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The Relationships Among Scientific Epistemic Beliefs, Conceptions of Learning Science, and Motivation of Learning Science: A study of Taiwan high school students

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This study explores the relationships among Taiwanese high school students' scientific epistemic beliefs (SEBs), conceptions of learning science (COLS), and motivation of learning science. The questionnaire responses from 470 high school students in Taiwan were gathered for analysis to explain these relationships. The structural equation modeling technique was utilized to reveal that the students' absolutist SEBs led to reproduced COLS (i.e. learning science as memorizing, preparing for tests, calculating, and practicing) while sophisticated SEBs were related to constructive COLS (i.e. learning science as increase of knowledge, applying, and attaining understanding). The students' reproduced COLS were also negatively associated with surface motive of learning science, whereas the constructive COLS were positively correlated with students' deep motive of learning science. Finally, this study found that students who viewed scientific knowledge as uncertain (advanced epistemic belief) tended to possess a surface motive of learning science. This finding implies that the implementation of standardized tests diminishes Taiwanese high school students' curiosity and interest in engaging deeply in science learning.

Keywords: *Scientific epistemic beliefs; Conceptions of learning science; Motivation of learning science*

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Introduction

Our beliefs about people and things in this world influence our attitudes and behavior in certain ways. In education, psychologists have found that students' beliefs about knowledge (i.e. epistemic beliefs) impact their beliefs about learning (i.e. conceptions of learning), learning motivation, and academic performance (Hofer & Pintrich, 1997; Schommer, 1990; Schommer, Crouse, & Rhodes, 1992). For example, sophisticated epistemic beliefs were found to be associated with deep motive such as intrinsic motivation and mastery goal orientation in academic learning (Hofer, 1994; Kuhn, 1991); they were also positively related to higher level conceptions of learning (Liang & Tsai, 2010). Additionally, students' epistemic beliefs were considered more contextualized and have been conceptualized as domain-specific (Hofer, 2000). Thus, interests in linking learning motivation and conceptions of learning to the domain-specific epistemic beliefs have emerged in more recent studies, especially in the science area (Chen & Pajares, 2010; Chiou & Liang, 2012; Lin, Deng, Chai, & Tsai, 2013). Nevertheless, these studies have yet to fully integrate the three components for a complete overview of their interrelationship. This research extends the previous efforts to analyze how students' epistemic beliefs interact with their motivation and conceptions of learning science.

Scientific Epistemic Beliefs

Epistemic belief refers to an individual's viewpoints about the nature of knowledge and the process of knowing (Hofer & Pintrich, 1997). Epistemic beliefs are conceptualized as a system with multiple dimensions of knowledge, where each dimension may develop at different rates (Schommer, 1990).

After incorporating various epistemic belief models and relevant theories, Hofer and Pintrich (1997) identified four dimensions of individual epistemic beliefs: 'certainty' of knowledge (e.g. knowledge is fixed or fluid), 'simplicity' of knowledge (e.g. knowledge is absolute or relative), 'source' of knowing (e.g. knowledge is handed down by authority or self-constructed), and 'justification' of knowing (e.g. knowledge is evaluated in a dualistic or multiplistic way). Each dimension can continuously change and evolve from naïve (e.g. knowledge is absolute and stable) to sophisticated (e.g. knowledge is tentative and can be created).

The epistemic beliefs were suggested as being domain-general but also domain-specific (Buehl & Alexander, 2006; Buehl, Alexander, & Murphy, 2002; Muis & Gierus, 2014). Domain-specific epistemic beliefs may be more influential on students' task learning in a particular domain than their domain-general epistemic beliefs (Buehl & Alexander, 2006; Schraw, 2001). Based on the work of Hofer and Pintrich, researchers in the science field have made efforts to form a systemic view of students' scientific epistemic beliefs (SEBs; Elder, 2002; Hofer, 2000; Stathopoulou & Vosniadou, 2007; Tsai & Liu, 2005). For instance, Conley, Pintrich, Vekiri, and Harrison (2004) identified four dimensions of elementary school students' epistemic beliefs about science knowledge as 'source' (e.g. science knowledge comes from authority or is invented), 'certainty' (e.g. science knowledge has only one answer or should have different alternatives), 'development' (e.g. science knowledge is evolving or unchanging), and 'justification' (e.g. science knowledge should be justified from different perspectives or from one perspective). The same classifications have been replicated in other research with different sample groups (e.g. Liang & Tsai, 2010; Tsai, Ho, Liang, & Lin, 2011). In brief, the characterizations of SEBs are intended to understand students' thinking and reasoning about the nature of science, which may relate to students' learning and guide teachers' instructional practices. This study adapted the theoretical framework proposed by Conley et al. (2004). We replaced 'source' and 'certainty' with the more sophisticated terms 'multiple sources' and 'uncertainty' to avoid naïve conceptualization and misinterpretations.

