitive as self-concept was negatively associated with science achievement. This indicates that the LAG students who had higher authentic science ability tended to have the perception of low science ability. However, it should be noted that the environments where students are learning play a prominent role in students' perceptions of their own science academic self-concepts (Marsh, 1987). However, these environment factors were not included in the study. Future studies could examine the role of contextual factors at different levels (e.g. teacher or school) in the relations of students' motivational beliefs and science achievements through taking advantage of multilevel modeling to address the issues. On the other hand, the relation of intrinsic value to science achievement was significantly positive in the LAG, but not in the HAG. That is to say, LAG students who inherently disengaged in science tasks tended to have lower science achievements.

In sum, this study sheds light on the general patterns of relations between the motivational beliefs in the science learning and science achievement of Taiwanese eighth grade students based on the EVT. Moreover, the patterns of the different ability groups (i.e. the HAG and LAG) have also been elaborated. This study also contributes to the science education literature by examining the motivational construct in different cultural contexts from the viewpoint of an East Asian culture. In general, the EVT could also effectively interpret science achievement for all students. However, it may have limited relevance in terms of specific ability groups in Taiwan.

While the values of explained variance are modest in each group, this study only discussed and focused on the role of students' motivational beliefs in science learning. Future studies can examine whether other important omitted variables from different levels, such as student family background and contextual factors, could explain students' science achievements in Taiwan, especially for the LAG, which had the largest proportion of unexplained variance in the current study. More importantly, the relations of the omitted variables to students' motivational beliefs and their effect on the prediction of motivational beliefs to science achievement should be addressed because these can reduce bias in terms of the specification error.

For example, the magnitude of relative relations of each motivational belief to science achievement was rather different before (i.e. correlation analysis) and after controlling for the other motivational beliefs (i.e. multiple regression analysis) across the three groups because the three motivational beliefs moderately and positively correlated with each other. This suggests that when future studies aim to compare the relative prediction of each motivational belief to science achievement, all the three types of motivational beliefs should be taken into account in order to reduce the specification error.

Although the significance of this study lies in revealing the relative prediction of motivational beliefs to science achievement among various ability groups, the findings of this study would be more ensured and generalized through being confirmed by alternative methodologies. For example, the analysis of this study did not consider the measurement error, which could be addressed by using structural equation modeling in future studies. Additionally, the relationship which was reported based on cross-sectional data in this study may not offer a causal inference. Given that, future studies can design a longitudinal or experimental study to confirm the causal relationships between motivational beliefs in science learning and science achievement for students with different levels of science ability. It is also necessary for future studies to seek out other possible reasons to explain the findings, especially for specific groups (i.e. HAG and LAG) from the perspective of the qualitative method. With more discussion from alternative methodologies, these findings might give science educators a new perspective to intervene in students' science learning process in terms of specific science-performing students.

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