TZUNG-JIN LIN and CHIN-CHUNG TSAI

# A MULTI-DIMENSIONAL INSTRUMENT FOR EVALUATING TAIWANESE HIGH SCHOOL STUDENTS' SCIENCE LEARNING SELF-EFFICACY IN RELATION TO THEIR APPROACHES TO LEARNING SCIENCE

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ABSTRACT. In the past, students' science learning self-efficacy (SLSE) was usually measured by questionnaires that consisted of only a single scale, which might be insufficient to fully understand their SLSE. In this study, a multi-dimensional instrument, the SLSE instrument, was developed and validated to assess students' SLSE based on the previous literature. Besides, the interrelations between students' approaches to learning science and SLSE were explored. A total of 311 Taiwanese eighth graders were invited to respond to the SLSE instrument and the Approaches to Learning Science (ALS) questionnaire. After ensuring several types of validity (e.g. construct validity and criterion-related validity) and the reliability of the SLSE questionnaire, the results suggested that the SLSE instrument should have satisfactory validity and reliability to measure Taiwanese eighth graders' SLSE in terms of 5 dimensions: Conceptual Understanding, Higher-Order Cognitive Skills, Practical Work, Everyday Application, and Science Communication. Moreover, through Pearson correlation analyses, the results revealed that the Taiwanese eighth graders who perceived themselves as having a deep motive, along with the orientation of surface motive, tended to report higher SLSE. Also, those students who reported adopting deep strategies to learn science were more likely to possess higher SLSE. The regression results indicated that, overall, the students' deep strategies and deep motive were strong predictors of their SLSE, particularly for the Higher-Order Thinking Skills SLSE. Yet, the Practical Work SLSE could only be predicted by the Deep Strategy dimension of ALS.

KEY WORDS: approaches to learning science, high school students, science learning self-efficacy

## Introduction

Self-efficacy, one of the essential components of Bandura's (1977) social cognitive theory, has been recognized as a critical aspect that relates to students' engagement in learning activities and outcomes (e.g. Pintrich & De Groot, 1990; Printrich & Schunk, 2002). In the field of science education, students' learning science self-efficacy and its relationship with other science learning factors such as conceptions of learning science and scientific epistemic beliefs have received a great deal of attention

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(e.g. Britner & Pajares, 2006; Chen & Pajares, 2010; Chiou & Liang, 2012; Tsai, Ho, Liang & Lin, 2011), highlighting the domain-specific feature of self-efficacy (Koballa & Glynn, 2007). Nevertheless, in the past studies (e.g. Pintrich & De Groot, 1990; Tuan, Chin & Shieh, 2005; Glynn, Taasoobshirazi & Brickman, 2009), students' self-efficacy in learning science is often conceptualized as a singular scale, which might be insufficient to fully understand their science learning self-efficacy.

Several researchers have attempted to develop multi-dimensional instruments to understand students' science learning self-efficacy at either the undergraduate or high school levels (Baldwin, Ebert-May & Burns, 1999; Capa Aydin & Uzuntiryaki, 2009; Uzuntiryaki & Capa Aydin, 2009). Among these instruments, four dimensions that characterize students' science learning self-efficacy have emerged: self-efficacy for knowledge/comprehension-level skills (Uzuntiryaki & Capa Aydin, 2009), self-efficacy for higher-order skills (e.g. analytical skills or problem solving skills) (Baldwin et al., 1999; Uzuntiryaki & Capa Aydin, 2009), self-efficacy for practical work (e.g. laboratory activities or related cognitive and psychomotor skills) (Baldwin et al., 1999; Capa Aydin & Uzuntiryaki, 2009; Uzuntiryaki & Capa Aydin, 2009), and self-efficacy for everyday applications of science concepts and skills (Baldwin et al., 1999; Uzuntiryaki & Capa Aydin, 2009).

Although the abovementioned dimensions conform to the features of science literacy (e.g. Roberts, 2007), there are still some valuable features, for example, the interpersonal aspects of science literacy, which should be taken into consideration, such as discussion or communication with peers. Studies (Chang, Chen, Guo, Cheng, Lin & Jen, 2011; Yore, Bisanz & Hand, 2003) have indicated that the current notion of science literacy that stresses the importance of communication should be applied in the classroom to promote science learning, reflecting its socio-cultural feature which emphasizes the role of language and interpersonal interaction. Besides, recent science education reforms have emphasized the importance of equipping students with the ability to communicate with others on science-related topics or issues as one of the central goals (Jenkins, 1999). Recently, Chang et al. (2011) have attempted to develop the "Competence in Communication scale" to explore Taiwanese students' science self-perceived confidence and competence, suggesting the need to understand students' science learning self-efficacy in this regard. In sum, the dimension of science communication self-efficacy that embraces the merits of the socio-cultural feature of science learning should not be neglected.

In addition, researchers have been devoted to examining the inter-relations between students' approaches to learning and self-efficacy (e.g.

Chiou & Liang, 2012; Liem, Lau & Nie, 2008; Phan, 2007, 2011). For example, in Phan's (2007) study, it was found from performing a path analysis that undergraduate students' usage of deep learning approaches positively predicted their self-efficacy. Chiou & Liang (2012) explored the structure of Taiwanese high school students' science self-efficacy, conceptions of learning science, and approaches to learning science through a structural equation modeling method. The results showed that the students' approaches to learning science were a significant predictor of their science self-efficacy. In sum, the abovementioned studies have suggested that students' approaches to learning might serve as a potential predictor of their self-efficacy.

## Literature Review

### *Self-Efficacy*

In the past several decades, studies have shown that self-efficacy has strong influences on students' motivation, cognition, and actual performance (e.g. Pintrich & De Groot, 1990; Sungur, 2007; Usher & Pajares, 2006). Based on Bandura's (1977) social cognitive theory, individuals' perceptions of their own capabilities to organize and execute certain tasks or actions required to achieve designated types of performance are characterized as the notion of self-efficacy. It is documented that, in general, students with higher levels of self-efficacy have been found to set higher goals, select more challenging tasks, persist in the face of difficulties, exert greater effort to successfully complete academic tasks, and use different learning strategies (Bandura, 1986). For example, Liem et al. (2008) found that students with high self-efficacy are prone to adopt deep learning strategies and also obtain better academic performance levels and achievement. In contrast, students with lower levels of self-efficacy tend to avoid the tasks and activities they believe to be beyond their capabilities.

