International Journal of Science Education
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tsed20

Conceptions of Memorizing and Understanding in Learning, and Self-Efficacy Held by University Biology Majors

Tzu-Chiang Lin[a], Jyh-Chong Liang[b] & Chin-Chung Tsai[a]
[a] Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, Taipei, Taiwan
[b] Graduate Institute of Applied Science and Technology, National Taiwan University of Science and Technology, Taipei, Taiwan
Published online: 15 Dec 2014.

To cite this article: Tzu-Chiang Lin, Jyh-Chong Liang & Chin-Chung Tsai (2015) Conceptions of Memorizing and Understanding in Learning, and Self-Efficacy Held by University Biology Majors, International Journal of Science Education, 37:3, 446-468, DOI: 10.1080/09500693.2014.992057

To link to this article: http://dx.doi.org/10.1080/09500693.2014.992057

International Journal of Science Education, 2015
Vol. 37, No. 3, 446–468, http://dx.doi.org/10.1080/09500693.2014.992057

Routledge
Taylor & Francis Group

Conceptions of Memorizing and Understanding in Learning, and Self-Efficacy Held by University Biology Majors

Tzu-Chiang Lin[a], Jyh-Chong Liang[b*] and Chin-Chung Tsai[a]
[a]*Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, Taipei, Taiwan;* [b]*Graduate Institute of Applied Science and Technology, National Taiwan University of Science and Technology, Taipei, Taiwan*

This study aims to explore Taiwanese university students' conceptions of learning biology as memorizing or as understanding, and their self-efficacy. To this end, two questionnaires were utilized to survey 293 Taiwanese university students with biology-related majors. A questionnaire for measuring students' conceptions of memorizing and understanding was validated through an exploratory factor analysis of participants' responses. As for the questionnaire regarding the students' biology learning self-efficacy (BLSE), an exploratory factor analysis revealed a total of four factors including higher-order cognitive skills (BLSE-HC), everyday application (BLSE-EA), science communication (BLSE-SC), and practical works (BLSE-PW). The results of the cluster analysis according to the participants' conceptions of learning biology indicated that students in the two major clusters either viewed learning biology as understanding or possessed mixed-conceptions of memorizing and understanding. The students in the third cluster mainly focused on memorizing in their learning while the students in the fourth cluster showed less agreement with both conceptions of memorizing and understanding. This study further revealed that the conception of learning as understanding was positively associated with the BLSE of university students with biology-related majors. However, the conception of learning as memorizing may foster students' BLSE only when such a notion co-exists with the conception of learning with understanding.

Keywords: *Self-efficacy for learning science; Conceptions of learning science; Biology education*

*Corresponding author. Graduate Institute of Applied Science and Technology, National Taiwan University of Science and Technology, #43, Sec.4, Keelung Rd., Taipei 106, Taiwan. Email: aljc@mail.ntust.edu.tw

Introduction

In the past decades, educators have put great efforts into exploring the psychological features of students that contribute to their performance in academic learning. Conceptions of learning (i.e. viewpoints on the nature of learning) and learning self-efficacy (i.e. self-confidence to accomplish learning tasks) are hence identified as crucial factors that correlate to science learning (Chiou & Liang, 2012; Pintrich & Schunk, 2002; Tsai, Ho, Liang, & Lin, 2011). A considerable number of studies have recognized the predictive value of these factors for outcomes, engagement, and motivation in learning science (Klatter, Lodewijks, & Aarnoutse, 2001; Usher & Pajares, 2008; Walker, Greene, & Mansell, 2006). Comparatively, only a few investigations have aimed at exploring these two highly related factors of higher education students' learning of biological knowledge. Due to the procedural and factual nature of biological knowledge (Tsai, 2006; Wandersee, Fisher, & Moody, 2000), learning such knowledge may require both students' true understanding (e.g. reasoning and comprehension) and memorization of learning contents (Barsoum, Sellers, Campbell, Heyer, & Paradise, 2013; Myant & Williams, 2008; Wandersee & Fisher, 2000). However, almost no empirical evidence has been found to identify whether students viewed biology learning as memorizing or as understanding from the perspective of their self-confidence in learning such a subject domain. This study accordingly highlights the necessity of examining the learning self-efficacy and the conceptions of learning of students majoring in the biology-related subject domain. To this end, this study validated the corresponding instruments in order to explore students' conceptions of memorizing and understanding in learning biology in accordance with their biology learning self-efficacy (BLSE).

Conceptualizing Learning Science as Memorizing versus Understanding

Generally, the construct of conceptions of learning is defined as one's beliefs about or understanding of the nature of learning. Since Marton and Säljö (1976) introduced conceptions of learning to the field of education, relevant investigations have received considerable attention from educators. Conceptions of learning have been found to be effectively associated with students' utilization of cognitive strategies in learning (Prosser & Trigwell, 1999) and with motivational orientation toward learning activities (Klatter et al., 2001). These conceptions to some extent also contribute to students' perceptions of the classroom environment and approaches to learning (Dart et al., 2000). By and large, educators hold a common viewpoint that students' conceptions of learning originate from their daily experience of learning (Entwistle & Peterson, 2004; Klatter et al., 2001; Yang & Tsai, 2010). Based on this experience-dependent characteristic, learning in varied subject domains or learning tasks may lead to different conceptions of learning. With a focus on students' learning in science, Tsai (2004) further claimed that conceptions of learning should be domain-specific.

With regard to precisely defining the theoretical scope of conceptions of learning, several studies have attempted to identify the multi-dimensional framework of such beliefs from empirical evidence. For instance, Säljö (1979) proposed five dimensions of conceptions of learning based on findings from interviewing college students. The identified conceptions regarded learning are (1) increase in knowledge; (2) memorizing; (3) acquisition of facts or procedures that can be retained and/or utilized in practice; (4) abstraction of meaning; and (5) the interpretative process aimed at the understanding of reality. In a later investigation, the researchers proposed a sixth dimension as 'changing as a person' and hence highlighted a more comprehensive framework to represent one's conceptions of learning (Marton, Dall'Alba, & Beaty, 1993). Moreover, Tsai (2004) specifically framed students' conceptions of learning science (COLS) in seven hierarchical categories that deemed learning science as (1) memorizing; (2) preparing for tests; (3) calculating and practicing tutorial problems; (4) the increase in knowledge; (5) applying; (6) understanding; and (7) seeing in a new way. Based on students' responses in interviews, Tsai also argued that most participants expressed their ideas about learning science with more than one of the aforementioned conceptions. This implies that the more sophisticated conceptions and naïve ones may either coordinate with each other or coexist as 'mixed-conceptions' (Dahlin & Watkins, 2000; Tavakol & Dennick, 2010).

In order to differentiate sophisticated/naïve conceptions of learning, Säljö (1979) and Marton et al. (1993) grouped the first three of their categories as 'fragmented' conceptions that represent learning as passive acquisition of fragmentary knowledge. The remaining categories were grouped as 'cohesive' conceptions that highlight the internalization of knowledge as well as meaningful learning. Thereafter, several different terminologies were used to describe the similar dualism of conceptions of learning, such as reproductive/constructive (van Rossum & Schenk, 1984), quantitative/qualitative (Biggs, 1994), and reproducing/transforming (Brownlee, Purdie, & Boulton-Lewis, 2003). As for Tsai's (2004) study of COLS, he directly used 'lower-level' to group the conceptions of 'memorizing', 'testing', and 'calculating and practicing'. By contrast, 'higher-level' was used to include conceptions such as 'increasing one's knowledge', 'applying', 'understanding', and 'seeing in a new way'. Although the research contexts and learning subject domains may vary in these studies, it is still worth noting that researchers commonly deem 'understanding' as a more sophisticated conception, while 'memorizing' is considered as a naïve one.

