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### Undergraduate Students' Conceptions of and Approaches to Learning in Biology: A study of their structural models and gender differences

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## RESEARCH REPORT

# Undergraduate Students' Conceptions of and Approaches to Learning in Biology: A study of their structural models and gender differences

Guo-Li Chiou<sup>a</sup>, Jyh-Chong Liang<sup>b</sup> and Chin-Chung Tsai<sup>c\*</sup>

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This study reports the findings of a study which examined the relationship between conceptions of learning and approaches to learning in biology. This study, which used structural equation modelling, also sorted to identify gender differences in the relationship. Two questionnaires, the Conceptions of Learning Biology (COLB) and the Approaches to Learning Biology (ALB), were developed to investigate 582 undergraduate biology majors' (275 females and 307 males) conceptions of and approaches to learning biology, respectively. The results indicate a general trend that, while the students possessing lower-level COLB, 'Memorizing', 'Testing', and 'Calculating and Practising', tend to adopt a surface approach to learning in biology, the students expressing higher-level conceptions, 'Increasing one's knowledge', 'Application', and 'Understanding and seeing in a new way', are more likely to adopt a deep approach to learning in biology. This study also found several salient gender differences in the COLB, as well as in the way in which the COLB affected the ALB. For example, female students tended to express more sophisticated COLB than male students. The 'Memorizing' conception of learning biology held by male students is inclined to engender both deep motive and deep strategy, but this tendency was not found among the female students.

**Keywords:** *Biology education; Learning; University*

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## Introduction

Among the factors that may be attributed to students' academic performance, their conceptions of learning and approaches to learning are considered to be two crucial and closely related factors (Biggs, Kember, & Leung, 2001; Dart et al., 2000). Although there have been many studies investigating students' conceptions of learning (e.g., Marton, Dall'Alba, & Beaty, 1993; Säljö, 1979) and their learning approaches (e.g., Biggs, 1987; Biggs et al., 2001) since the 1980s, few of these have focused specifically on the relationship between these two factors and on a distinct content domain, such as physics or biology. Given that students' conceptions of learning are domain-specific (Buehl & Alexander, 2001; Tsai, 2004), and biology is a unique and substantial learning discipline in the science domain (Tsai, 2006; Wandersee, Fisher, & Moody, 2000), we argue that it is important for science educators to investigate students' conceptions of learning and approaches to learning in biology. Accordingly, this study was, first, to validate two instruments of assessing students' conceptions of learning and approaches to learning in biology, and then explored the structural relationship between these two constructs. Moreover, since gender has been recognized as an important factor in science learning (e.g., Becker, 1986; Kahle & Meece, 1994), this study also aimed to examine the gender difference in students' conceptions of learning and in their approaches to learning in biology.

### *Research on Conceptions of Learning*

In general, a conception of learning refers to an individual's understanding or belief about learning. Given that this is a personal construction built upon an individual's actual learning experience (Entwistle & Peterson, 2004), researchers have used the so-called 'phenomenographic' method to investigate people's qualitatively different conceptualizations of their learning experiences (e.g., Marton et al., 1993; Säljö, 1979; Tsai, 2004). For example, by interviewing 90 participants about their learning experiences and their conceptualizations of learning, Säljö (1979) identified five categories of conceptions of learning: (1) an increase of knowledge, (2) memorizing, (3) an acquisition of facts or principles, (4) an abstraction of meaning, and (5) an interpretive process aimed at understanding reality. In Marton et al.'s (1993) consecutive longitudinal study, they identified a sixth category, 'changing as a person', and argued that these six categories could represent most people's conceptions of learning. Also, Marton et al. proposed that students' conceptions of learning in terms of the six categories appear to show a developmental and hierarchical trend. That is, a mature learner's conception of learning might have originated as the first category and then subsequently moved toward the sixth category; any former category might be hierarchically subsumed by the latter, consecutive one. Some studies (e.g., Lin & Tsai, 2008; Tsai, 2004) also found that when responding to the interview questions about conceptions of learning, most of the participants used more than one previous category to express their ideas of learning at the same time.