A handful of studies have explored the role of self-efficacy in science education (i.e. science learning self-efficacy) (e.g. Liu, Hsieh, Cho & Schallet, 2006; Tsai et al., 2011), echoing a more specific and situational view of self-perceived competence from the past studies (Printrich & Schunk, 2002). As suggested by researchers, students' academic self-efficacy is related to their choices and performance of science learning activities (e.g. Capa Aydin & Uzuntiryaki, 2009), scientific epistemic beliefs (Tsai et al., 2011), science academic achievements (e.g.

Kupermintz, 2002), and conceptions of learning science (Chiou & Liang, 2012). For example, Tsai et al. (2011) examined the relationships among Taiwanese high school students' scientific epistemic beliefs, conceptions of learning science, and self-efficacy through rigorous structural equation modeling techniques. One of the results showed that students who viewed scientific knowledge as uncertain (i.e. had sophisticated epistemic beliefs) tended to judge themselves as possessing lower science learning self-efficacy. In sum, although the domain-specific feature of self-efficacy has received much attention from science education researchers, the studies exploring how students' science learning self-efficacy functions in students' science learning (e.g. approaches to learning) may still be insufficient and may be worth investigating further in the line of self-efficacy research.

*Students' Science Learning Self-Efficacy May Be Multi-Dimensional*

As indicated by some researchers (e.g. Multon, Brown & Lent, 1991; Pajares, 1996), studies exploring students' self-efficacy should avoid using general self-efficacy items and should develop more appropriate measures that can be adapted to various contexts. In other words, students' science learning self-efficacy should not be merely regarded as one unified measurement but might in fact be able to be dissected into several aspects for finer exploration.

In fact, as has been presented in the science education literature, several major aspects regarding science learning have been identified by researchers. Duschl (2008) synthesized three different lines of research including learning sciences, science studies, and science education research and made suggestions that science learning should incorporate, for example, the domains of "*the conceptual structures and cognitive processes used when reasoning scientifically*" (p.277), indicating the importance of students' conceptual understanding of scientific knowledge and higher-order thinking skills such as reasoning and critical thinking. Moreover, practical work, such as science learning activities in which the students manipulate and observe real objects and materials (e.g. laboratory experiments), is also a crucial component of students' science learning (Millar, Marechal & Tiberghien, 1999) to help them to learn science, to learn about science, and to allow them to do science (Hodson, 1996; Tsai, 2003).

Besides, to become scientifically literate, students should be equipped with the ability to apply what they have learned (e.g. scientific concepts) to daily life and phenomena (e.g. Millar & Osborne, 1998; Roberts, 2007). Researchers (e.g. Campbell & Lubben, 2000) have argued that incorporating everyday science applications into school science is crucial to the learners' mastery of science learning. When science learning fails to provide a bridge between students' everyday experiences and their school science, it might result in the students possessing two isolated knowledge systems related to science: one for school science and the other for their daily lives (Osborn & Freyberg, 1985). Recently, the significance of language has been characterized as a salient feature in students' science learning processes (e.g. Carlsen, 2007; Chang et al., 2011; Yore et al., 2003), suggesting the importance of interpersonal communication in knowing science. That is, in science classrooms, students should be able to scientifically communicate, debate, or discuss the inquiries, procedures, and their science understandings with their peers. Based on the abovementioned discussion, it is evident that, at least, science learning could be conceptualized as the following dimensions: conceptual understanding, higher-order thinking skills, practical work, everyday application, and science communication. Thus, in this study, students' science learning self-efficacy was explored according to the proposed framework.

A few available studies have attempted to develop multi-dimensional questionnaires to measure students' self-efficacy in science domains (e.g. Baldwin et al., 1999; Uzuntiryaki & Capa Aydin, 2009). Baldwin et al. (1999) developed an instrument (the Biology Self-Efficacy Scale) which consists of three dimensions, including methods of biology, generalization to other biology/science courses and analyzing data, and the application of biological concepts and skills, to identify non-science major undergraduates' biology self-efficacy. Capa Aydin & Uzuntiryaki (2009) developed a scale designated the "High School Chemistry Self-Efficacy Scale" to measure 150 Turkish high school students' self-efficacy from the perspectives of cognitive and laboratory competencies. However, the abovementioned studies did not include the aforementioned pivotal aspects of science learning in their entirety. Moreover, these studies of students' science-related self-efficacy focus on specific areas of science rather than on the science domain in general, such that they are not easily applicable to common high school science classrooms. Also, it seems that there are still relatively few studies aimed at assessing students' self-efficacy in science learning from multiple dimensions.

### *The Relationships Between Self-Efficacy and Approaches to Learning*

Researchers have begun to pay close attention to the relationships between learners' self-efficacy and their approaches to learning in various contexts (e.g. Chiou & Liang, 2012; Phan, 2007, 2011). Approaches to learning refer to the methods by which students process their academic tasks and are associated with their motivation regarding the given tasks (Biggs, 1994; Chin & Brown, 2000). Researchers have broadly categorized learning into deep and surface approaches (e.g. Entwistle & Ramsden, 1983; Liang, Lee & Tsai, 2010). By and large, a positive relationship between learners' self-efficacy and deep approaches to learning and a negative association between self-efficacy and surface approaches have been found (Diseth, 2011; Moneta, Spada & Rost, 2007; Prat-Sala & Redford, 2010). In other words, it might be possible that learners who adopt deep approaches to learning are more likely to possess higher self-efficacy, while those who utilize a surface approach are prone to have lower learning self-efficacy (e.g. Phan, 2007). Chiou & Liang (2012) also proposed a structural model to explore the relationships among conceptions of learning science, approaches to learning science, and science self-efficacy with 321 Taiwanese high school students. The findings indicated that students' conceptions of learning science had an indirect effect on their science self-efficacy through the mediator of their approaches to learning science.