Tsai's (2004) study has specifically interpreted students' conceptions of 'learning science as memorizing' and 'learning science as understanding' based on phenomenographic analysis of interview data. 'Memorizing' represents learning science as keeping bits of science information in mind, including scientific definitions, formulae, and terms. As for 'understanding', learning science is to make sense of natural phenomena and to build coherent knowledge of science. Several studies regarding science education have further revealed the relationships among these two conceptions of learning and students' approaches to learning. For instance, Lee, Johanson, and Tsai (2008) surveyed high school students in Taiwan and found that the participants' conception of memorizing significantly and positively correlated to their surface motive (e.g. being afraid of failure) and surface strategies (e.g. cram learning) for learning science. Furthermore, students' conception of understanding may enhance their deep motive (e.g. intrinsic motivation) and deep strategies (e.g. meaning making). Similar findings were also found in Chiou, Liang, and Tsai (2012) and Hazel, Prosser, and Trigwell's (2002) investigations of university students. Memorizing and understanding seem to contribute to students' science learning in diverse directions.

In general, encouraging students' understanding for meaningful learning rather than memorizing has become a point of consensus (Dahlin & Watkins, 2000). Such a viewpoint results from the notion that memorizing and understanding seem to be incompatible conceptions. With regard to learning biology, it also implies that students' focus on cram learning in part restrains their comprehension of learning contents in accordance with what they already know (Chiou et al., 2012; Momsen, Long, Wyse, & Ebert-May, 2010). Nevertheless, educators have especially argued the possibility that students may combine the process of memorizing and understanding to confront learning tasks and achieve successes (Marton, Wen, & Wong, 2005; Tsai et al., 2011). To some students, the goal of memorizing the learning contents is to acquire better understanding in the process of learning (Dahlin & Watkins, 2000; Kember, 1996, 2000; Marton, Watkins, & Tang, 1997). This may reflect that, in biology education, researchers emphasize the importance of 'mindful memorization' with the intention of understanding and making sense of biological knowledge (Anderson & Schönbornx, 2008). From the derived debates on the influence of memorization and understanding in learning biology therefore emerges the research space to scrutinize these two conceptions of students majoring in biology-related subject domains. Moreover, there is also a lack of empirical evidence to particularly clarify students' learning biology as memorizing or as understanding through their cognitive traits regarding learning such as self-efficacy.

Science Learning Self-Efficacy

Bandura (1977) first introduced the construct of self-efficacy from the social cognitive theory. Self-efficacy refers to an individual's belief in her/his capability to conduct the tasks and actions for achieving certain goals or performance. One's perceived self-efficacy may contribute to the cognitive process in light of motivation, decision of goals and strategies, and persistence to overcome challenges (Bandura, 1986, 1993). As for applying the notion of self-efficacy in the educational system, a variety of studies have revealed that students' self-efficacy positively affects their level of motivation in learning (Bong, 2004; Bong & Skaalvik, 2003; Zimmerman, 2000), choice of college majors and career (Grunert & Bodner, 2011; O'Brien, Martinez-Pons, & Kopala, 1999; Zeldin, Britner, & Pajares, 2008), as well as academic achievements (Badura, Barbaranelli, Caprara, & Pastorelli, 1996; Martin & Dowson, 2009; Pajares, 1996; Phillips & Gully, 1997). With respect to the aforementioned literature, self-efficacy in learning acts as a cognitive trait that supports one's development of competence with specific disciplines and contexts. In other words, it is notable that self-efficacy is domain-specific and task-dependent (Bandura, 1997; Bong, 2001; Shell, Colvin, & Brunning, 1995). Accordingly, science learning self-efficacy (SLSE) is a substantial factor in predicting students' performance or achievement in learning science (Usher & Pajares, 2008).

To get a better understanding of SLSE, science educators have conducted a handful of investigations regarding a variety of related factors. For instance, Thomas, Anderson, and Nashon (2008) developed an instrument to examine Hong Kong high school students' self-efficacy, metacognition, and learning process in science learning. Their findings showed that the students' self-efficacy is positively related to their perceptions of monitoring, evaluation, and planning for learning science. As for learning in a biology non-majors' course, Lawson, Banks, and Logvin (2007) found that undergraduate students' self-efficacy and reasoning ability were positively correlated. Velayutham and Aldridge (2013) surveyed Australian high school students and identified self-efficacy in science learning as a contributory factor to students' self-regulation in the science classroom. Tsai et al.'s study (2011) as well as Chiou and Liang's study (2012) proved that Taiwanese high school students' COLS may to some extent predict their SLSE. However, a large part of the relevant investigations still measured students' SLSE with simply a single scale that is considered insufficient to comprehensively explore students' ideas (Lin & Tsai, 2013b).

Several studies have endeavored to develop multi-dimensional instruments to explore students' self-efficacy situated in various contexts of science learning. For example, Baldwin, Ebert-May, and Burns (1999) focused on the self-efficacy in biology by surveying students with non-biology majors in three different dimensions, including 'methods of biology', 'generalization to other biology/science courses and analyzing data', and 'application of biological concepts and skills'. In Uzuntiryaki and Çapa Aydın's study (2009), an instrument was developed to survey university freshmen's chemistry self-efficacy with respect to 'cognitive skills', 'psychomotor skills', and 'everyday applications' (EAs). Recently, Lin and Tsai (2013b) developed a more sophisticated instrument to examine students' SLSE in the following dimensions: (1) conceptual understanding (CU), (2) higher-order cognitive skills (HCS), (3) practical work (PW), (4) EA, and (5) science communication (SC). In sum, it seems that multi-dimensional instruments may more precisely measure task-dependent self-efficacy regarding pivotal aspects of learning science. Nevertheless, research on science learning that simultaneously aims at multi-dimensional self-efficacy for a specific subject domain in science (e.g. biology) and other related factors, such as COLS, is still in the preliminary stage. The necessity of further investigation in this line of research on SLSE may hence emerge.

Research Purpose

Based on the existing literature, the relationships among students' conceptions of memorization and understanding in learning biology as well as their BLSE are still uncertain. Empirical investigations on university students with biology-related majors may provide direct evidence to gain a better understanding of these factors due to their domain-specific nature. The current study hence aims at both categorizing the university students by their conceptions of memorization and understanding in learning biology, and unveiling their BLSE. Accordingly, we first adapted the instrument of COLS (Chiou & Liang, 2012) and modified it to specifically measure the students' beliefs about memorizing and understanding in learning biology. The research purpose then moved to clustering of the students in terms of their conceptions of memorizing and understanding. This study especially focused on biology-major students' multi-dimensional self-efficacy for learning biology that has seldom received attention in previous research. We hence adopted Lin and Tsai's (2013b) instrument to assess the students' BLSE with respect to CU, HCS, PW, EA, as well as SC. Last, further comparisons were conducted to reveal the students' self-efficacy while possessing varied conceptions of memorizing and understanding in learning biology.

Method

Participants

A total of 293 university students in Taiwan participated in this study. All of these valid samples were majoring in biology-related domains such as biological science, biological technology, and life sciences. Also, these students had taken part in a series of biology-related courses or at least had taken the fundamental biology courses. The participants were from 14 universities with varied geographical locations (i.e. northern, central, and southern Taiwan) and of varied types (i.e. research university, normal university, and medical university). Only 54 (18%) master students participated in this study and the remaining participants ($N = 239$, 82%) were at undergraduate level. Of the undergraduate level students, 64 (27%) were freshmen, 53 (22%) sophomores, 61 (26%) juniors, and 61 (26%) seniors. Slightly more than a half of these valid samples were male ($N = 153$, 52%). The average age of the students was 21 (SD = 1.90) and their ages ranged from 17 to 29.