Conceptions of Learning Science

Students' beliefs about the nature of learning represent their conceptions of learning and are viewed as their academic epistemic beliefs (Tsai, 2004). The pioneering research conducted by Säljö (1979) categorized students' conceptions of learning as (1) increase of knowledge, (2) memorizing, (3) acquisition of facts or procedures that can be retained and/or utilized in practice, (4) abstraction of meaning, and (5) interpretative process aimed at the understanding of reality. Later studies generally followed these classifications for investigation in different educational contexts (e.g. Eklund-Myrskog, 1998; Marshall, Summer, & Woolnough, 1999; Marton, Dall'Alba, & Beaty, 1993), whereas the research evidence suggests that students' conceptions of learning vary across different domains and cultural contexts (Chiou, Lee, & Tsai, 2013; Marton, Watkins, & Tangs, 1997). For example, Tsai (2004) used interview questions to explore students' conceptions of learning science (COLS), identifying them as (1) Memorizing, (2) Testing or Preparing for tests, (3) Practicing and Calculating, (4) Increase of knowledge, (5) Applying, (6) Understanding, and (7) Seeing in a new way. Among them, the conceptions of 'Testing' and 'Practicing and Calculating' were specifically attributed to Taiwan's educational context and science learning features. Similar to Marton et al. (1993), Tsai (2004) also found that students' COLS were formed as a hierarchical structure ranging from lower level reproduced COLS (e.g. memorizing) to more sophisticated COLS (e.g. understanding). In a later study, Lin, Tsai, and Liang (2012) further confirmed that students' COLS can be grouped into lower level, *reproduced*, COLS (i.e. Memorizing, Testing, Practicing, and Calculating) and higher level, *constructive,* COLS (i.e. Increase of knowledge, Applying, Understanding, and Seeing in a new way). These two profile groupings also echoed the categorizations in other similar studies (e.g. Ellis, Goodyear, Calvo, & Prosser, 2008; Marton et al., 1993).

SEBs and COLS

Beliefs about knowledge and the nature of knowing can easily connect with the beliefs of learning (Hofer & Pintrich, 1997; Schommer, 1990; Tsai, 2004). However, epistemic beliefs emphasize students' thinking and reflections on the nature of knowledge, while conceptions of learning pay more attention to students' views on the learning process. Research has shown that students' conceptions of learning are influenced through their judgment and evaluations of the nature of the information that was intended to be acquired (e.g. Chan & Elliott, 2004; Kardash & Scholes, 1996; Richter & Schmid, 2010). In the science field, for instance, Carey and Smith (1993) found that it is difficult for students who had more realistic or objectivist views on knowledge to adapt a constructivist approach to learn science. Liang and Tsai (2010) also revealed that students who viewed science as certain tended to have reproduced COLS, whereas those students who viewed science knowledge as tentative tended to have constructive COLS. In other words, the previous research seemed to show that students' epistemic beliefs were generally correlated with their conceptions of learning. Sophisticated SEBs were associated with constructive COLS, and naïve beliefs of scientific knowledge were related to reproduced COLS.

SEBs, COLS, and Motivation of Learning Science

Student motivation is a pivotal factor that influences their classroom engagement and learning performance. One important aspect of motivation theory concerns the reason students have for doing the task, which involves the students' goals, interests, and beliefs to the importance of the task. This motivation component was described in many ways such as mastery/performance goal orientation, surface/deep motive, or intrinsic/extrinsic motivation. Research has shown that students who have deep motive in learning are intrinsically motivated, mastery goal-oriented, and actively seek the most meaning from their learning; in contrast, students who are surface motivated in learning tend to be motivated by external incentives, are performance goal-oriented, and only care about the essentials of the learning materials (Biggs, 1987; Pintrich & DeGroot, 1990; Pintrich & Schunk, 2002). Extensive evidence has supported that intrinsic and deep motivations usually result in the adoption of deep learning strategies and better academic performance (Buehl & Alexander, 2006; Kizilgunes, Ceren, & Semra, 2009; Paulsen & Feldman, 2005).

Recent works about epistemic beliefs and conceptions of learning have started to explore the connections between these beliefs and learning motivation. In general, sophisticated epistemic beliefs were associated with mastery goal orientation, deep engagement of learning, and intrinsic motivation (Hofer, 1994, 1999; Schutz, Pintrich, & Young, 1993). For instance, to examine the relationship between sixth grade students' epistemic beliefs and learning motivation in the science area, Chen and Pajares (2010) found that students who had more sophisticated SEBs possessed mastery goal orientation and had higher science achievement. Conversely, students who had absolutist views of science were more performance-oriented and had lower science achievement. On the other hand, Liang and Tsai (2010) investigated the relationship between Taiwanese college students' SEBs and learning approaches, and found that the advanced SEBs such as 'development' and 'justification' positively related to deep motive in learning science. Nevertheless, 'justification' also positively correlated with surface motive. The existence of this mixed motive implied that Taiwanese students were intrinsically interested in reasoning and understanding science; however, they were also motivated to learn science for extrinsic rewards (e.g. the chance to pursue a better career in the science field). Thus, the particular sociocultural context may play a role in students' motivation for science learning.