Although studies have unraveled the possible relations between students' approaches to learning and self-efficacy, several reasons might strengthen the necessity of exploring this connection further in the current study. First, due to the domain-specific nature of learners' self-efficacy and approaches to learning (e.g. Ellis, Goodyear, Smith-Brillant & Prosser, 2008; Kember, Biggs & Leung, 2004; Tsai et al., 2011), this line of research is still in its infancy and is worth investigating further to clarify the relationships between the two variables in the field of science education. Such explorations of the two variables would contribute to contemporary self-efficacy theories. In the current study, a multi-dimensional science learning self-efficacy instrument was developed that covered diverse aspects of science learning. The relationships between the two variables might be further clarified. It is plausible to conjecture that learners' approaches to learning science might have different impacts on their science learning self-efficacy, an issue explored in the current study.

### *The Science Learning Self-Efficacy of Taiwanese Students*

It is worth noting that Taiwan had taken part in several series of The Trends in International Mathematics and Science Study (TIMSS), in 1999, 2003, and 2007. The results all indicated that Taiwanese eighth graders were categorized as some of the lowest in terms of their self-confidence in science learning (Chang & Cheng, 2008), contrasting strongly with their top science achievement compared with students from other countries. Moreover, Hong & Lin (2012) found that the science learning self-efficacy of Taiwanese students declines from elementary to junior high school. In order to increase Taiwanese students' science learning self-efficacy, it may be necessary for science education researchers to focus on exploring this issue. Understanding the science learning self-efficacy of Taiwanese high school students from various dimensions will provide valuable insights to inform and give feedback on the current status of classroom science teaching and learning.

## Research Purpose and Research Questions

The main purposes of this study were, first, to develop a multi-dimensional instrument that could be used to identify Taiwanese high school students' science learning self-efficacy based on the proposed theoretical framework. Second, this study aimed to explore the relationship between the students' science learning self-efficacy and their approaches to learning science. Besides, the effects of their approaches as the predictor of their science learning self-efficacy were also investigated. Derived from the research purposes, this study addressed the following questions (also see Fig. 1):

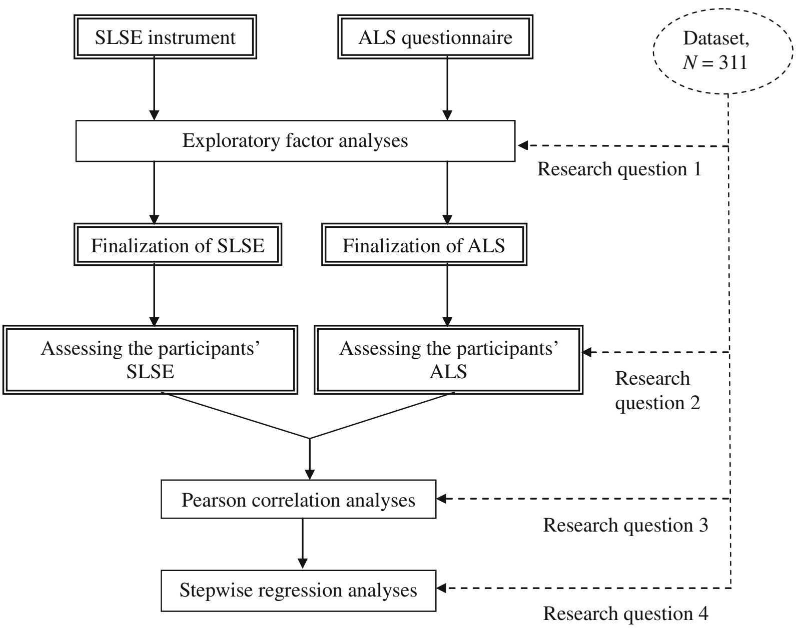


*Figure. 1.* Outline of the research procedure

1. Were the newly developed Science Learning Self-Efficacy (SLSE) instrument and the existing Approaches to Learning Science (ALS) questionnaire valid and reliable to assess, respectively, the Taiwanese high school students' science learning self-efficacy and approaches to learning science?
2. How did the Taiwanese eighth graders perceive their science learning self-efficacy and approaches to learning science?
3. What are the relationships between the Taiwanese eighth graders' science learning self-efficacy and their approaches to learning science?
4. Through regression analysis, can the Taiwanese eighth graders' approaches to learning science be used to make significant predictions about their science learning self-efficacy?

## Method

### *Sample*

The participants were 311 eighth graders (around 13–14 years old) enrolled at two high schools in Taiwan. For each school, three to five classes were selected. The participants consisted of 161 males and 150 females. Data were collected by way of the three instruments used in this study, as described below. After receiving the teacher's permission for data collection from each class, the survey was then administered to the students. They were informed that the data collection process was anonymous and voluntary. They were given no more than 30 min to respond to the survey, and they all finished it within the given time period. The surveyed students were composed of those who had divergent academic achievements and came from different demographic areas of various socioeconomic backgrounds in northern Taiwan. Although the participants were not randomly selected, they could be said to represent, to a certain extent, many eighth graders in Taiwan.

### *Assessing Students' Self-Efficacy in Science Learning*

The Science Learning Self-Efficacy (SLSE) instrument was developed to assess students' self-efficacy in learning science. The SLSE instrument was adapted from previous studies (Baldwin et al., 1999; Capa Aydin & Uzuntiryaki, 2009; Uzuntiryaki & Capa Aydin, 2009) with four dimensions (i.e. conceptual understanding, higher-order cognitive skills, practical work, and everyday application). Moreover, in the current study, the "Science

Communication" dimension was added into the SLSE instrument to probe students' self-efficacy in learning science because of the importance of interpersonal science communication advocated by science education researchers (e.g. Carlsen, 2007; Chang et al., 2011; Yore et al., 2003).

To design the items for each dimension, the researchers initially sought past related literature and instruments (e.g. Baldwin et al., 1999; Capa Aydin & Uzuntiryaki, 2009; Uzuntiryaki & Capa Aydin, 2009). Based on the consensus of the researchers of this study, including one doctoral student and one science education professor, the items were selected and revised to suit the context (i.e. science) of this study. Moreover, the items in the Science Communication dimension were also based on the ability indices of the science curriculum guidelines of Taiwan (Ministry of Education, Taiwan 2001). According to Pajares (1997), the criterion tasks such as semester grades or achievement test results do not lend themselves to particularized self-efficacy assessment. The items in the five dimensions, which align to the contemporary notion of science literacy, were also specifically designed to avoid this issue and to ensure that students can make context-specific judgments of specific learning (i.e. students' science learning self-efficacy in school science). After the procedure of item development, the content validity of the established SLSE instrument was then evaluated, approved, and verified by two science education professors who hold doctorate degrees in science education.