Instrumentation

The current study measured the participants' COLS regarding memorizing and understanding by a COLS questionnaire. Lee et al. (2008) first developed a COLS questionnaire that was based on the conceptual framework in Tsai's (2004) phenomenographic study on Taiwanese students. However, in their version of the questionnaire, the factor 'understanding' was combined with the other factor 'seeing in a new way'. This factor structure is inconsistent with the aim of our current study. We therefore adopted Chiou and Liang's (2012) revised COLS questionnaire (COLS-R) that deemed the conceptions of memorizing and understanding as independent factors. Chiou and Liang's (2012) COLS-R, based on the findings from Taiwanese students, demonstrated satisfactory validity and reliability of each sub-scale with statistical evidence. We therefore assume that the COLS-R should be sensitive enough to probe the conceptions of students situated in the Taiwanese education system. In this study, the two sub-scales of 'Memorizing' and 'Understanding' were especially applied to measure university students' naïve/sophisticated conceptions of learning. Two science education researchers in this study validated the scales with the consideration of participants' different academic levels from a previous study by Chiou and Liang (2012). The applied version of the 2 scales included 15 items (8 for memorizing and 7 for understanding). All the items were on a five-point Likert scale that ranged students' agreement from 'strongly disagree' to 'strongly agree'. Based on the definitions, the two conceptions regard learning are:

(1) Memorizing. Learning science denotes cram memorization of scientific contents. A sample item is 'Learning biology means memorizing the important concepts found in the biology textbook.'
(2) Understanding. Learning science denotes building personal comprehension of the learning contents. A sample item is 'Learning in biology-related curricula is to enhance my comprehension of biological knowledge.'

In order to precisely investigate the students' self-efficacy for learning, researchers have suggested more specific measures regarding varied dimensions of self-efficacy (Çapa Aydın & Uzuntiryaki, 2009; Lin & Tsai, 2013b; Pajares, 1996). Instead of applying measurement with one unified construct of self-efficacy, this study adopted Lin and Tsai's (2013b) multi-dimensional questionnaire, namely the SLSE questionnaire, to explore university students' BLSE. In Lin and Tsai's study, the researchers conducted a factor analysis to confirm the construct validity of the SLSE questionnaire. They also reported the satisfactory reliability (Cronbach's alpha = .97) of the instrument. Overall, the SLSE questionnaire was developed to probe students' self-efficacy in terms of five dimensions that respectively comprised of five to eight items.

Since the participants in the current study were different from those in Lin and Tsai's investigation (2013b), the same two professors in science education hence reexamined the appropriateness of the items to establish the expert validity. The applied version of the questionnaire included 32 items. All the items were presented on a five-point Likert scale showing respondents' opinions from 'strongly diffident' to 'strongly confident'. The definitions and sample items of the five dimensions are described as follows:

(1) Conceptual understanding: Students' self-confidence in their ability to learn to understand the definitions of science concepts, laws, or theories. A sample item regarding this dimension is 'I am able to explicitly describe the definition of basic scientific concepts such as photosynthesis.'
(2) Higher-order cognitive skills: Students' self-confidence in their ability to learn to apply more sophisticated cognitive skills including scientific inquiry, problem-solving, or critical thinking. A sample item is 'When I come across a biology problem, I will actively think over it first and devise a strategy to solve it.'
(3) Practical work: Students' self-confidence in their ability to learn to conduct practical activities in science such as scientific experiments or laboratory operations. A sample item is 'I know how to set up equipment for laboratory experiments.'

(4) Everyday application: Students' self-confidence in their ability to learn to apply the science content in daily life. A sample item is 'I am able to explain everyday life by using biological theories.'
(5) Science communication: Students' self-confidence in their ability to learn to communicate or discuss with others. A sample item is 'I am able to use what I have learned about biology to discuss with others.'

Data Collection

The data collection of this study was accomplished with printed surveys. Invitations were first distributed to the potential participants (i.e. university students with biology-related majors in Taiwan) through email, telephone calls, and face to face requests. This made sure that all the participants volunteered to take part in and to respond to the questionnaires. At the beginning of the surveys, the university students were informed of the aim of this study and the purposes of the questionnaires. In the questionnaires, we only addressed the intention to investigate university students' perspectives and confidence about learning biology. Also, we explained the students' right to withdraw from participation before they answered the surveys.

Data Analysis

The data analysis of this study was threefold. First, we determined whether the data were appropriate to perform an exploratory factor analysis through Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. The exploratory factor analysis was then conducted to examine the factor structure of the scales of 'Memorizing' and 'Understanding' in the COLS-R as well as the SLSE questionnaire. Acceptable levels of construct validity in the two questionnaires were identified in the previous studies (Chiou & Liang, 2012; Lin & Tsai, 2013b). Therefore, the factor analysis in this study majorly aimed at maximizing the dispersion of loading onto factors within a simple and interpretable structure. To this end, as recommended by Gorsuch (1983), Kaiser (1958), as well as by Fraser, Aldridge, and Adolphe (2010), we applied principle component analysis with orthogonal (varimax) rotation to reveal meaningful clusters of factors from the results of the questionnaires. In order to justify the appropriateness of parametric analysis on the results from Likert scales (Carifio & Perla, 2007; Dawis, 1987; Knapp, 1990), we have also carefully examined the distribution of the data and revealed the skewness and kurtosis. Second, the patterns of the students' conceptions of 'Memorizing' and 'Understanding' were revealed by the analysis of non-hierarchical clustering using the K-means method (Lorr, 1983). To examine the difference in conceptions of 'Memorizing' and 'Understanding', an analysis of variance (ANOVA) was conducted on the responses of students in different clusters. If significant main effects were found, we applied pair-wise *post hoc* tests with the least significant difference (LSD) method to determine where the significant differences were. Third, the clusters of students'

SLSE were compared by ANOVA with *post hoc* tests using the LSD method. This was expected to further unveil the connections between the students' conceptions of 'Memorizing' and 'Understanding' and self-efficacy for learning biology.

Results and Discussion

Exploratory Factor Analysis of the Questionnaires

In this study, we performed the exploratory factor analysis to identify the construct validity of the applied questionnaires. We performed principal component analysis with varimax rotation to extract the existing factors in these research tools. Items categorized as a certain factor with a factor loading of less than .50 were eliminated. Besides, items cross-loaded on different factors with a loading larger than .50 were also omitted from the questionnaire.

Table 1 shows the results of the exploratory factor analysis on the students' conceptions of memorizing and understanding in learning science. The KMO value was .87 and the result of Bartlett's test was significant ($\chi^2 = 2030.79, p < .001$), indicating that the samples were appropriate for factor analysis. A total of 13 items were retained and loaded on the 2 expected factors of 'Memorizing' (7 items) and 'Understanding' (6 items). A full list of the items is shown in Appendix 1. The total variance explained of the items was 61.98%. For the overall reliability, the Cronbach's alpha value was .80. The alpha values of the 2 sub-scales were .88 and .89. According to West, Finch, and Curran (1995), the revealed values of skewness (at least less than

Table 1. Rotated factor loadings, Cronbach's alpha values, skewness, and kurtosis of the modified questionnaire of COLS

	Factor 1: Memorizing	Factor 2: Understanding
Factor 1: Memorizing, $\alpha = .88$, skewness ranged from $-.52$ to .52, kurtosis ranged from $-.81$ to $-.40$		
Memorizing1	.81	
Memorizing2	.78	
Memorizing3	.84	
Memorizing4	.85	
Memorizing5	.74	
Memorizing6	.75	
Memorizing7	.52	
Factor 2: Understanding, $\alpha = .89$, skewness ranged from -1.17 to $-.43$, kurtosis ranged from $-.04$ to 2.37		
Understanding1		.75
Understanding2		.81
Understanding3		.76
Understanding4		.79
Understanding5		.89
Understanding6		.85

Note: Overall Cronbach's α:.80. Total variance explained: 61.98%.