Students' learning motivation may relate to their conceptions of learning as well. An earlier work conducted by Schommer (1990) found that students who believed that learning is quick usually showed overconfidence and provided oversimplified solutions in tests. Apparently, if students believe in quick learning, they may not be willing to invest efforts to reach a deep level of true understanding of the materials. As a result, if students believed that learning is to memorize the facts, to receive better grades or to gain extrinsic rewards, they would be inclined to possess a surface motive in learning; conversely, students who considered learning as improving or fully understanding the to-be-acquired knowledge may hold a deep or intrinsic motive for learning (Biggs, 1987; Hofer, 1999; Pintrich & DeGroot, 1990). On the other hand, learning motivation could be influenced by sociocultural differences (e.g. Clark & Estes, 2002; McInerney, Hinkley, Dowson, & Van Etten, 1998). Such differences can probably be explained by examining students' beliefs and attitudes toward learning (Pintrich & Schunk, 2002). Lee, Johnson, and Tsai (2008) found that the Taiwanese high school students who believed that science learning involves 'Calculating and Practicing' and 'Applying' may have both surface and deep motives for learning science. Chiou et al. (2013) also claimed that the conception of 'Seeing in a new way' was positively correlated with students' deep motive for learning physics, while the conception of 'Understanding' was also positively associated with the surface motive. These studies revealed that either lower level or higher level conceptions of learning did not necessarily result in only the surface or deep motive for learning science.

Taken together, previous research has shown that students' SEBs and COLS play a role in their motivation for learning science (MLS). However, the relationships between all three of these factors have yet to be systematically examined. Consequently, this study intends to establish a structural model for exploring the interrelationships among these three variables.

Research Purpose

The purpose of this study is to investigate the relationships among Taiwanese students' SEBs, COLS, and MLS by using the structural equation modeling (SEM) technique. Based on the aforementioned literature, a hypothesized model suggested in Figure 1 illustrates the interrelationship among students' SEBs, COLS, and MLS. In brief, students' MLS is hypothesized to be influenced by their COLS and SEBs, whereas SEBs also have a direct relationship with students' COLS. The path hypotheses are depicted in Figure 1. The dotted lines are used to depict negative relationships between the constructs, whereas the solid lines postulate the positive relationships. In brief, it is hypothesized that the relationship between the sophisticated SEBs and

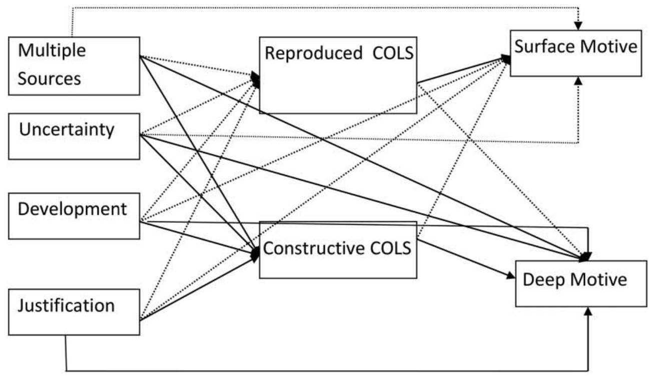

Figure 1. The hypothesized model of the structural relations among SEBs, COLS, and MLS

reproduced COLS (i.e. Multiple Sources, Uncertainty, Development, and Justification) is negative, while the relationship between the sophisticated SEBs and the constructive COLS is positive. Conversely, the naïve SEBs are assumed to have a positive relationship with the reproduced COLS but to have a negative relationship with the constructive COLS. Furthermore, the students' reproduced COLS are considered to be positively correlated with Surface Motive, and are negatively related to the Deep Motive. The students' constructive COLS are then believed to positively associate with Deep Motive and negatively correlate with the Surface Motive. Finally, the advanced SEBs are hypothesized to negatively link to the Surface Motive and positively connect with Deep Motive. The naïve SEBs and the Surface Motive are then assumed to positively relate to each other, whereas the naïve SEBs and the Deep Motive are negatively associated.

Data Analysis

First, normality test (Kolmogorov–Smirnov Test) was used to verify the normal distribution of the given data. SEM was utilized in the study to examine the structural relationships among the students' SEBs, the COLS, and the MLS. The confirmatory factor analysis (CFA) and path analysis were integrated into the SEM analysis to estimate the designated measurement and structural model. The CFA was conducted to verify the construct validity of the SEBs, COLS, and MLS factors. To measure the convergent validity of each construct, the values of item loadings and composite reliability were examined. Then, several indicators were used to evaluate the fitness of the hypothesized model. Finally, path analysis was employed to better approach the direct and indirect relations among the measured variables (Hair, Black, Babin, Anderson, & Tatham, 2006). Based on the aforementioned research findings, students' SEBs served as the exogenous variable to predict both students' COLS and MLS, while students' COLS were also selected as the endogenous variable between their SEBs and MLS.