Thus, the SLSE questionnaire comprised five to eight items for each dimension that were presented with bipolar strongly agree/strongly disagree options on a five-point Likert scale (i.e. strongly agree, agree, somewhat agree and somewhat disagree, disagree, strongly disagree). The "strongly agree" response was assigned a score of 5, while the "strongly disagree" response was designated a score of 1. A description of each dimension with sample items is presented below:

1. Conceptual Understanding (CU/5 items): measuring students' confidence in their ability to use cognitive skills in understanding the definitions of science concepts, laws, and theories. A sample item is, "I know the definitions of basic scientific concepts (for example, gravity, photosynthesis, etc.) very well."
2. Higher-Order Cognitive Skills (HCS/6 items): assessing students' confidence in their ability to employ more complex/sophisticated skills, such as scientific inquiry skills, problem solving, critical thinking, and other higher-order cognitive skills. A sample item is, "I am able to critically evaluate the solutions of scientific problems."

3. Practical Work (PW/7 items): evaluating students' confidence in their ability to accomplish laboratory activities included in both the cognitive and psychomotor domains. A sample item is, "I know how to collect data during science laboratories."
4. Everyday Application (EA/8 items): addressing students' confidence in their ability to apply science concepts and skills to everyday events. A sample item is, "I am able to apply what I have learned in school science to daily life."
5. Science Communication (SC/6 items): evaluating students' confidence in their ability to communicate or discuss with others. A sample item is, "I am able to use what I have learned in science classes to discuss with others."

Besides, in order to establish the criterion validity of the SLSE instrument, the self-efficacy scale (nine items) of the Motivated Strategies Learning Questionnaire (MSLQ) (Pintrich & De Groot, 1990) was selected and renamed as the "modified-MSLQ" instrument in order to perform a criteria-related correlation analysis. In addition, to evaluate the high school students' self-efficacy in learning science, the wording of the scale was tailored to meet the needs of the science course context (i.e. science learning). For instance, one of the original statements "I expect to do very well in this class" was modified to the statement "I expect to do very well in the *science class*." Almost the same items were adopted (i.e. eight items) by Tsai et al. (2011) to explore Taiwanese high school students' science learning self-efficacy. Similarly, this scale, consisting of nine items, was also presented with bipolar strongly agree/strongly disagree options on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree).

### *Questionnaire Evaluating Students' Approaches to Learning Science*

The Approaches to Learning Science (ALS) questionnaire developed and validated by Lee, Johanson & Tsai (2008) was administered. The ALS questionnaire was modified from the Revised Learning Process Questionnaire (R-LPQ-2F) of Kember et al. (2004). In a previous study (Lee et al., 2008), the structure of the ALS questionnaire including deep approaches (i.e. deep motive and deep strategy factors) and surface approaches (i.e. surface motive and surface strategy factors) was revealed through both exploratory and confirmatory factor analyses. The ALS questionnaire comprised six to nine items for each factor presented with bipolar always/never options on a five-point Likert scale. That is, the “always” response was assigned a score of 5, while the “never” response was designated a score of 1. The original Cronbach’s alpha reliability scores for the above four factors were 0.90, 0.89, 0.84, and 0.84, respectively. A description of each factor with sample items is shown below:

1. Deep Motive (DM/7 items): assessing the extent of students’ intrinsic motivation that is prompted by their own curiosity and interest while learning science. A sample item is, “I feel that science topics can be highly interesting once I get into them.”
2. Deep Strategy (DS/7 items): evaluating the extent of students’ adoption of meaningful learning strategies while encompassing science learning, including making connections and summarizing key points. A sample item is, “I try to understand the meaning of the contents I have read in science textbooks.”
3. Surface Motive (SM/6 items): assessing the extent of students’ extrinsic motivation that is caused by external demands such as pursuing a high grade and meeting others’ expectations. A sample item is, “I worry that my performance in science class may not satisfy my teacher’s expectations.”
4. Surface Strategy (SS/9 items): evaluating the extent of students’ usage of surface learning strategies, including unreflective memorization and rote-learning. A sample item is, “I find the best way to pass science examinations is to try to remember the answers to likely questions.”

### *Data Analysis and Procedures*

Three instruments (i.e. the SLSE, modified-MSLQ, and ALS) were administered in the current study. Exploratory factor analysis was used to reduce the items and ensure the structures. In the exploratory factor analysis, the following criteria were followed. First, only those items with a factor loading of at least 0.50 within their own factor were retained in the questionnaire (Costello & Osborne, 2005; Hair et al., 2006). Second, items with factor loadings of many cross-loadings were omitted in the process (Bentler, 1990). Therefore, the construct validity was established. The Cronbach’s alpha coefficient for each dimension of the SLSE instrument, the modified-MSLQ instrument, and the ALS questionnaire were calculated to ensure the reliability (internal consistency) of each factor as well as the overall alpha coefficients of the three instruments. It should be noted that all of the 311 students’ responses on the SLSE, modified-MSLQ, and ALS instruments were used to assess the validity and reliability of the three instruments, respectively.

Besides, in order to examine the additional criterion-related validity of the SLSE instrument, the correlation coefficients between the SLSE and modified-MSLQ instruments were also computed through a series of Pearson correlation analyses. Furthermore, Pearson correlation analysis was also performed to examine the relationship between SLSE and ALS. Then, through a stepwise multiple regression analysis, the students' approaches to learning science were viewed as predictors to explain their science learning self-efficacy measured by the SLSE instrument. It should be noted that, due to the large sample size and for the conceptual clarity of the results, the level of statistical significance was adjusted to 0.01 for further interpretation (Cohen, Manion & Morrison, 2007).