2) and kurtosis (at least less than 7) in Table 1 suggested normal distribution of the data. The results indicated the satisfactory level of construct validity and internal consistency of this modified questionnaire. Also, it was suitable to measure the university students' conceptions of learning biology.

The results of the factor analysis of the SLSE questionnaire are shown in Table 2. The KMO value (.95) and the result of Bartlett's test ($\chi^2 = 5329.27$, $p < .001$) suggested the suitability of conducting factor analysis on the surveyed responses. A

Table 2. Rotated factor loadings, Cronbach's alpha values, skewness, and kurtosis of the BLSE questionnaire

	Factor 1: HC	Factor 2: EA	Factor 3: SC	Factor 4: PW
Factor 1: BLSE-HC, $\alpha = .89$, skewness ranged from $-.74$ to $-.25$, kurtosis ranged from $-.24$ to 1.31				
BLSE-HC1	.57			
BLSE-HC2	.55			
BLSE-HC3	.76			
BLSE-HC4	.70			
BLSE-HC5	.67			
BLSE-HC6	.73			
Factor 2: BLSE-EA, $\alpha = .89$, skewness ranged from $-.70$ to $-.26$, kurtosis ranged from $-.19$ to 1.24				
BLSE-EA1		.56		
BLSE-EA2		.57		
BLSE-EA3		.67		
BLSE-EA4		.55		
BLSE-EA5		.83		
BLSE-EA6		.79		
BLSE-EA7		.51		
BLSE-EA8		.59		
Factor 3: BLSE-SC, $\alpha = .91$, skewness ranged from $-.93$ to $-.44$, kurtosis ranged from $-.08$ to 1.92				
BLSE-SC1			.65	
BLSE-SC2			.53	
BLSE-SC3			.71	
BLSE-SC4			.67	
BLSE-SC5			.80	
BLSE-SC6			.79	
Factor 4: BLSE-PW, $\alpha = .89$, skewness ranged from $-.63$ to $-.41$, kurtosis ranged from $-.04$ to .63				
BLSE-PW1				.57
BLSE-PW2				.71
BLSE-PW3				.68
BLSE-PW4				.76
BLSE-PW5				.71
BLSE-PW6				.57
BLSE-PW7				.55

Note: Overall Cronbach's α:.96. Total variance explained: 63.68%.

total of 27 items were retained from the original version of the questionnaire with 32 items. A full list of the items in the final version of the SLSE questionnaire is presented in Appendix 2. The 27 items were categorized into the following factors: higher-order cognitive skills (BLSE-HC), everyday application (BLSE-EA), science communication (BLSE-SC), and practical works (BLSE-PW). The total variance explained was 63.68%. The range of skewness and kurtosis of all the items (Table 2) indicated normal distribution of the data. The reliability coefficients (Cronbach's alpha) of the factors in the SLSE questionnaire were .89, .89, .91, and .89, respectively. For the whole questionnaire, the alpha value achieved .96 and represented sufficient reliability to assess the BLSE of university students with biology-related majors.

It was notable that the process of validation of the SLSE questionnaire categorized the items with only four factors in spite of the original five-factor structure. The analysis individually loaded the items of HC, EA, SC, and PW onto the expected factors. However, the items of 'Conceptual learning (CL)' were eliminated. The removal of the items regarding CL was due to the concerns of low reliability and cross-loading on different factors. For example, in the preliminary stage of factor analysis, we found that the item 'I am able to interpret figures and tables with science-related content' was cross-loaded on both the factors of SC and PW with a loading larger than .50. This was quite reasonable because both the SC and PWs in science more or less involved the conceptualization of figures and tables with science-related content. As a result, omitting the items in the CL factor would ensure more reasonable construct and satisfactory reliability of the SLSE questionnaire.

The results indicated the difficulties of separating the CL from the other factors in the students' self-efficacy for learning biology. Such difficulties were not found in the previous studies that developed the SLSE questionnaire mainly with the responses of high school students (Lin & Tsai, 2013a, 2013b). This implied that the advanced learners such as the university students with biology-related majors in this study, have already integrated their CL in HCS, EA, SC, and PW. Moreover, high school students, at least in Taiwan, generally learn different subject domains in science including biology, physics, chemistry, and earth science. The high school students might answer each item of the SLSE questionnaire with their impression of the varied subject domains of science. Such a finding also echoed the domain-specific feature of students' self-efficacy for learning (Bandura, 1997; Buehl & Alexander, 2001; Quinnell, May, & Peat, 2012). As a result, this study validated an adequate questionnaire to measure students' BLSE.

Students' Learning Biology as Memorizing and as Understanding

According to the results of the descriptive analysis, the mean of the university students' 'Memorizing' was 2.79 (SD = .54, ranging from 1.67 to 5.00) while their mean for 'Understanding' was 4.23 (SE = .78, ranging from 1.00 to 5.00). Obviously, the university students scored their 'Understanding' higher than neutral in the five-point Likert scale. Such results indicated that university biology majors possessed higher level/more sophisticated conceptions while learning biology. This implied that the students generally viewed 'Understanding' as a necessary process in learning biology. The findings also concurred with the surveyed results in a previous investigation (Chiou et al., 2012). Students' higher level conceptions of learning were closely related to their intrinsic motivation and meaningful strategies for learning (Chiou et al., 2012; Klatter et al., 2001; Prosser & Trigwell, 1999). The students' conceptions of understanding might hence trigger their success in biology learning. Moreover, conceptions of learning were critically based on learners' experiences in learning (Entwistle & Peterson, 2004; Klatter et al., 2001). Therefore, the students' positive notion regarding learning by understanding could in part associate with their successful experiences in learning biology.

Also, students' conceptions of memorizing might result from their successful experiences. In Taiwan, as in many other Asian countries, students have been situated in an educational system with a test-oriented culture for decades (Dahlin & Watkins, 2000; Shih, 2005; Yang, 2004). In most cases, rote learning helped them to pass the tests that mainly aimed at reproducing factual knowledge. Such 'successful experiences' accordingly consolidated some students' conceptions of learning by memorizing. Nevertheless, the direction of development of high-stakes assessment in Taiwan such as university entrance examinations has gradually changed in recent years. More attention was paid to evaluating students' achievement in line with higher level cognitive competence such as reasoning or application of the content knowledge (Chang, Chang, & Yang, 2009). Students who simply relied on memorizing the subject content might have encountered difficulties and failed to perform well in such nationwide examinations. Cram memorization of learning contents no longer acted as the only useful strategy for learning. Instead, students might have realized the importance of building true understanding of the learning contents.

Further analysis of non-hierarchical clustering based on the participants' conceptions of memorizing and understanding in learning biology yielded four clusters of students with varied patterns of the two conceptions. Table 3 gives the descriptive results of the four clusters of students. The four clusters' mean scores of memorizing ranged from 2.03 (cluster 4) to 3.58 (cluster 1). As for their conception of understanding, the mean scores ranged from 3.35 (cluster 3) to 4.42 (cluster 2).

An ANOVA of the students' conception of 'Memorizing' revealed a significant difference among the four clusters ($F = 177.81$, $p < .001$). The clusters of students also significantly differed in their conception of 'Understanding' ($F = 96.70$, $p < .001$). Therefore, we conducted a series of *post hoc* tests using the LSD method to examine the differences between any two groups. As presented in Table 3, the results indicated that the students in cluster 1 (Mixed cluster) showed high scores for their conceptions of both memorizing and understanding. The students in cluster 2 (Understanding cluster) focused more on their conception of understanding, while the students in cluster 3 (Memorizing cluster) addressed memorization in biology learning. The rest of the students (cluster 4: Passive cluster) had lower scores in both the conceptions than the overall means. A possible explanation was that these students tended to passively receive the taught knowledge in learning biology rather than actively memorizing or understanding the learning contents.