However, among the categories mentioned by any individual participant, one category, but not necessarily the most sophisticated one, might serve as a dominant concept to coordinate the others (Lin & Tsai, 2008; Tsai, 2004). Based on the discussion above, there might be a developmental component to conceptions of learning as well as an experiential component. Therefore, an individual can hold multiple conceptions of learning even if she/he has already constructed a more sophisticated view beyond the naïve one.

Moreover, the previous six categories can be divided into two groups based on their different features of conceptualizing learning. For example, in agreement with Säljö (1979), Marton et al. (1993) argued that in the first three categories (i.e., an increase of knowledge, memorizing, and an acquisition of facts or principles), learning is conceived as a passive accumulation of external fragmentary information. In contrast, in the last three categories (i.e., an abstraction of meaning, an interpretive process aimed at understanding reality, and changing as a person), learning involves an active transformation of external information into meaningful, understandable, and applicable knowledge. While different researchers prefer different terminologies to describe these dichotomized groups, such as lower level/higher level (Dart et al., 2000) and reproducing/transforming (Brownlee, Purdie, & Boulton-Lewis, 2003), the essence of these two groups appears to be similar. To avoid confusion with the terms used in approaches to learning in the next section, this study will use lower-level view and higher-level view (Dart et al., 2000; Tsai, 2004) to denote these two broad categories of conceptions of learning.

Since conceptions of learning are experience-dependent, different learning experiences of different subject domains may result in different conceptions of learning. Tsai (2004) thus claimed that conceptions of learning should be domain-specific, and conducted a phenomenographic study to investigate high-school students' conceptions of learning 'science'. Based on the students' responses to the interview questions, Tsai (2004) identified two distinct conceptions of learning science, 'preparing for tests' and 'calculating and practising tutorial problems', in addition to Säljö's (1979) five categories. Tsai (2004) further suggested that the identified conceptions of learning science could be divided into two broad groups. The first is a lower-level one, which includes 'Memorizing', 'Testing', and 'Calculating and Practising'. The second is a higher-level one, which includes 'Increasing one's knowledge', 'Applying', 'Understanding', and 'Seeing in a new way'. This categorization was confirmed by a large-sample study by Lee, Johanson, and Tsai (2008). Obviously, most of these categories of learning science originate from the students' school learning experiences. Tsai (2004) thus further proposed that conceptions of learning in a specific domain could be referred to as academic domain-specific epistemological beliefs, given that students' learning experiences are usually school-based, domain-subjective, and knowledge-related. Currently, studies on students' learning in various disciplines also illustrate this domain-specific nature of conceptions of learning, such as in mathematics (Reid, Wood, Smith, & Petocz, 2005) and engineering (Lin & Tsai, 2009; Marshall, Summer, & Woolnough, 1999).

Based on Tsai's (2004) suggestion that conceptions of learning are domain-specific, our understanding of students' conceptions of learning science can be enhanced by investigating these conceptions in a specific science domain. Although Tsai's (2004) study was especially designed to elicit students' conceptions of learning science, it provided no clue as to what 'science' the participants referred to when they were answering the interview questions. For example, in an attempt to find out the differences between students' views of the nature of biology and physics, Tsai (2006) indicated that students believe that biology is more tentative than physics. Therefore, to gain a deeper understanding of how students learn various scientific domains, we should move forward to explore their conceptions of learning in a more specific discipline, such as biology in this study. In particular, college science education involves finer differentiations among science disciplines; hence, a better understanding regarding the science students in higher education by discipline (such as biology) is necessary.

### *Research on Approaches to Learning*

Students' approaches to learning refer to 'the way in which students go about their academic work' (Biggs, 1994). This construct originated from the attempt to explain why learners achieve different outcomes after studying the same learning materials (Biggs, 2001; Gibbs, Morgan, & Taylor, 1982; Marton & Säljö, 2005). Traditionally, there have been two major types of evidence in addressing this issue (Biggs et al., 2001). The first has involved the phenomenographic method, from which people's learning processes can be directly elicited by the introspections of their own learning experiences. For example, in Marton and Säljö's (1976a) seminal study, they first asked the participants to read some given material, and then not only examined the participants' learning outcomes, but also evoked the participants' reflections on how they processed the material in interviews. The authors indicated that the participants who failed to get the point of the material did so just because they did not attempt to process it. Furthermore, the authors identified two qualitatively different processes which the participants adopted to learn the materials: surface-level and deep-level processes. The participants who adopted the surface-level approach focused only on memorizing the isolated information in the text. In contrast, the participants who adopted the deep-level approach tried to understand the text by searching for the relations between the text and their prior knowledge or between different parts of the text.