## Results

### *Validity and Reliability of the Science Learning Self-Efficacy (SLSE) Instrument*

To validate the SLSE questionnaire, an exploratory factor analysis with a Varimax rotation was performed to clarify its structure. As a result, the students' responses were grouped into the following five orthogonal factors as expected: Conceptual Understanding, Higher-Order Cognitive Skills, Practical Work, Everyday Application, and Science Communication. The eigenvalues of the five factors from the principle component analysis were all larger than one. Items with a factor loading of less than 0.50 and with many cross-loadings were excluded from the instrument (Costello & Osborne, 2005). A total of 28 items were retained in the final version of the SLSE instrument (shown in Table 1), and the total variance explained was 73.64 %, indicating a satisfactory construct validity to assess the eighth graders' self-efficacy in science learning. Researchers (Costello & Osborne, 2005; Netemeyer, Bearden & Sharma, 2003) have suggested that at least three items are needed to identify a factor. Therefore, the number of retained items in each SLSE dimension is regarded as sufficient. Furthermore, the reliability (Cronbach's alpha) coefficients for these factors were 0.83, 0.92, 0.87, 0.94, and 0.94, respectively, and the overall alpha was 0.97, suggesting that they had high reliability in assessing the students' self-efficacy in learning science.

Table 1 also shows the 311 students' means and standard deviations of responses to the SLSE dimensions assessed by the SLSE instrument developed in this study. As shown in Table 1, the students scored highest on the "Practical Work" dimension ($M$=3.44), followed by the "Everyday

**TABLE 1**

Rotated factor loadings, Cronbach's alpha values, factor means, and standard deviations of the SLSE instrument

| | *Factor 1* | *Factor 2* | *Factor 3* | *Factor 4* | *Factor 5* |
|---|---|---|---|---|---|
| Factor 1: conceptual understanding (CU), $\alpha$=0.83, mean=2.93, SD=0.87 | | | | | |
| CU 1 | 0.66 | | | | |
| CU 2 | 0.72 | | | | |
| CU 3 | 0.63 | | | | |
| CU 4 | 0.63 | | | | |
| Factor 2: higher-order cognitive skills (HCS), $\alpha$=0.92, mean=2.83, SD=0.931 | | | | | |
| HCS 1 | | 0.59 | | | |
| HCS 2 | | 0.75 | | | |
| HCS 3 | | 0.66 | | | |
| HCS 4 | | 0.54 | | | |
| HCS 5 | | 0.67 | | | |
| HCS 6 | | 0.50 | | | |
| Factor 3: practical work (PW), $\alpha$=0.87, mean=3.44, SD=0.90 | | | | | |
| PW 1 | | | 0.75 | | |
| PW 2 | | | 0.82 | | |
| PW 3 | | | 0.67 | | |
| PW 4 | | | 0.60 | | |
| Factor 4: everyday application (EA), $\alpha$=0.94, mean=3.01, SD=0.95 | | | | | |
| EA 1 | | | | 0.67 | |
| EA 2 | | | | 0.66 | |
| EA 3 | | | | 0.69 | |
| EA 4 | | | | 0.73 | |
| EA 5 | | | | 0.75 | |
| EA 6 | | | | 0.78 | |
| EA 7 | | | | 0.62 | |
| EA 8 | | | | 0.61 | |
| Factor 5: science communication (SC), $\alpha$=0.94, mean=2.94, SD=1.06 | | | | | |
| SC 1 | | | | | 0.59 |
| SC 2 | | | | | 0.75 |
| SC 3 | | | | | 0.73 |
| SC 4 | | | | | 0.82 |
| SC 5 | | | | | 0.80 |
| SC 6 | | | | | 0.74 |

Total variance explained=73.64 %, overall Cronbach's alpha=0.97

*CU* conceptual understanding, *HCS* higher-order cognitive skills, *PW* practical work, *EA* everyday application, *SC* science communication

Application" dimension (*M*=3.01), the Science Communication dimension (*M*=2.94), the Conceptual Understanding dimension (*M*=2.93), and the Higher-Order Cognitive Skills dimension (*M*=2.83).

### *Validity and Reliability of the Modified-MSLQ Instrument*

The other instrument adopted in the current study, the modified-MSLQ, was taken from the original self-efficacy scale of the MSLQ. In order to validate this instrument, the same criteria of exploratory factor analysis were utilized to clarify its items and structure. The results indicated that the nine items were all retained and grouped into one factor. The total variance explained was 71.83 %. Moreover, the reliability (Cronbach's alpha) coefficient was 0.95, suggesting that the instrument is reliable for evaluating students' science learning self-efficacy in general. The mean score of the 311 students on the modified-MSLQ instrument was 2.80.

Additionally, as indicated by Capa Aydin & Uzuntiryaki (2009), it is important to examine additional criterion-related validity relationships when validating a multi-dimensional self-efficacy questionnaire. Thus, in order to establish the criterion validity of the SLSE questionnaire, a correlation analysis was conducted to explore the relationships between the 311 students' responses on the SLSE questionnaire and the modified-MSLQ instrument, which served as the criterion-related variable. Accordingly, the five dimensions of the SLSE questionnaire were all positively correlated with the modified-MSLQ instrument (CU/modified-MSLQ, $r$=0.70; HCS/modified-MSLQ, $r$=0.71; PW/modified-MSLQ, $r$= 0.56; EA/modified-MSLQ, $r$=0.67; SC/modified-MSLQ, $r$=0.72, $p$< 0.001). Since the modified-MSLQ items, modified from Pintrich & De Groot (1990), aimed to assess the students' confidence in their science classroom academic performance, the results from the criterion-related correlation analysis also suggested that the SLSE instrument had satisfactory criterion-related validity.