Table 3. The clustered participants' conceptions of 'Memorizing' and 'Understanding' in learning biology

Cluster	Memorizing (mean, SD)	Understanding (mean, SD)
Overall ($N = 293$)	2.79 (.54)	4.23 (.78)
(1) Mixed cluster ($N = 95$)	3.58 (.44)	4.41 (.38)
(2) Understanding cluster ($N = 141$)	2.30 (.48)	4.42 (.38)
(3) Memorizing cluster ($N = 31$)	3.29 (.44)	3.35 (.51)
(4) Passive cluster ($N = 26$)	2.03 (.51)	3.59 (.28)
F (ANOVA)	177.81***	96.70***
LSD test	(1) > (3) > (2) > (4)	(1) > (4) > (3) (2) > (3) (2) > (4)

***$p < .001$.

The aforementioned findings indicated that some students' ideas about memorizing and understanding might co-exist as a 'mixed-conception' to support their academic learning. A possible reason for the development of the students' 'mixed-conceptions' of learning biology was rooted in the nature of this knowledge system. Science is commonly deemed as an abstract, difficult, and complicated knowledge system (Novak, 2005; Stern & Roseman, 2004; Ward & Wandersee, 2002). Especially, biology comprises a considerable amount of factual knowledge (Momsen et al., 2010; Myant & Williams, 2008; Wandersee et al., 2000). It might be reasonable that students' 'mixed-conceptions' of learning biology helped them to memorize the biology content and further contributed to their deeper understanding of such knowledge. Moreover, as previous investigations have addressed, the focus on memorizing factual knowledge in undergraduate biology courses has existed for a long time (Barsoum et al., 2013; Momsen et al., 2010; Wood, 2009). The domain-specific learning context might also reinforce students' beliefs about memorizing in their 'mixed-conceptions' of learning biology. Taken together, the university students with biology-related majors in Taiwan perceived the importance of understanding in the process of learning biology, yet some of them believed that memorizing might coordinate with their understanding.

University Biology-related Majors' Multi-dimensional Self-efficacy for Biology Learning

The descriptive results of the participants' BLSE are given in Table 4. Generally, the results indicated that the four clusters of university students showed rather high BLSE in the overall questionnaire (mean ranged from 3.36 to 3.83). The students also rated their self-efficacy with respect to the four factors higher than neutral (BLSC-HC, mean ranged from 3.23 to 3.75; BLSE-EA, mean ranged from 3.33 to 3.87; BLSE-SC, mean ranged from 3.41 to 3.83; BLSE-PW, mean ranged from 3.41 to 3.85).

ANOVA for the participants' BLSE revealed the significant differences among the four groups of students (BLSE-Overall: $F = 9.28, p < .001$; BLSE-HC: $F = 7.90, p < .001$;

Table 4. The clustered participants' BLSE

Cluster	BLSE-overall (mean, SD)	BLSE-HC (mean, SD)	BLSE-EA (mean, SD)	BLSE-SC (mean, SD)	BLSE-PW (mean, SD)
Overall ($N = 293$)	3.70 (.59)	3.58 (.70)	3.75 (.60)	3.70 (.73)	3.73 (.66)
(1) Mixed cluster ($N = 95$)	3.70 (.59)	3.53 (.72)	3.80 (.56)	3.68 (.76)	3.75 (.68)
(2) Understanding cluster ($N = 141$)	3.83 (.53)	3.75 (.62)	3.87 (.57)	3.83 (.69)	3.85 (.60)
(3) Memorizing cluster ($N = 31$)	3.37 (.64)	3.23 (.69)	3.40 (.65)	3.41 (.80)	3.41 (.65)
(4) Passive cluster ($N = 26$)	3.36 (.53)	3.28 (.72)	3.33 (.49)	3.44 (.64)	3.41 (.68)
F (ANOVA)	9.28***	7.90***	11.03***	4.35**	6.46***
LSD test	(1) > (3)	(2) > (1) > (3)	(1) > (3)	(2) > (3)	(1) > (3)
	(1) > (4)	(2) > (4)	(1) > (4)	(2) > (4)	(1) > (4)
	(2) > (3)		(2) > (3)		(2) > (3)
	(2) > (4)		(2) > (4)		(2) > (4)

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

$^{***}p < .001$.

BLSE-EA: $F = 11.03, p < .001$; BLSE-SC: $F = 4.35, p < .01$; BLSE-PW: $F = 6.46, p < .001$). Therefore, we consecutively conducted a series of *post hoc* tests using the LSD method to determine where the significant differences were. The results of the *post hoc* tests are given in Table 4. The students in the Mixed cluster and Understanding cluster rated their overall BLSE, BLSE-EA, and BLSE-PW significantly higher than those in the Memorizing and Passive clusters. However, there was no significant difference between the Mixed and Understanding clusters in the overall BLSE, BLSE-EA, and BLSE-PW. As for the BLSE-SC scale, no significant difference was found between the Mixed cluster and each of the other clusters. However, the students in the Understanding cluster showed significantly higher BLSE-SC than those in the Memorizing and Passive clusters. The only significant difference between the students in the Mixed and Understanding clusters was found in the BLSE-HC scale. The Understanding cluster students performed better on this scale than those in the Mixed cluster. The students in the Understanding cluster also showed significantly higher BLSE-HC than those in the Memorizing and Passive clusters. Students in the Memorizing and Passive clusters showed no significant difference in all the scales.

The comparative results of BLSE between students in the Mixed and Understanding clusters indicated that either their conception of understanding alone or their mixed conceptions of memorizing and understanding are associated with high confidence in learning biology. It was noteworthy that students in both of these clusters presented stronger self-belief in learning biology with understanding than the students in the Memorizing and Passive clusters. Learning biology with the conception of understanding was therefore a major factor that positively associated with students'

BLSE. The conception of understanding might have especially fostered students' confidence in accomplishing learning tasks that required more sophisticated cognitive competence such as BLSE-HC and BLSE-SC (Table 4). To attain students' self-efficacy to scientifically communicate, which requires them to discuss, explain, or debate in learning science, higher-order thinking skills were crucial (Chang et al., 2011; Chowning, Griswold, Kovarik, & Collins, 2012; Sadler, 2009). It was reasonable that the students' BLSE-SC to some extent was aligned with their BLSE-HC.

The results were also consistent with the previous research findings that students who possessed higher-level COLS showed higher self-efficacy for learning science (Lin & Tsai, 2013a; Tsai et al., 2011). Past studies in this line indeed pay much attention to higher-level COLS. For example, researchers have commonly aggregated the conceptions of learning regarding 'Understanding' and 'Seeing in a new way' as a single factor (Chiou et al., 2012; Lee et al., 2008; Lin & Tsai, 2013a). Tsai et al. (2011) further perceived conceptions of 'Increase of knowledge', 'Applying', and 'Understanding and seeing in a new way' as a unity of 'Higher-level conceptions of learning science'. However, the findings in this study provided an extra insight that naturally different conceptions such as memorizing and understanding might work in parallel to support students' learning in biology.

Since the surveyed participants in this study were all university students with similar majors in the field of biology, learning of this subject domain should be highly associated with their daily life. The findings in this study indicated that learning biology with understanding to some extent helped the students to transfer and apply the school science to their everyday experience. Besides, understanding might have motivated the students' confidence in daily scientific practices such as observation or manipulation in laboratory experiments. As for the students in the Mixed cluster, their conception of memorizing could form together with the purpose of achieving understanding. As suggested by Kember (1996), the intention to learn both by memorizing and understanding lead to students' approaches to learning distinct from a surface approach such as rote learning. Memorization of learning contents seemed to help the students retrieve and employ corresponding knowledge to afford meaningful comprehension regarding learning in daily life and laboratory works (Anderson & Schönbornx, 2008; Cobern, Gibson, & Underwood, 1999; Lee, Lai, Yu, & Lin, 2012). By contrast, the students who deemed learning biology as memorizing rather than as understanding (Memorizing cluster) were less self-confident of their success in the authentic contexts of biology learning. In light of the students' BLSE about EA and PWs, the conception of memorizing was profitable to biology learning only with the coexistence of the conception of understanding.