The second type addressed the previously mentioned issue by searching for appropriate constructs and scales to measure learning processes. For example, through conducting a series of studies using factor analyses (Biggs, 1978, 1987; Biggs et al., 2001; Kember, Biggs, & Leung, 2004), Biggs and his colleagues found two major approaches to learning, the surface and the deep approach. The surface approach is related to extrinsic motivation (such as fear of failure and passing an examination), and uses lower-level cognitive activities, e.g. rote learning, to memorize the fragmentary bits of knowledge. In contrast, the deep approach is associated

with intrinsic motivation (such as inner interest and self-satisfaction), and aims to pursue a thorough understanding of the main ideas and principles involved in the learning material.

Apparently, the results of the two different types of approaches to learning share some common features. First of all, they both assume that individual differences in learning outcomes might result from their different learning processes. Second, they both apply the surface/deep dichotomy to distinguish different approaches to learning. More importantly, the essence of the identified surface and deep approaches is similar in both types of study. That is, the critical difference between the surface and deep approaches lies in whether an individual actively creates meaning out of the learning material. Last but not least, they propose that approaches to learning include two main components: strategy and motive. While the strategy component represents the actual process engaged in a learning task, the motive component denotes the orientation, or motivation, to perform a specific learning task. Moreover, this dual component may result in multiple motive–strategy combinations of approaches to learning. For example, an individual may have a deep, intrinsic motivation, while adopting a surface, rote process to tackle a specific task. In brief, these commonalities denote the characteristics of the construct of approaches to learning.

However, the essence of the deep and the surface approaches to learning varies widely across different disciplines (Ramsden, 1992). For example, in mathematics, the surface approaches to learning may refer to the processes of repeatedly calculating and following an algorithm, while in biology, the surface approaches to learning may refer to the processes of matching the name of a specific species with its distinct features. Ramsden further argues that the differences in the approaches to learning in different disciplines may be related to the ways in which the specialists in different disciplines conduct their work, and to how students conceive the special demands of different subject areas based on their experiences. Although some researchers in the field of science education have started to tackle this issue (e.g., Lee et al., 2008; Liang & Tsai, 2010), they concentrated only on students' approaches to learning in a broad content domain, science. Given that the natures of different disciplines in the field of science, such as physics, chemistry, and biology, are different (Tsai, 2006), there would be merit in exploring students' approaches to learning in different scientific disciplines. Based on this premise, this study planned to focus specifically on students' ALB.

### *Relationships between Conceptions of and Approaches to Learning*

The relationships between students' conceptions of learning and their approaches have attracted many researchers' attention since the 1980s. For example, in van Rossum and Schenk's (1984) study, they first used an open-ended questionnaire to investigate 60 psychology students' conceptions of learning, then they asked them to read an article and, afterward, to report how they approached the reading task. With respect to both the conceptions of learning and approaches to learning, the categories identified by van Rossum and Schenk were similar to those found by Säljö



(1979) and Marton and Säljö (1976a) mentioned above. In addition, van Rossum and Schenk indicated that the students' lower-level conceptions of learning were closely linked to their surface approaches to learning. In contrast, the students' higher-level conceptions of learning were highly related to their deep approaches to learning. Similar results have also been found in other subsequent studies, such as Dart et al. (2000), Edmunds and Richardson (2009), Ferla, Valcke, and Schuyten (2008), Lee et al. (2008), and Minasian-Batmanian, Lingard, and Prosser (2006).

Although the nature of the relationship between conceptions and approaches to learning is still unclear, some researchers (e.g., Edmunds & Richardson, 2009; Marton & Sajlo, 2005) suggest that it could be a causal one. That is, students' conceptions of learning may affect their approaches to learning. This causal relationship appears to be promising given that how people perform a task (approaches to learning) partially depends on their understanding of performing that task (conceptions of learning). Based on this hypothesis, the present study, via a structural equation modelling (SEM) technique, attempted to examine the possible causal relationship between conceptions of learning and approaches to learning using biology as the learning discipline.