Methodology

Participants

A total of 470 students (10th, 11th, and 12th grade) from 10 high schools in Taiwan participated in the present study. These high schools are located across the northern (n = 4), central (n = 3), and southern (n = 3) areas of Taiwan. One class was randomly selected from each school for the survey. The total number of male students was 241 and 229 were female. Their ages ranged from 15 to 18, with a mean of 16.27 (SD = 0.84). According to the curriculum guidelines in Taiwan, students in Taiwan are required to take science courses since the third grade (around 9 years old). In high school, the 10th and 11th graders are required to take four science courses in one school year, but these courses become optional for 12th graders. Therefore, including all of the graders in the study should better represent the Taiwanese high school population. Finally, the participants were considered sharing similar socio-cultural and economic status even though they were from various demographic areas and had different academic backgrounds. That is, most of these participants came from middle-class family and determined that going to college was their academic goal.

Instruments

SEB survey. The students' SEB survey was developed based on the instrument from Conley et al. (2004). The previous studies (Liang & Tsai, 2010; Tsai et al., 2011) have also confirmed the reliability and validity of this instrument. For the current study, the overall Cronbach's alpha value was 0.82 and the value of each construct ranged from 0.77 to 0.86. Besides, results from CFA analysis also showed that the factor loading values between the indicators and latent variables are significant and higher than 0.5, ranging from 0.53 to 0.83; the composite reliability values of all constructs range from 0.78 to 0.86, exceeding the cutoff values of 0.7. Furthermore, the fit indices (Chi-square value = 291.64, degree of freedom = 113, $p < .001$; GFI = 0.93, CFI = 0.97, NFI = 0.95, and SRMR = 0.059) indicated sufficient reliability and validity of each construct.

The four SEB constructs were, as previously mentioned, renamed as Multiple Sources, Uncertainty, Development, and Justification, and their definitions are provided as follows:

(1) Multiple Sources: assessing students' beliefs about the various sources or origins of scientific knowledge.
(2) Uncertainty: evaluating students' beliefs about the uncertainty of answers for scientific knowledge.
(3) Development: assessing students' beliefs about whether scientific knowledge is continuously evolving and changing.
(4) Justification: examining students' views on the role of experiments and the beliefs they have regarding reasoning, arguing, and justifying scientific knowledge.

Conley's questionnaire included some reverse-stated items for measuring 'Source/Multiple sources' (e.g. 'Everybody has to believe what scientists say') and 'Uncertainty/Certainty' (e.g. 'All questions in science have one right answer'). Thus, the scoring responses of 'Multiple Sources' and 'Uncertainty' were coded in reverse. That is, students who received higher scores for all of the four factors had more sophisticated SEBs.

COLS questionnaire. The COLS survey developed by Lee, Johanson, and Tsai (2008) was used for measuring students' COLS. The rating scale was from 'strongly disagree' to 'strongly agree' on a 7-point Likert scale. In Lee et al.'s study, the survey structure was confirmed with a reasonable model fit and good internal reliability. Consistent with Lee et al. (2008), Tsai et al. (2011) also showed the satisfactory reliability and validity of this instrument. In the present study, the overall Cronbach's alpha value was 0.87, while individual construct ranged from 0.82 to 0.94. The reliability coefficient value for both reproduced COLS and constructive COLS was 0.94. Furthermore, the findings from CFA analysis indicated that the factor loading values for the seven factors were significant and larger than 0.5 (ranging from 0.58 to 0.9); the composite reliability values of all COLS constructs were higher than 0.7, ranging from 0.83 to 0.93. In addition, the values of fit indices (Chi-square value = 131.26, degree of freedom = 26, $p < .001$; GFI = 0.94, CFI = 0.97, NFI = 0.96, and SRMR = 0.058) suggested sufficient internal consistency and validity of the survey structure.

Seven factors with a total of 46 items were identified in the COLS survey. Each of the factors is defined below:

(1) Memorizing: learning science means memorizing the definitions, formula, principles, and laws stated in a science textbook.
(2) Testing: learning science means getting high scores or good performance on examinations.
(3) Calculating and practicing: learning science means practicing calculation and solving problems frequently.
(4) Increase of knowledge: learning science means acquiring and accumulating scientific knowledge.
(5) Applying: learning science is to learn how to apply the scientific knowledge.
(6) Understanding: learning science means to understand scientific knowledge by integrating, elaborating, and constructing theoretically consistent scientific knowledge structures.
(7) Seeing in a new way: learning science aims to construct a new perspective, and to acquire scientific knowledge by getting a new way to clarify natural phenomena.

According to Tsai et al. (2011) and Lin et al. (2012), the COLS constructs were distinguished into lower level (reproduced) and higher level (constructive) factors. The items in 'Memorizing', 'Testing', and 'Calculating and Practicing' were composed of the reproduced COLS, whereas 'Increase of Knowledge', 'Applying', and 'Understanding', and 'Seeing in a new way' were grouped as the constructive COLS.

MLS survey. The MLS survey was implemented to assess students' science learning motivation. The MLS survey was generated by extracting the motivational items from the approaches to learning science (ALS) survey (Lee et al., 2008). The ALS survey was used to measure both students' science learning approaches and motivation. In Lee et al.'s study, four factors were established in the ALS survey: Deep Motive, Deep Strategy, Surface Motive, and Surface Strategy. For the current study, only the items used to measure students' Deep Motive and Surface Motive were adapted. The descriptions of the two factors and sample items are as follows:

(1) Deep motive: Students have deep motive or are intrinsically motivated to learn science (e.g. I find that at times studying science makes me feel really happy and satisfied.)
(2) Surface motive: Students have surface motive or are extrinsically motivated to learn science (e.g. No matter whether I like it or not, I know that getting a good achievement in science could help me to get an ideal job in the future.)