Conclusions and Implications

The study was designed to explore the university students' conceptions of memorizing and understanding in learning biology and their learning self-efficacy. The reliability and validity of the modified questionnaire (Chiou & Liang, 2012) that specifically focused on students' conceptions of memorizing and understanding were confirmed.

The results from the exploratory factor analysis also identified the valid factors in the multi-dimensional BLSE questionnaire. The cluster analysis based on the participants' conceptions of memorizing and understanding successfully categorized their patterns of viewing the learning in biology. The two major clusters of students either regarded learning simply through understanding or possessed mixed-conceptions of memorizing and understanding in the learning process. Both the patterns (with the conception of understanding alone or with the mixed-conceptions of memorizing and understanding) of university students positively associated with their high BLSE. The other two clusters of students simply focused on their learning biology by memorizing or passively receiving the learning contents. The BLSE of the students in these two clusters was comparatively lower.

This study clarified the relationships among students' conceptions of memorization and understanding in learning biology as well as their BLSE. In light of the aforementioned findings, seeking ways to transform students' lower-level conceptions of learning into higher-level ones might be the next challenge for science educators. A recent study compared college students' conceptions of web-based learning and conceptions of learning in general (Tsai, 2009). The researcher concluded that the web-based environment had the potential to promote students' learning with real understanding. This implied that the application of innovative technologies in instruction might strengthen students' higher-level conceptions of learning. Based on this notion, Lin, Liang, and Tsai (2012) conducted an experimental study to examine the effect of the Internet-assisted physiology instruction on university students' conceptions of learning. The findings in the study indicated that the Internet-assisted instruction fostered students' conceptions of learning. Future studies are suggested to integrate technologies in instruction or in learning to enhance students' conceptions of learning biology or other subject domains in science.

Besides, this study identified two domain-specific questionnaires to survey university students majoring in the biology-related subject domain. In accordance with the domain-specific and task-dependent feature of conceptions of and self-efficacy for learning, it seemed more appropriate to apply customized research tools to investigate science-major students. However, the relationships between these two factors regarding learning in other scientific subject domains, including physics, chemistry, and earth science, still remain unclear. The research approach and findings of this study could inspire future investigations to develop corresponding tools to explore the psychological features regarding learning from students with other academic majors.

The findings of this study also indicated that the students' self-efficacy for learning science majorly related to their conception of understanding. A mixture of higher-level conceptions (understanding) and lower-level conceptions (memorizing) was also found to associate with the students' confidence in biology learning. Future investigations in this line are therefore suggested to further unveil whether there are other higher-level and lower-level conceptions working in coordination to support science learning. Science educators can also extend the findings of students' BLSE in this study to explore possible sources (Bandura, 1997; Usher & Pajares, 2008) of such domain-specific self-efficacy. As to further verifying and confirming the findings of this study, a variety of research methods such as qualitative and mixed methods may also be useful to thoroughly depict students' BLSE and their conceptions of memorizing and understanding in learning biology in future research.

Finally, this study revealed that a cluster of students with biology-related majors indeed deemed learning biology as memorizing simultaneously with understanding. This was consistent with previous studies situated in the context of Chinese culture that especially argued for students' coordination of these two conceptions while facing assessments (Kember, 2000; Marton et al., 2005). As previously mentioned, this might be attributed to the 'test-oriented' culture and the design of biology education programs. The findings may suggest that policy-makers in those countries with a similar educational context should pay more attention to the direction of the development of high-stakes assessment. High-stakes assessment could be a critical factor fostering the development of students' conceptions of meaningful learning. Stakeholders in higher education are also recommended to arrange more adaptive biology education programs to afford students' learning needs when students have distinct viewpoints about the nature of learning. It may be a limitation of this study that we only investigated Taiwanese students rather than exploring students in countries with similar or different cultures. Future research with cross-national comparisons would provide more insights into the cultural impacts on students' conceptions of learning and self-efficacy for learning.

Acknowledgement

This research work was supported by the Ministry of Science and Technology (MOST), Taiwan, under the grant number MOST 103-2511-S-011-004-MY2, NSC 101-2628-S-011-001-MY3, and NSC 100-2511-S-011-004-MY3.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Anderson, T. R., & Schönborn, K. J. (2008). Bridging the educational research-teaching practice gap. Conceptual understanding, part 1: The multifaceted nature of expert knowledge. *Biochemistry and Molecular Biology Education*, *36*(4), 309–315.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191–215.

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

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice- Hall.

Bandura, A. (1993). Perceived self-efficacy in cognitive development and functioning. *Educational psychologist*, *28*(8), 117–148.

Badura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (1996). Multifaceted impact of self-efficacy beliefs on academic functioning. *Child Development*, *67*(3), 1206–1222.

Baldwin, J. A., Ebert-May, D., & Burns, D. J. (1999). The development of a college biology self-efficacy instrument for nonmajors. *Science Education*, *83*(4), 397–408.
Barsoum, M. J., Sellers, P. J., Campbell, A. M., Heyer, L. J., & Paradise, C. J. (2013). Implementing recommendations for introductory biology by writing a new textbook. *CBE-Life Sciences Education*, *12*(1), 106–116.
Biggs, J. (1994). Approaches to learning: Nature and measurement of. In T. Husen & T. N. Postlethwaite (Eds.), *The international encyclopedia of education* (2nd ed., Vol. 1, pp. 318–322). Oxford: Pergamon Press.
Bong, M. (2001). Between- and within-domain relations of academic motivation among middle and high school students: Self-efficacy, task value, and achievement goals. *Journal of Educational Psychology*, *93*(1), 23–34.
Bong, M. (2004). Academic motivation in self-efficacy, task value, achievement goal orientations, and attributional beliefs. *Journal of Educational Research*, *97*(6), 287–297.
Bong, M., & Skaalvik, E. M. (2003). Academic self-concept and self-efficacy: How different are they really? *Educational Psychology Review*, *15*(1), 1–40.
Brownlee, J., Purdie, N., & Boulton-Lewis, G. (2003). An investigation of student teachers' knowledge about their own learning. *Higher Education*, *45*(1), 109–125.
Buehl, M. M., & Alexander, P. A. (2001). Beliefs about academic knowledge. *Educational Psychology Review*, *13*(4), 385–418.
Çapa Aydın, Y., & Uzuntiryaki, E. (2009). Development and psychometric evaluation of the high school chemistry self-efficacy scale. *Educational and Psychological Measurement*, *69*(5), 868–880.
Carifio, J., & Perla, R. J. (2007). Ten common misunderstandings, misconceptions, persistent myths and urban legends about Likert scales and Likert response formats and their antidotes. *Journal of Social Sciences*, *3*(3), 106–116.
Chang, C. Y., Chang, Y. H., & Yang, F. Y. (2009). Exploring secondary science teachers' perceptions on the goals of earth science education in Taiwan. *International Journal of Science Education*, *31*(17), 2315–2334.
Chang, H. P., Chen, C. C., Guo, G. J., Cheng, Y. J., Lin, C. Y., & Jen, T. H. (2011). The development of a competence scale for learning science: Inquiry and communication. *International Journal of Science and Mathematics Education*, *9*(5), 1213–1233.
Chiou, G. L., & Liang, J. C. (2012). Exploring the structure of science self-efficacy: A model built on high school students' conceptions of learning and approaches to learning in science. *The Asia-Pacific Education Researcher*, *21*(1), 83–91.
Chiou, G. L., Liang, J. C., & Tsai, C. C. (2012). Undergraduate students' conceptions of and approaches to learning in biology: A study of their structural models and gender differences. *International Journal of Science Education*, *34*(2), 167–195.
Chowning, J. T., Griswold, J. C., Kovarik, D. N., & Collins, L. J. (2012). Fostering critical thinking, reasoning, and argumentation skills through bioethics education. *PLOS ONE*, *7*(5), e36791.
Cobern, W. W., Gibson, A. T., & Underwood, S. A. (1999). Conceptualizations of nature: An interpretive study of 16 ninth graders' everyday thinking. *Journal of Research in Science Teaching*, *36*(5), 541–564.
Dahlin, B., & Watkins, D. (2000). The role of repetition in the processes of memorising and understanding: A comparison of the views of German and Chinese secondary school students in Hong Kong. *British Journal of Educational Psychology*, *70*(1), 65–84.
Dart, B. C., Burnett, P. C., Purdie, N., Boulton-Lewis, G., Campell, J., & Smith, D. (2000). Students' conceptions of learning, the class environment, and approaches to learning. *Journal of Educational Research*, *93*(4), 262–270.
Dawis, R. V. (1987). Scale construction. *Journal of Counseling Psychology*, *34*(4), 481–489.
Entwistle, N. J., & Peterson, E. R. (2004). Conceptions of learning and knowledge in higher education: Relationships with study behaviour and influences of learning environments. *International Journal of Educational Research*, *41*(6), 407–428.