### *Exploratory Factor Analysis for the Approaches to Learning Science (ALS) Questionnaire*

Table 2 shows the exploratory factor analysis results for the ALS questionnaire. It is noted that the same criteria were adopted as for the other instruments (i.e. the SLSE and modified-MSLQ instruments) used in the present study. Consequently, 22 items were included in the final version of ALS, with a total of 69.17 % of variation explained. The alpha reliability from the sample of this study was 0.92 for the DM and DS factors, 0.87 for the SM factor, and 0.79 for the SS factor, as well as 0.92 for the overall reliability of the ALS questionnaire, suggesting satisfactory internal consistency of assessing students' approaches to science learning. Table 2 also shows the 311 students' average item scores and the standard deviations of the four ALS factors. The students showed strongest

**TABLE 2**

Rotated factor loadings, Cronbach's alpha values, factor means, and standard deviations of the ALS questionnaire

| | *Factor 1* | *Factor 2* | *Factor 3* | *Factor 4* |
|---|---|---|---|---|
| Factor 1: deep motive (DM), $\alpha$=0.92, mean=2.85, SD=1.02 | | | | |
| DM 1 | 0.73 | | | |
| DM 2 | 0.83 | | | |
| DM 3 | 0.82 | | | |
| DM 4 | 0.82 | | | |
| DM 5 | 0.55 | | | |
| Factor 2: deep strategy (DS), $\alpha$=0.92, mean=3.02, SD=0.97 | | | | |
| DS 1 | | 0.68 | | |
| DS 2 | | 0.78 | | |
| DS 3 | | 0.81 | | |
| DS 4 | | 0.84 | | |
| DS 5 | | 0.80 | | |
| DS 6 | | 0.70 | | |
| DS 7 | | 0.58 | | |
| Factor 3: surface motive (SM), $\alpha$=0.87, mean=3.43, SD=1.00 | | | | |
| SM 1 | | | 0.80 | |
| SM 2 | | | 0.85 | |
| SM 3 | | | 0.70 | |
| SM 4 | | | 0.57 | |
| SM 5 | | | 0.67 | |
| SM 6 | | | 0.70 | |
| Factor 4: surface strategy (SS), $\alpha$=0.79, mean=2.71, SD=0.90 | | | | |
| SS 1 | | | | 0.81 |
| SS 2 | | | | 0.73 |
| SS 3 | | | | 0.80 |
| SS 4 | | | | 0.78 |

Total variance explained=69.17 %, overall Cronbach's alpha=0.92
*DM* deep motive, *DS* deep strategy, *SM* surface motive, *SS* surface strategy

agreement on the Surface Motive factor (*M*=3.43), followed by the Deep Strategy factor (*M*=3.02), the Deep Motive factor (*M*=2.85), and the Surface Strategy factor (*M*=2.71).

### *Relationships Between Students' Self-Efficacy in Science Learning and Approaches to Science Learning*

In order to understand the relationships between the students' self-efficacy in learning science and their approaches to science learning, Pearson correlation analysis based on their responses to the SLSE and

ALS was performed. Thus, as shown in Table 3, the three ALS factors (i.e. DM, DS, and SM) were positively related to all scales of the SLSE instrument (i.e. CU, HCS, PW, EA, and SC) ($r$=0.35~0.76, $p$<0.001), suggesting medium (i.e. the SM factor) to large (i.e. the DM and DS factors) effect size coefficients (Cohen, 1992). In general, the correlation results indicate that those students who reported adopting deep strategies for science learning (DS) and who held both intrinsic and extrinsic motivations (i.e. DM and SM) tended to report stronger science learning self-efficacy in the aspects of conceptual understanding (CU), higher-order thinking skills (HCS), practical work (PW), application of learned science knowledge to daily life (EA), and science communication with others (SC). However, no significant relationships were found between the Surface Strategy (SS) factor and any of the probed scales of science efficacy in this study.

### *Stepwise Multiple Regression Estimates for Predicting Students' Self-Efficacy in Science Learning*

Stepwise multiple regression analyses were conducted to identify the predictive effects of the ALS scales on the scales of the SLSE instrument. That is, for each regression analysis, the ALS factors served as predictor variables, while each scale of the SLSE was processed as an outcome variable, as shown in Table 4. The regression analysis revealed that both Deep Strategy (DS) and Deep Motive (DM) factors were the significant predictors for each scale of the SLSE instrument, except for the PW factor. More specifically, in general, both DS ($\beta$=0.57~0.62) and DM ($\beta$=0.17~0.20) could

**TABLE 3**

Correlation of the students' science learning self-efficacy and their approaches to learning science

| *Scale* | *CU* | *HCS* | *PW* | *EA* | *SC* |
|---|---|---|---|---|---|
| Deep motive | 0.60** | 0.65** | 0.52** | 0.60** | 0.64** |
| Deep strategy | 0.70** | 0.76** | 0.62** | 0.72** | 0.74** |
| Surface motive | 0.39** | 0.48** | 0.35** | 0.42** | 0.42** |
| Surface strategy | 0.04 | 0.12 | 0.12 | 0.09 | 0.08 |

*CU* conceptual understanding, *HCS* higher-order cognitive skills, *PW* practical work, *EA* everyday application, *SC* science communication

*$p$<0.01, **$p$<0.001

**TABLE 4**

Stepwise regression model of predicting students' science learning self-efficacy (SLSE, *N*=311)

| *SLSE (outcome)* | *Predictor(s)* | *ß* | *Adjusted $R^2$* | *t* | *F* |
|---|---|---|---|---|---|
| Conceptual understanding | Constant | | 0.50 | 8.40** | 158.74** |
| | Deep strategy | 0.57 | | 9.66** | |
| | Deep motive | 0.19 | | 3.19* | |
| Higher-order cognitive skills | Constant | | 0.60 | 4.76** | 228.33** |
| | Deep strategy | 0.62 | | 11.64** | |
| | Deep motive | 0.20 | | 3.75** | |
| Practical work | Constant | | 0.38 | 13.04** | 193.12** |
| | Deep strategy | 0.62 | | 13.90** | |
| Everyday application | Constant | | 0.53 | 6.53** | 174.21** |
| | Deep strategy | 0.60 | | 10.49** | |
| | Deep motive | 0.17 | | 2.90* | |
| Science communication | Constant | | 0.56 | 2.93* | 201.04** |
| | Deep strategy | 0.58 | | 10.62** | |
| | Deep motive | 0.21 | | 3.87** | |

*$p<0.01$, **$p<0.001$

significantly and positively predict the CU, HCS, EA, and SC scales, and they explained 50 %, 60 %, 53 %, and 56 % of the students' science learning self-efficacy, respectively. In addition, the DS factor is the only significant predictor for the PW scale of SLSE, and the DS factor accounted for 38 % of its variance. By and large, the Taiwanese students who reported themselves as adopting deep strategies and possessing intrinsic motivation toward science learning tended to express higher levels of self-efficacy in various dimensions, such as the ability to understand the definitions, formulae, and theories of science concepts (CU), the ability to utilize various higher-order scientific approaches when learning science (HCS), the capability to apply what they have learned in school science to daily life (EA), and the capability to communicate and discuss with others (SC). The students who reported utilizing deep strategies tended to perceive themselves as having higher confidence in their competence of accomplishing laboratory activities (PW).