Six items were included in measuring the deep motive factor, while three items were used to identify the surface motive. Students were asked to respond on a 5 Likert Scale, ranging from 'Never' to 'Always'. The overall Cronbach's alpha value for this study was 0.86, for 'deep motive' was 0.94 and for 'surface motive' was 0.82. Besides, the CFA results revealed that the loadings between the indicators and latent variables ranged from 0.57 to 0.99, and the composite reliability values for the 'deep motive' factor and the 'surface motive' factor were 0.94 and 0.84, respectively. Among the fit indices, only GFI value was less than but approaches 0.9 (GFI = 0.83), which is considered acceptable (Browne & Cudeck, 1993). The values of Chi-square = 1664.68, degree of freedom = 552, $p < .001$, CFI = 0.98, NFI = 0.97, SRMR = 0.045, which show adequate internal consistency and construct validity of the survey items.

All of the detailed loading values and questionnaire items can be obtained through the supplemental data.

Results

Preliminary Analysis

The results of the normality tests indicate normal distribution of the data ($p > .05$). Pearson correlation coefficient analysis was performed to explain the relationships among the SEBs, COLS, and MLS constructs. The results from Table 1 show the relationships between SEB and COLS. In general, there were significant relationships between the SEBs and COLS constructs, except for the relationship between 'Multiple sources' and 'Seeing in a new way'. Among all of the factors, the students'

Table 1. The correlations between students' responses to EPS and COLS

	Multiple sources	Uncertainty	Development	Justification
Memorizing	−0.33***	−0.33***	−0.17***	−0.17***
Testing	−0.23***	−0.23***	−0.16**	−0.16***
Calculating and practicing	−0.19***	−0.23***	−0.12**	−0.12**
Increasing one's knowledge	0.15**	0.15**	0.38***	0.46***
Application	0.10*	0.16***	0.29***	0.42***
Understanding	0.10*	0.18***	0.38***	0.46***
Seeing in a new way	0.08	0.18***	0.35***	0.52***
Reproduced COLS	−0.29***	−0.30***	−0.17***	−0.18***
Constructive COLS	0.13**	0.20***	0.41***	0.54***

*$p < .05$.

**$p < .01$.

***$p < .001$.

SEB constructs have negative relationships with the reproduced COLS (i.e. 'Memorizing', 'Testing', and 'Calculating and Practicing'), and are positively related to constructive COLS (i.e. 'Increase of Knowledge', 'Application', 'Understanding', and 'Seeing in a New way').

On the other hand, the findings from Table 2 display the relationships between SEBs and MLS. Although there was a significant relationship between students' SEBs and MLS, the correlations were considered as relatively weak. For example, the coefficients between 'Multiple Sources', 'Development' and 'Deep Motive' are 0.13 and 0.23, respectively. Overall, there were significant and positive relationships between students' deep motive and 'Multiple Sources', 'Development', and 'Justification', indicating that the more sophisticated their SEBs, the more deep motives the students possessed. Regarding the relationship between students' SEBs and surface motive, 'Source' was the only factor significantly and negatively related to the surface motive of learning science.

Finally, Table 3 is presented to reveal the relationship between students' COLS and MLS. There were significant relationships between the COLS and MLS constructs, and the relationships were relatively strong. In sum, the relationship between deep motive and reproductive COLS was negative, while the relationship between

Table 2. The correlations between students' responses to EPS and MLS

	Multiple sources	Uncertainty	Development	Justification
Deep motive	0.13**	0.06	0.23***	0.27***
Surface motive	−0.13**	−0.07	0.06	0.05

**$p < .01$.

***$p < .001$.

Table 3. The correlations between students' responses to MLS and COLS

	Deep motive	Surface motive
Memorizing	−0.44***	0.08
Testing	−0.60***	0.13**
Calculating and practicing	−0.36***	0.18***
Increasing one's knowledge	0.39***	0.10*
Application	0.35***	0.11*
Understanding	0.42***	0.13**
Seeing in a new way	0.44***	0.16**
Reproduced COLS	−0.55***	0.15**
Constructivist COLS	0.47***	0.14**

*$p < .05$.

**$p < .01$.

***$p < .001$.

constructive COLS and deep motive was positive. Finally, it is surprising that most of the students' COLS constructs (except for 'Memorizing') and surface motive were significantly and positively correlated; however, such relationships were relatively weak.

Interrelationships Among SEBs, COLS, and MLS

The technique of SEM was applied to further test the hypothesized model that specifies the relations among SEBs, COLS, and MLS. First, the evaluation of model-to-data-fit indices showed that the proposed model well explained the data. Among the fit indices, the values of Chi-square = 48.03, degree of freedom = 8, $p < .001$, GFI = 0.98, CFI = 0.96, NFI = 0.95, SRMR = 0.046 indicated a good model fit (Hair et al., 2006; Hu & Bentler, 1999). These fit statistics suggested that the hypothesized model was appropriate for interpreting the structural relationships among SEBs, COLS, and MLS.