#### *Gender Issues in Approaches to Learning*

Whether gender plays a role in students' approaches to learning remains an unclear issue. On the one hand, several studies have indicated that there is no significant gender difference in students' approaches to learning (e.g., Miller, Finley, & McKinley, 1990; Richardson, 1993; Wilson, Smart, & Watson, 1996). On the other hand, among those studies which have indicated that gender does play a significant role, some have found that females score higher on surface approaches compared to males (e.g., Sadler-Smith, 1996; Severiens & ten Dam, 1998), while the others claim that females score higher for deep approaches (e.g., Gledhill & van Der Merwe, 1989). Addressing this in more depth, Duff (2002) proposed that gender differences in approaches to learning appear to be more salient at the scale level of related instruments. After reviewing related studies, Duff summarized that, while females are more likely to score higher on fear of failure (a surface motive) and relating ideas (a deep strategy), males have more chance of scoring higher on extrinsic motivation. However, Hayes and Richardson (1995) argued that gender differences in approaches to learning might depend on the learning discipline and context. For example, they found that female students who took courses in a more male environment scored higher on deep approaches than did male students, but other female students who took science courses in a female only environment obtained similar scores on deep approaches compared to the male students in other schools. Thus, to tackle gender issues in approaches to learning, focusing on both a specific learning discipline and the different levels of approaches to learning appears to be a promising start.

Some research studies (e.g., Miller, Blessing, & Schwartz, 2006; Trumper, 2006) have indicated that female students are more likely to have a greater interest in



biology than male students, whereas they have less interest in other science disciplines such as physics. This finding provided an inspiration for us to move forward to examine whether gender differences exist in students' ALB. Moreover, as mentioned above, given that there is a close relationship between students' approaches to learning and their conceptions of learning, it is also fruitful to explore the gender differences in COLB.

### *Research Purposes*

This present study focused on the structural relationships between undergraduate students' conceptions of learning and approaches to learning in biology. However, although the quantitative research approach that uses questionnaires as the main instruments has been an established way to investigate students' conceptions of learning and approaches to learning (Biggs et al., 2001; Lee et al., 2008; Peterson, Brown, & Irving, 2010; Purdie, Hattie, & Douglas, 1996), there have been almost no questionnaires specifically designed to measure undergraduate students' COLB and ALB. Therefore, this study, first, was to validate two instruments modified from previous studies (Lee et al.'s, 2008; Liang, Lee, & Tsai, 2010) to assess undergraduate biology students' COLB and ALB. It then moved on to examine the relationship between the students' COLB and ALB by using the method of SEM. Last, this study tested whether gender differences exist in students' COLB, in their ALB and in the structural relationships between these two constructs.

## **Method**

### *Participants*

The participants in this study included 582 undergraduate students (275 males and 307 females) from 10 different universities in Taiwan. These universities were across different geographical regions and different types of schools (such as research university, teaching university, and technological university). All of the students were biology-related majors (such as life science, biological science, and biological technology), and had taken a series of biology-related courses before participating in this study. Their ages ranged from 18 to 31, and the average age was 20.21. The average ages of the male and female students were 20.25 ( $SD = 1.48$ ) and 20.16 ( $SD = 1.29$ ), respectively, and the result of a *t*-test showed that there was no significant age difference between the male and the female groups ( $t = 0.85, p > 0.05$ ).

### *Measures*

To investigate the students' COLB, this study developed a survey, Conceptions of Learning Biology (COLB; see Appendix 1), which was modified from Lee et al.'s (2008) and Liang and Tsai's (2010) surveys, which aims to probe college students' conceptions of learning science. Since both Lee et al.'s (2008) and Liang and Tsai's

(2010) surveys were rooted in findings from a phenomenographic study conducted in Taiwan (i.e., Tsai, 2004), we believe the COLB was sensitive to Taiwanese culture, and thus could adequately measure Taiwanese college students' COLB. For example, the survey included the conception, 'learning as preparing for tests', which may be unique in Taiwan socio-cultural environments. This response was found by Taiwan university students across different majors or subject domains (Lin & Tsai, 2008, 2009).