## Discussion

The purpose of the current preliminary study was to develop and validate the SLSE instrument to measure Taiwanese high school students' self-efficacy in science learning. Accordingly, the proposed framework consisted of five dimensions of students' science learning self-efficacy including Conceptual Understanding (CU), Higher-Order Cognitive Skills (HCS), Practical Work (PW), Everyday Application (EA), and Science Communication (SC). After ensuring several types of validity of the SLSE questionnaire (i.e. content validity, construct validity, and criterion-related validity) and the reliability of each dimension, the results suggested that the SLSE instrument has satisfactory validity and reliability to measure Taiwanese high school students' multi-dimensional self-efficacy in learning science. It is expected that SLSE can be used as an adequate prototype questionnaire by science educators of other countries or for different levels of learning, after certain modifications.

Moreover, in the present study, the relationship between Taiwanese eighth graders' science learning self-efficacy and their approaches to learning science was revealed by correlation analysis. The results indicate that deep approaches to learning science (deep strategy/deep motive) as well as surface motives were positively correlated with the students' self-efficacy in science learning. In other words, the Taiwanese eighth graders who perceive themselves as having an intrinsic motive such as personal desire or fulfillment for learning, along with the orientation of extrinsic motive such as preparing for future careers or achieving others' (e.g. parents or teachers) expectations by getting good grades in school, tended to possess higher science learning self-efficacy. Also, those students who reported adopting deep strategies to learn science (e.g. seeking comprehension) were more prone to possess higher science learning self-efficacy.

In the past literature, students' deep approaches to learning (deep strategy/deep motive) were often found to be positively correlated with their self-efficacy (e.g. Moneta et al., 2007; Prat-Sala & Redford, 2010; Walker, Greene & Mansell, 2006); the same conclusion was drawn by this study. Yet, the current study found that the Taiwanese eighth graders' surface motive for learning science also positively correlated with their science learning self-efficacy. As indicated by Chiou & Liang (2012), Taiwanese high school students may treat surface motive for learning science (e.g. studying science just for passing a test) as a basic and attainable goal and then feel efficacious in their science learning. Another interpretation of this result might signify the specificity of Taiwanese culture. In other words, Taiwanese students are more compliant to authority such as teachers and parents and mold their attitudes according to the opinions of highly respected authorities (Lin et al., 2013; Mau, 2000; Tweed & Lehman, 2002). It is argued here that this attitude that is common among Taiwanese students might either enhance or impede their science learning self-efficacy. Based on the findings of the current study, it is suggested that the supports and positive behaviors of science teachers and parents might play a crucial role in developing Taiwanese students' self-efficacy in learning science. However, this interpretation could be revisited and verified in future research.

In this study, overall, it was also found from the regression results that the students' deep strategies and deep motive were strong predictors of their science learning self-efficacy. More specifically, Taiwanese eighth graders' deep strategies of science learning have the largest predictive impact on the targeted science learning self-efficacy dimensions in the current study. Bandura (1997) argued that individuals' behaviors and their self-efficacy beliefs are closely related. Therefore, it is probable that students' usage of deep strategies to learn science, which are directly related to their actions (behaviors) of science learning, might have more significant impacts on their science learning self-efficacy.

Also, it is worth noting that students with an orientation toward using deep approaches (including deep strategies and deep motive) were most likely to show confidence in employing higher-order thinking skills such as problem-solving and critical thinking skills. That is, compared with other dimensions of SLSE, the Deep Strategy and Deep Motive factors could account for more than 60 % of the variation (i.e. adjusted $R^2$= 60 %) in the Higher-Order Cognitive Skills dimension of SLSE. A deep approach to learning is usually closely linked with students' higher-order forms of learning such as problem solving, self-reflection, or critical thinking (e.g. Chin & Brown, 2000; Kember, 2000). For instance, Chin & Brown (2000) indicated that, when learners employed a deep approach to learning science, they would actively recall required prior knowledge and experiences to critically judge and evaluate the tasks, problems or information, and move away from the procedural and observational levels to the conceptual, analytical, and meta-conceptual levels. Throughout this process, students might gain self-efficacy in their higher-order thinking skills. As a result, it would be possible that deep-approach learners might tend to possess higher science learning self-efficacy. Yet, it should be noted that the over-emphasized paper–pencil high-stakes standardized examinations at both the school and national levels in Taiwan might prevent them from using deep approaches to learning science and guide them towards having deep motives to a lesser extent and more frequent adoption of surface strategies such as rote-learning (e.g. Lee et al., 2008).

Moreover, it seems that the Practical Work scale of SLSE could only be predicted by the Deep Strategy dimension of ALS. The stepwise regression results suggest that the students' deep strategies of learning science explained their science learning self-efficacy of Practical Work to a significant extent. In fact, during practical work activities, students may largely focus on seeking different strategies that link with declarative, procedural, and operational knowledge to carry out experimental procedures or set up required equipment (Hofstein & Kind, 2012). From this perspective, the students' deep motive did not play an essential role as it did in other dimensions of SLSE.

## Implications

Although this study has identified students' science learning self-efficacy from various dimensions, the influencing sources are still unclear. As indicated by Bandura (1997), there are four main hypothesized sources of self-efficacy, including mastery experiences, vicarious experiences, verbal persuasion, and emotional arousal. Researchers are encouraged to explore these sources further using qualitative, quantitative, or mixed methods. For example, Kiran & Sungar (2012) have developed a five-point Likert scale instrument (Sources of Self-Efficacy Scale) to measure Turkish middle school students' sources of science self-efficacy in order to explore the relationships between science self-efficacy and its sources. The results indicate that most of the proposed sources, except for vicarious experience, were significant predictors of their science self-efficacy. The mastery experiences predictor was found to be the strongest predictor of science self-efficacy. Furthermore, Chiou & Liang (2012) have identified a structural model of Taiwanese high school students among their conceptions of learning science, approaches to learning science, and science self-efficacy. Their results suggested that the students' conceptions of learning science could be one of the underlying sources that might have an influence on their science self-efficacy. Yet, the science self-efficacy questionnaires used by both studies consist of only a single scale (i.e. MSLQ).