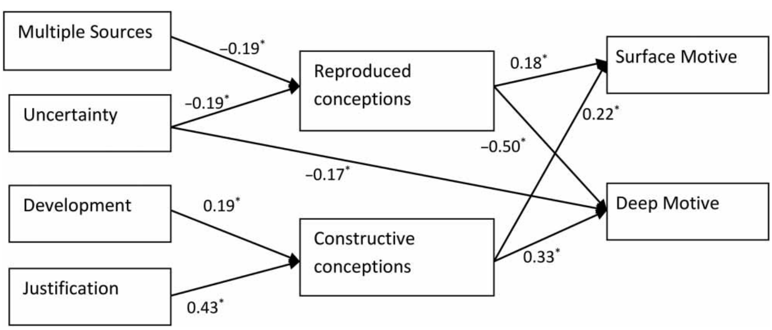

Figure 2. The final model of the structural relations among SEBs, COLS, and MLS

Path analysis then was employed to assess the direct and indirect relationships among each variables of the structural model. Figure 2 illustrates the parameter estimates for the structural model. As shown in Figure 2, 'Multiple Sources' ($\beta = -0.19$, $p < .05$) and 'Uncertainty' ($\beta = -0.19$, $p < .05$) were the significant and negative factors predicting students' reproduced COLS, whereas 'Development' ($\beta = 0.19$, $p < .05$) and 'Justification' ($\beta = 0.43$, $p < .05$) significantly fostered students' constructive COLS. Furthermore, from the path coefficients, the reproduced COLS and surface motive were positively correlated ($\beta = 0.18$, $p < .05$), whereas the reproduced COLS and deep motive were negatively correlated ($\beta = -0.5$, $p < .05$). Finally, there were significant and positive relationships between constructive COLS, surface motive, and deep motive ($\beta = 0.22$, 0.33, $p < .05$). Nevertheless, it is interesting to find that 'Uncertainty' was the only factor directly and negatively related to students' deep motive ($\beta = -0.17$, $p < .05$).

Taken together, students' SEBs played a direct role in their COLS. 'Multiple Sources', 'Development', and 'Justification' were indirectly associated with students' MLS through COLS. 'Uncertainty' was the only factor that both directly and indirectly linked to students' MLS. Finally, the reproduced COLS fostered both surface and deep motives, whereas the constructive COLS also directly connected with students' surface and deep motives for learning science.

Discussion

The present study investigated the relationships among Taiwanese high school students' SEBs, COLS, and MLS. The CFA results indicate that all of the survey items for measuring these three constructs are adequately loaded on the designated factors. For SEBs, the structure of the four dimensions (i.e. source, certainty, development, and justification) identified in Conley et al. (2004) was replicated and confirmed. Regarding students' COLS, the results from the CFA analysis support the previous studies (Lin et al., 2012; Tsai, 2004; Tsai et al., 2011) that students' COLS are classified into seven factors. These seven factors can then be distinguished into lower level (reproduced) and higher level (constructive) COLS constructs. Finally, consistent with the previous research (e.g. Chiou & Liang, 2012; Lee et al., 2008), the current study also successfully allocated the MLS items to the 'surface motive' and 'deep motive' groups. By and large, this study provides additional evidence to show the perfect validity and reliability of these instruments for measuring Taiwanese students' epistemic beliefs, conceptions of learning, and motivation of learning in the science field. Future research may replicate the current findings in other domains to examine the generality of these instruments.

The Relationship Between Students' SEBs and COLS

The findings from the SEM analysis show that the dimensions of 'Multiple Sources' and 'Uncertainty' significantly and negatively relate to the reproduced COLS. The 'Development' and 'Justification' beliefs are significantly and positively associated with the constructive COLS. These results support the previous research that students' epistemic beliefs are related to their conceptions of learning (Chan, 2007; Chan & Elliott, 2004; Schommer, 1990), while the naïve SEBs are generally associated with the reproduced COLS, and the sophisticated SEBs are correlated with the constructive COLS (Liang & Tsai, 2010).

On the other hand, this study failed to find relationships among 'Multiple Sources', 'Uncertainty', and 'Constructive COLS'. Similarly, no relationships were established among 'Justification', 'Development', and 'Reproduced COLS'. Tsai et al. (2011) argued that despite students possessing sophisticated beliefs in 'Multiple Sources' and 'Uncertainty', they still have difficulty conceptualizing science learning in a more constructive way. The lack of relationships between constructive COLS and the beliefs of 'multiple sources' and 'Uncertainty' actually reflects that certain students may view constructive pedagogical practices, such as hands-on experiments and observations, only as a way to find a solution for scientific problems or to test the theory hypotheses (Driver, Leach, Millar, & Scott, 1996). It is possible that these students' SEBs have dominated how they would learn science, and it is difficult to alter their SEBs (Carey & Smith, 1993; Roth & Roychoudhury, 1994). Another possibility is that teachers may believe that they teach students in a constructive way, but their actual practices are the opposite of constructivist (Cheng, Chan, Tang, & Cheng, 2009; Schommer, 1990). That is, although teachers may emphasize that science knowledge can be found from multiple sources or that there is more than one right answer, the learning environment still involves the structure of teacher-centered instruction or a reward-based system (Lee, Chang, & Tsai, 2009). The lack of critical thinking opportunities probably impedes the development of students' epistemic beliefs toward a more constructivist perspective (Smith, Maclin, Houghton, & Hennessey, 2000). Future research should identify how different instructional elements and the classroom atmosphere play a role in influencing the development of students' epistemic beliefs, which in turn impact their conceptions of learning.