Fraser, B. J., Aldridge, J. M., & Adolphe, F. S. G. (2010). A cross-national study of secondary science classroom environments in Australia and Indonesia. *Research in Science Education*, *40*(4), 551–571.

Gorsuch, R. L. (1983). *Factor analysis* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Grunert, M. L., & Bodner, G. M. (2011). Finding fulfillment: Women's self-efficacy beliefs and career choices in chemistry. *Chemistry Education Research and Practice*, *12*(4), 420–426.

Hazel, E., Prosser, M., & Trigwell, K. (2002). Variation in learning orchestration in university biology courses. *International Journal of Science Education*, *24*(7), 737–751.

Kaiser, H. F. (1958). The varimax criterion for analytic rotation in factor analysis. *Psychometrika*, *23*(3), 187–200.

Kember, D. (1996). The intention to both memorise and understand: Another approach to learning? *Higher Education*, *31*(3), 341–354.

Kember, D. (2000). Misconceptions about the learning approaches, motivation and study practices of Asian students. *Higher Education*, *40*(1), 99–121.

Klatter, E. B., Lodewijks, H. G. L. C., & Aarnoutse, C. A. J. (2001). Learning conceptions of young students in the final year of primary education. *Learning and Instruction*, *11*(6), 485–516.

Knapp, T. R. (1990). Treating ordinal scales as interval scales: An attempt to resolve the controversy. *Nursing Research*, *39*(2), 121–123.

Lawson, A. E., Banks, D. L., & Logvin, M. (2007). Self-efficacy, reasoning ability, and achievement in college biology. *Journal of Research in Science Teaching*, *44*(5), 706–724.

Lee, M. H., Johanson, R. E., & Tsai, C. C. (2008). Exploring Taiwanese high school students' conceptions of and approaches to learning science through a structural equation modeling analysis. *Science Education*, *92*(2), 191–220.

Lee, S. W. Y., Lai, Y. C., Yu, H. T. A., & Lin, Y. T. K. (2012). Impact of biology laboratory courses on students' science performance and views about laboratory courses in general: Innovative measurements and analyses. *Journal of Biological Education*, *46*(3), 173–179.

Lin, T. J., & Tsai, C. C. (2013a). An investigation of Taiwanese high school students' science learning self-efficacy in relation to their conceptions of learning science. *Research in Science and Technological Education*, *31*(3), 308–323.

Lin, T. J., & Tsai, C. C. (2013b). A multi-dimensional instrument for evaluating Taiwanese high school students' science learning self-efficacy in relation to their approaches to learning science. *International Journal of Science and Mathematics Education*, *11*(6), 1275–1301.

Lin, Y. H., Liang, J. C., & Tsai, C. C. (2012). Effects of different forms of physiology instruction on the development of students' conceptions of and approaches to science learning. *Advances in Physiology Education*, *36*(1), 42–47.

Lorr, M. (1983). *Cluster analysis for social scientists: Techniques for analyzing and simplifying complex blocks of data*. San Francisco: Jossey-Bass.

Martin, A. J., & Dowson, M. (2009). Interpersonal relationships, motivation, engagement, and achievement: Yields for theory, current issues, and educational practice. *Review of Educational Research*, *79*(1), 327–365.

Marton, F. M., Dall'Alba, G., & Beaty, E. (1993). Conceptions of learning. *International Journal of Educational Research*, *19*(3), 277–299.

Marton, F. M., & Säljö, R. (1976). On qualitative differences in learning II: Outcome as a function of the learner's conception of the task. *British Journal of Educational Psychology*, *46*(2), 115–127.

Marton, F. M., Watkins, D., & Tang, C. (1997). Discontinuities and continuities in the experience of learning: An interview study of high-school students in Hong Kong. *Learning and Instruction*, *7*(1), 21–48.

Marton, F. M., Wen, Q., & Wong, K. C. (2005). 'Read a hundred times and the meaning will appear ...' Changes in Chinese University students' views of the temporal structure of learning. *Higher Education*, *49*(3), 291–318.

Momsen, J. L., Long, T. M., Wyse, S. A., & Ebert-May, D. (2010). Just the facts? Introductory undergraduate biology courses focus on low-level cognitive skills. *CBE-Life Sciences Education*, *9*(4), 435–440.

Myant, K. A., & Williams, J. M. (2008). What do children learn about biology from factual information? A comparison of interventions to improve understanding of contagious illnesses. *British Journal of Educational Psychology*, *78*(2), 223–244.

Novak, J. D. (2005). Results and implications of a 12-year longitudinal study of science concept learning. *Research in Science Education*, *35*(1), 23–40.

O'Brien, V., Martinez-Pons, M., & Kopala, M. (1999). Mathematics self-efficacy, ethnic identity, gender, and career interests related to mathematics and science. *Journal of Educational Research*, *92*(4), 231–235.

Pajares, F. (1996). Self-efficacy beliefs in academic settings. *Review of Educational Research*, *66*(4), 543–578.

Phillips, J. M., & Gully, S. M. (1997). Role of goal orientation, ability, need for achievement, and locus of control in the self-efficacy and goal-setting process. *Journal of Applied Psychology*, *82*(5), 792–802.

Pintrich, P. R., & Schunk, D. H. (2002). *Motivation in education: Theory, research and applications*. Ohio: Merrill Prentice Hall.

Prosser, M., & Trigwell, K. (1999). *Understanding learning and teaching: The experience in higher education*. Buckingham: Society for Research into Higher Education/Open University Press.

Quinnell, R., May, E., & Peat, M. (2012). Conceptions of biology and approaches to learning of first year biology students: Introducing a technique for tracking changes in learner profiles over time. *International Journal of Science Education*, *34*(7), 1053–1074.

van Rossum, E. J., & Schenk, S. M. (1984). The relationship between learning conception, study strategy and learning outcome. *British Journal of Educational Psychology*, *54*(1), 75–83.

Sadler, T. D. (2009). Situated learning in science education: Socio-scientific issues as contexts for practice. *Studies in Science Education*, *45*(1), 1–42.

Säljö, R. (1979). *Learning in the learner's perspective I: Some commonsense conceptions*. Report from the Institute of Education, University of Cambridge, No. 76.