As previously mentioned, the educational and testing systems in Taiwan may discourage high school students from utilizing deep approaches to learning science and, subsequently, probably decrease their self-confidence in learning science. Science educators in Taiwan should cultivate students' use of deeper approaches to learning science and promote their self-efficacy levels by engaging them in more authentic science practice through, for instance, inquiry-based science instruction, argumentation, and socio-scientific issue instruction (e.g. Brickman et al., 2009; Dawson & Venville, 2010; Tsai et al., 2011; Zeidler & Nichols, 2009). For example, Brickman, Gormally, Armstrong & Hallar (2009) found that students gained "*confidence in using a scientific approach to solve problems, including using analytical skills to conduct experiments and general confidence for success in the course"* (p. 6) after experiencing inquiry-oriented learning emphasizing active thinking and involvement in the given tasks.

Besides, researchers have suggested that individuals' past successful experiences or positive authentic accomplishments could increase their self-efficacy beliefs (Bandura, 1997). It is contended here that socio-cultural approaches (e.g. argumentation) with an adequate context that links to students' daily life experiences (e.g. socio-scientific issues) might be able to foster various dimensions (e.g. HCS, EA, or SC) of students' science learning self-efficacy. In traditional education settings, students might rarely gain such positive experiences to develop their SLSE of HCS, EA, or SC due to the limited types of science practice. Therefore, appropriate instructional strategies including discourse argumentation activities or socio-scientific issue-based discussions (e.g. Cavagnetto, 2010; Kolsto, 2001) in which students can employ higher-order thinking skills, apply their science concepts to real-life contexts, and communicate scientifically with others would be helpful for students to accumulate positive experiences of related abilities. Students may become more efficacious in participating in these activities and develop their science learning self-efficacy in the abovementioned aspects accordingly.

Some of the limitations of this study could serve as future directions for conducting related studies. First, even though most of the items were adapted from other instruments, it is recommended that researchers modify those SLSE items that might contain vague wording and thus possibly confuse the respondents. For example, items with the words "very" and items with conjunctions could be avoided in the item refinement process. Second, since the students' self-efficacy in learning science were acquired from their self-reported scores on the SLSE instrument, the interpretations of the results regarding the potential relationships between the students' SLSE and ALS derived from this study should be carefully verified in the future.

Moreover, in the current study, the SLSE instrument was developed to assess the students' science learning self-efficacy from the more refined five dimensions. As suggested by Pajares (1996), the idea of "specificity" should be considered. That is, the assessment items of self-efficacy should correspond with the specific criterion tasks being assessed (i.e. instructional tasks) (see Moores & Chang, 2009). In fact, the purpose of this study was to gain an overview of the Taiwanese high school students' science learning self-efficacy by a more refined multi-dimensional instrument (i.e. the SLSE instrument). Researchers are encouraged to revisit this issue with the newly developed instrument (i.e. the SLSE) of this study as a basis to further identify students' science learning self-efficacy under specific instructional tasks.

In addition, the newly developed SLSE instrument should be validated with a larger sample across different grade-levels and with a more rigorous method such as confirmatory factor analysis. Moreover, as previously mentioned, researchers can adopt qualitative or mixed methodologies to explore students' science learning self-efficacy from different perspectives and identify additional dimensions. Besides, several factors that may be related to students' science learning self-efficacy such as conceptions of learning science or their views of nature of science can be explored further to attain a clearer picture of their relationships.

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## APPENDIX A. THE SCIENCE LEARNING SELF-EFFICACY (SLSE) QUESTIONNAIRE (FINAL VERSION)

### *Conceptual Understanding*

CU1. I can explain scientific laws and theories to others.
CU2. I can choose an appropriate formula to solve a science problem.
CU3. I can link the contents among different science subjects (for example biology, chemistry and physics) and establish the relationships between them.
CU4. I know the definitions of basic scientific concepts (for example, gravity, photosynthesis, etc.) very well.

### *Higher-Order Cognitive Skills*

HCS1. I am able to critically evaluate the solutions of scientific problems.

HCS2. I am able to design scientific experiments to verify my hypotheses.
HCS3. I am able to propose many viable solutions to solve a science problem.
HCS4. When I come across a science problem, I will actively think over it first and devise a strategy to solve it.
HCS5. I am able to make systematic observations and inquiries based on a specific science concept or scientific phenomenon.
HCS6. When I am exploring a scientific phenomenon, I am able to observe its changing process and think of possible reasons behind it.

*Practical Work*

PW1. I know how to carry out experimental procedures in the science laboratory.
PW2. I know how to use equipment (for example measuring cylinders, measuring scales, etc.) in the science laboratory.
PW3. I know how to set up equipment for laboratory experiments.
PW4. I know how to collect data during the science laboratory.

*Everyday Application*

EA1 I am able to explain everyday life using scientific theories.
EA2 I am able to propose solutions to everyday problems using science.
EA3 I can understand the news/documentaries I watch on television related to science.
EA4 I can recognize the careers related to science.
EA5 I am able to apply what I have learned in school science to daily life.
EA6 I am able to use scientific methods to solve problems in everyday life.
EA7 I can understand and interpret social issues related to science (for example nuclear power usage and genetically modified foods) in a scientific manner.
EA8 I am aware that a variety of phenomena in daily life involve science-related concepts.

*Science Communication*

SC1 I am able to comment on presentations made by my classmates in science class.
SC2 I am able to use what I have learned in science classes to discuss with others.
SC3 I am able to clearly explain what I have learned to others.
SC4 I feel comfortable discussing science content with my classmates.
SC5 In science classes, I can clearly express my own opinions.
SC6 In science classes, I can express my ideas properly.

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Tzung-Jin Lin

*Graduate Institute of Applied Science and Technology*
*National Taiwan University of Science and Technology*
*#43, Sec.4, Keelung Rd, Taipei, 106, Taiwan*
*E-mail: D9822302@mail.ntust.edu.tw*

Chin-Chung Tsai

*Graduate Institute of Digital Learning and Education*
*National Taiwan University of Science and Technology*
*#43, Sec.4, Keelung Rd, Taipei, 106, Taiwan*
*E-mail: cctsai@mail.ntust.edu.tw*