The Relationship Between Students' COLS and MLS

The results from the SEM analysis reveal that there is a significant and positive relationship between reproduced COLS and surface motive. The present study supports the previous research that students who believe that science learning is 'memorizing', 'testing', and 'calculating and practicing' are motivated to learn science for passing tests or for pursuing their goals for their future career development. Obviously, students who possess reproduced COLS tended to reveal the pattern of performance goal orientation since they believe that science learning is mainly memorizing and testing (Ames, 1992; Anderman & Maehr, 1994).

On the other hand, the students' constructive COLS were found to positively and significantly associate with both surface and deep motives. Consistent with the previous research (Biggs, 1991; Chiou & Liang, 2012; Chiou et al., 2013; Lee et al., 2008), the present study found the existence of a 'mixed motive' between the constructive COLS and MLS. That is, the more the students believe that learning is 'applying', 'increase of knowledge', 'understanding', and 'seeing in a new way', the higher the expressions of both surface motive and deep motive. Biggs (1991) claimed a similar finding in his research analyzing Hong Kong students' conceptions of learning. The Hong Kong students who had sophisticated conceptions of learning tended to adapt both 'memorizing-understanding' learning strategies. These students believed that memorizing is important for understanding, and vice versa. On the other hand, they were also sensitive to the standardized assessment, so another purpose of memorization was to prepare for tests. As a result, the discovery of a 'mixed motive' may be similar to the perspective of the performance goal-orientation theory. Students who are performance goal-oriented generally exhibit their learning goal of achieving a high level of performance as well as demonstrating their superiority to others on assigned learning tasks (Elliot & Harackiewiez, 1996). These students use the normative test standard for their performance judgment, but in the meantime, they are also high in achievement motivation and deeply engage in the learning tasks, similar to mastery goal orientation (Pintrich & Schunk, 2002). It is possible that the students' constructive COLS impact their goal orientation and learning motivation, leading to the patterns of performance goal orientation and mixed motive. Since the learning purpose for these students is to be superior to others, which motive patterns they express should depend on the contexts and the requirement of the learning tasks (Chiou & Liang, 2012). This special feature of students' learning motivation may be shaped by the blending of traditional Chinese education culture and Western science education concepts. It would be worth continuously observing whether this cross-cultural influence will restructure the stereotype of Chinese students.

Moreover, the present study revealed different relational directions among reproduced COLS, surface motive, and deep motive. The stronger the reproduced COLS the students have, the higher surface motive they show and the less deep motive they demonstrate. Such a result implies that students with reproduced COLS tend to show the pattern of extrinsic goal orientation or avoidance performance goal orientation (Elliot, 1997; Pintrich & De Groot, 1990). That is, they are reluctant to be intrinsically motivated to learn science, and are fully extrinsically motivated by focusing on passing the tests, getting good grades, or avoiding the worst grades. In conclusion, the individual's conceptions of learning should be highly relevant to his or her learning purpose, which in turn will determine the level of engagement in the learning tasks. Future research should examine how students' COLS relate to their attribution patterns or learning behavior, and whether a change in COLS should alter the students' goal orientation and learning motivation.

The Relationship Between Students' SEBs and MLS

The empirical findings from the current study further confirm that all of the SEB dimensions 'multiple sources', 'uncertainty', 'development', and 'justification' indirectly connect with students' MLS by going through their COLS. This finding is consistent with Chiou et al. (2013) who found that students' conceptions of learning are more powerful in predicting students' learning motive and learning strategy than their epistemic beliefs. Besides, the present study reveals that only the 'uncertainty' SEB factor directly but negatively links to the deep motive. That is, the more the students view science knowledge as 'uncertain', the less likely they are to be intrinsically motivated to learn science. This finding is very different from previous studies which found that students who have sophisticated epistemic beliefs are likely to show deep cognitive engagement and intrinsic motivation in learning (Hofer, 1994, 1999).