Shell, D. F., Colvin, C., & Brunning, R. H. (1995). Self-efficacy, attributions, and outcome expectancy mechanisms in reading and writing achievement: Grade-level and achievement level differences. *Journal of Educational Psychology*, *87*(3), 386–398.

Shih, S. S. (2005). Role of achievement goals in children's learning in Taiwan. *Journal of Educational Research*, *98*(5), 310–319.

Stern, L., & Roseman, J. E. (2004). Can middle-school science textbooks help students learn important ideas? Findings from project 2061's curriculum evaluation study: Life science. *Journal of Research in Science Teaching*, *41*(6), 538–568.

Tavakol, M., & Dennick, R. (2010). Are Asian international medical students just rote learners? *Advances in Health Sciences Education: Theory and Practice*, *15*(3), 369–377.

Thomas, G., Anderson, D., & Nashon, S. (2008). Development of an instrument designed to investigate elements of science students' metacognition, self-efficacy and learning processes: The SEMLI-S. *International Journal of Science Education*, *30*(13), 1701–1724.

Tsai, C. C. (2004). Conceptions of learning science among high school students in Taiwan: A phenomenographic analysis. *International Journal of Science Education*, *26*(14), 1733–1750.

Tsai, C. C. (2006). 'Biological knowledge is more tentative than physics knowledge': Taiwan high school adolescents' views about the nature of biology and physics. *Adolescence*, *41*(164), 691–703.

Tsai, C. C. (2009). Conceptions of learning versus conceptions of web-based learning: The differences revealed by college students. *Computers & Education*, *53*(4), 1092–1103.

Tsai, C. C., Ho, H. N. J., Liang, J. C., & Lin, H. M. (2011). Scientific epistemic beliefs, conceptions of learning science and self-efficacy of learning science among high school students. *Learning and Instruction*, *21*(6), 757–769.

Usher, E. L., & Pajares, S. (2008). Sources of self-efficacy in school: Critical review of the literature and future directions. *Review of Educational Research*, *78*(4), 751–796.

Uzuntiryaki, E., & Çapa Aydın, Y. (2009). Development and validation of chemistry self- efficacy scale for college student. *Research in Science Education*, *39*(4), 539–551.

Velayutham, S., & Aldridge, J. M. (2013). Influence of psychosocial classroom environment on students' motivation and self-regulation in science learning: A structural equation modeling approach. *Research in Science Education*, *43*(2), 507–527.

Walker, C., Greene, B., & Mansell, R. (2006). Identification with academics, intrinsic/extrinsic motivation, and self-efficacy as predictors of cognitive engagement. *Learning and Individual Differences*, *16*(1), 1–12.

Wandersee, J. H., & Fisher, K. M. (2000). Knowing biology. In J. H. Wandersee, K. M. Fisher, & D. E. Moody (Eds.), *Mapping biology knowledge* (pp. 39–54). Dordrecht: Kluwer.

Wandersee, J. H., Fisher, K. M., & Moody, D. E. (2000). The nature of biology knowledge. In J. H. Wandersee, K. M. Fisher, & D. E. Moody (Eds.), *Mapping biology knowledge* (pp. 25–38). Dordrecht: Kluwer.

Ward, R. E., & Wandersee, J. H. (2002). Struggling to understand abstract science topics: A roundhouse diagram-based study. *International Journal of Science Education*, *24*(6), 575–591.

West, S. G., Finch, J. F., & Curran, P. J. (1995). Structural equation models with nonnormal variables: Problems and remedies. In R. H. Hoyle (Ed.), *Structural equation modeling: Concepts, issues and applications* (pp. 56–75). Newbery Park, CA: Sage.

Wood, W. B. (2009). Revising the AP biology curriculum. *Science*, *325*(5948), 1627–1628.

Yang, H. J. (2004). Factors affecting student burnout and academic achievement in multiple enrollment programs in Taiwan's technical-vocational colleges. *International Journal of Educational Development*, *24*(3), 283–301.

Yang, Y. F., & Tsai, C. C. (2010). Conceptions of and approaches to learning through online peer assessment. *Learning and Instruction*, *20*(1), 72–83.

Zeldin, A. L., Britner, S. L., & Pajares, F. (2008). A comparative study of the self-efficacy beliefs of successful men and women in mathematics, science, and technology careers. *Journal of Research in Science Teaching*, *45*(9), 1036–1058.

Zimmerman, B. J. (2000). Self-efficacy: An essential motive to learn. *Contemporary Education Psychology*, *25*(1), 82–91.

Appendix 1 The Modified Questionnaire of COLS

Memorizing1. Learning biology means memorizing the definitions, formulae, and laws found in the biology textbook.

Memorizing2. Learning biology means memorizing the important concepts found in the biology textbook.

Memorizing3. Learning biology means memorizing the proper nouns found in the biology textbook that can help answer the teacher's questions.

Memorizing4. Learning biology means remembering what the teacher lectures about in biology class.

Memorizing5. Learning biology means memorizing biological symbols, biological concepts, and facts.

Memorizing6. In learning biology, just like in learning history or geography, the most important thing is to memorize the content of the textbook.

Memorizing7. When learning biology, I need to memorize the biological definitions and formulae well or I will forget them.

Understanding1. Learning biology is to solve or explain the problems and phenomena I have no idea about.

Understanding2. Learning in biology-related curricula is to enhance my comprehension of biological knowledge.

Understanding3. Learning in biology-related curricula is to understand the meanings of scientific laws and formulae.

Understanding4. Learning biology can improve my comprehension and understanding of some problems I could not solve before.

Understanding5. Learning biology can expand my knowledge and experiences.

Understanding6. Learning biology can make me understand more natural phenomena and knowledge.

Appendix 2 The BLSE Questionnaire

BLSE-HC1. I am able to critically evaluate the solutions of biology problems.

BLSE-HC2. I am able to design biology experiments to verify my hypotheses.

BLSE-HC3. I am able to propose many viable solutions to solve a biology problem.

BLSE-HC4. When I come across a biology problem, I will actively think over it first and devise a strategy to solve it.

BLSE-HC5. I am able to make systematic observations and inquiries based on a specific biology concept or biological phenomenon.

BLSE-HC6. When I am exploring a biological phenomenon, I am able to observe its changing process and think of possible reasons behind it.

BLSE-EA1. I am able to explain everyday life by using biological theories.

BLSE-EA2. I am able to propose solutions to everyday problems by using biology.

BLSE-EA3. I can understand the news/documentaries I watch on television related to biology.

BLSE-EA4. I can recognize the careers related to biology.
BLSE-EA5. I am able to apply what I have learned in school science (biology) to daily life.
BLSE-EA6. I am able to use scientific methods (i.e. in biology) to solve problems in everyday life.
BLSE-EA7. I can understand and interpret social issues related to biology (e.g. genetically modified foods) in a scientific manner.
BLSE-EA8. I am aware that a variety of phenomena in daily life involve biology-related concepts.
BLSE-SC1. I am able to comment on presentations made by my classmates in class regarding biology.
BLSE-SC2. I am able to use what I have learned about biology to discuss with others.
BLSE-SC3. I am able to clearly explain what I have learned to others.
BLSE-SC4. I feel comfortable discussing biology content with my classmates.
BLSE-SC5. In classes regarding biology, I can clearly express my own opinions.
BLSE-SC6. In classes regarding biology, I can express my ideas properly.
BLSE-PW1. I know how to carry out experimental procedures in the biology laboratory.
BLSE-PW2. I know how to use equipment (for example measuring cylinders, measuring scales, etc.) in the biology laboratory.
BLSE-PW3. I am able to recognize the data in the biology experiments.
BLSE-PW4. I know how to set up equipment for laboratory experiments.
BLSE-PW5. I know how to collect data during the science laboratory.
BLSE-PW6. I know how to create an experimental report according to research data.
BLSE-PW7. I am able to understand the relationships among variables according to research data.