The explanation of this particular finding may be Taiwanese society's views on education and the reform efforts of Taiwan's science education. The educational tradition in Taiwan is strongly inherited from Confucian doctrine whereby teachers should be fully respected in the same way people respect their parents and elders. Teachers in Taiwan are equipped with the image of an authority to provide correct answers to problems. If students feel uncertain about their findings or solutions to the problem, they are used to accepting the teacher's opinion as the right answer. On the other hand, Taiwan has adopted the constructive pedagogy in its science education reforms for more than a decade (Ministry of Education Taiwan, 1998). It is not surprising that students' SEBs have been built through the constructive instruction to recognize that there should be more than one answer to scientific problems. Nevertheless, the traditional value of the teacher's role may make students believe that teachers' knowledge or answers should be more certain than theirs. As a result, although students recognize that science knowledge is uncertain, they may take teachers' opinions as correct judgments without further argument. Furthermore, students in Taiwan are required to take standardized national examinations for applying to college, and their performance on the examinations is taken as the judgment of their success or failure (Tsai et al., 2011). Thus, Taiwanese teachers are pressed by parents and school administrators to assign students quizzes, homework, and tests that are similar to the national examination format (i.e. providing a certain answer to a question) for practice. Although teachers may address the concept of meaningful learning and the importance of a constructive learning environment, in the real classroom practice, they may recognize students' performance based on their testing results for providing a certain answer. It is hypothesized that students who believe that scientific knowledge is uncertain should be intrinsically motivated to seek alternative solutions to scientific problems. However, in reality, the implementation of standardized tests diminishes these students' curiosity and interest in learning science deeply. The more the students believe in the uncertainty of scientific knowledge, the less they are motivated to seek deep understanding in learning. Further evidence to support this perspective is that 'certainty' is positively and indirectly related to 'surface motive' through 'reproduced COLS'. That is, despite possessing the advanced view of the uncertainty of scientific knowledge, students mainly believe that science learning is for memorizing or preparing for tests, whereas external incentives are the main reason to motivate them to learn.

Conclusion and Implications

This research was designed to analyze the relationship among students' SEBs, COLS, and MLS. The results from the SEM analysis show that students' SEBs significantly relate to their COLS. Specifically, students who view scientific knowledge as evolving and justified by experiments have constructive COLS; students believing that scientific knowledge is certain and delivered by authority expressed reproduced COLS. Furthermore, the reproduced COLS positively linked to students' surface motive in learning science, but negatively related to their deep motive in learning science. Conversely, the constructive COLS fostered students' deep motive for learning science.

Additionally, this study found that 'uncertainty' was the only variable directly impacting students' deep motive of learning science, but in a negative way. This discovery showed that the constructive science curriculum has become embedded in classroom practice, which may help to form students' beliefs about the nature of scientific knowledge. However, in the meantime, the emphasis of the standardized national examination also serves as the performance judgment in determining students' science achievement. As a result, some teachers may evaluate the students' learning performance by requiring them to provide certain and correct answers. It is possible that under the influence of Confucian teaching, the Taiwanese students would consider their teachers' perspective with great respect, and consequently, the students who believe that science knowledge is uncertain cannot be inspired to learn science deeply due to this particular 'Testing' culture in Taiwan.

Overall, the implication of this study is that some science teachers in Taiwan have successfully implemented constructivist instructional practices and conceptions in their classrooms. These teachers may help to conceptualize students' SEBs and COLS in a more constructive and sophisticated way. Since constructivism pedagogy emphasizes students' learning experience and active engagement (Kuhn, 2007), students may find the schoolwork interesting and important so that they are willing to truly comprehend the materials. Even though intrinsic motivation may not necessarily lead to high scores in the standardized tests, it generally increases students' cognitive engagement in the classroom, which should relate to the actual performance and meaningful learning (Pintrich & DeGroot, 1990). Some other teachers may also provide the rationale regarding the constructivist learning environments, but their assessment structure and reward systems are actually promoting memorization and testing (Baeten, Kyndt, Struyven, & Dochy, 2010). Consequently, in the learning environment that emphasizes test-driven assessment, students with advanced epistemic beliefs may lose motivation and interest in deeply learning science. It is suggested that future research use observational and qualitative research methods to investigate the relationship between teachers' scientific teaching epistemic beliefs and classroom practices as well as their influence on the development of students' SEBs, COLS, and learning performance.

Several limitations should be considered rigorously while interpreting the results of this study. The limitations can be considered for conducting future studies. This study did not randomly select students from different classes for examining whether there were interrelations among SEB, COLS and MLS factors. However, student-, class-, and school-level variations may play important roles in students' SEB, COLS, and MLS. It is suggested that a much larger number of student samples from different classes, schools and regions are recommended for the future study. Future studies may use hierarchical liner modeling to examine the relationships among these level variations. In addition, the current study is limited in generalizing the findings to a specific learning situation or to other cultural groups. Future research should investigate whether the structural model can be replicated to the sample subjects from different groups of learners.

Finally, the current study contributed to establishing a theory-based structural model among the high school students' SEBs, their COLS, and their MLS. Based on the results of this study, it can be concluded that, students who view that scientific knowledge is certain and delivered by authority tend to express reproduced COLS. However, students who view that scientific knowledge is evolving and justified by experiments tend to hold constructive COLS. Additionally, when students have reproduced conceptions, they tend to have surface motive, but not have deep motive in learning science. Furthermore, students' constructive conceptions can foster both of their deep and surface motives for learning science. In other words, the finding adds to the existing literature by providing a complete and thorough investigation about the interrelationships among students' SEBs, COLS, and MLS, particularly in the high school education.

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