Two experts in science education and one biology university lecturer examined the content of all the questionnaire items, providing expert validity for the survey. Six university biology majors (from freshmen to senior) were invited to examine the wording of the questionnaire items. A pilot study collecting questionnaire responses from approximately 150 university students was undertaken to initially appraise the appropriateness of using the subscales and items. A few question items were reworded and removed on the basis of the results of the pilot study. Following the procedure above, the questionnaire developed by Lee et al. (2008) and Liang and Tsai (2010) was slightly modified. The six subscales in the final COLB are described below:

- (1) *Memorizing*: Learning biology is conceptualized as the memorization of definitions, formulae, laws, and special terms.
- (2) *Testing*: Learning biology is to pass the examinations or to achieve high scores in biology tests.
- (3) *Calculating and practising*: Learning biology is viewed as a series of calculating, practising tutorial problems, and manipulating formulae and numbers.
- (4) *Increasing one's knowledge*: An increase of knowledge is seen as the main feature of learning biology.
- (5) *Applying*: The purpose of learning biology is the application of received knowledge.
- (6) *Understanding and seeing in a new way*: A true understanding is viewed as a major feature of learning biology; also biology learning is characterized in terms of getting a new perspective.

These six subscales represent students' COLB in a hierarchical framework, from the lower to the higher levels. It is worth mentioning that, 'Calculating and Practising' is also identified as a crucial subscale in the COLB because many college-level biology courses require students to conduct calculating and practising, such as in the courses of bioanalytical method, biotechnology laboratory, and biostatistics. Each of the COLB subscales includes six to eight items, and each item uses a seven-point Likert mode, ranging from strongly disagree (seven points) to strongly agree (one point). According to the findings by Lee et al. (2008) and Liang and Tsai (2010), the first three factors refer to the reproductive-oriented (lower-level), less sophisticated conceptions of learning, while the last three factors refer to the constructive-oriented (higher-level), more sophisticated conceptions of learning.

In addition, to explore the students' ALB, this study developed another instrument, Approaches to Learning Biology (ALB; see Appendix 2), by modifying

Kember et al.'s (2004), Lee et al.'s (2008), and Liang et al.'s (2010) survey which was designed to probe college students' ALB. In fact, the survey, Approaches to Learning Science, by university science majors, validated by Laing et al. (2010) via factor analyses, was the prototype for this study, as it was designed for Taiwan university science-major students, a similar target sample of this study. Again, two experts in science education and one biology university lecturer appraised the content of all questionnaire items, providing expert validity for the ALB. Six university biology majors were chosen to appraise the items of the questionnaire. A pilot study gathering questionnaire responses from around 150 university biology students was conducted to examine the suitability of using the subscales and items. A few question items were re-worded and removed as a result of the pilot study. Based on the above procedure, the questionnaire constructed by Lee et al. (2008) and Liang et al. (2010) was modified to fit the needs of this study.

The ALB includes four subscales to represent Biggs et al.'s (2001) deep and surface approaches in terms of both the predisposition and the process components, respectively. These four subscales are described below:

- (1) *Deep motive*: Students show their intrinsic motivation while learning biology, such as learning biology driven by their curiosity and own interest.
- (2) *Deep strategy*: Students utilize more meaningful strategies to learn biology, such as making connections and coherent understanding.
- (3) *Surface motive*: Students possess extrinsic motivation to learn biology, such as learning biology for course grades or others' expectations.
- (4) *Surface strategy*: Students use more rote-like strategies (such as remembering or narrowing targets) to learn biology.

Previous studies (Lee et al., 2008; Liang et al., 2010) suggest that these subscales capture Taiwanese science students' learning approaches. Each subscale in the ALB has six to eight items, and each item is also rated on a seven-point Likert scale, ranging from *strongly disagree* (seven points) to *strongly agree* (one point).

#### *Data Collection*

The questionnaire was distributed to the students with the permission of the 10 universities. The researchers contacted the university biology-related departments and administered the questionnaires on site. The students in this study volunteered to respond to the questionnaires. These students answered the two questionnaires at the same time anonymously. Before responding to the questionnaires, each student was invited to read the cover page of the questionnaires that addressed the aim and importance of this study, and informed her/his right to withdrawal.

#### *Data Analysis*

This study first used exploratory factor analysis to respectively examine the factor structure of the COLB questionnaire and the ALB survey. The correlations between

the COLB and ALB factors were analysed. Then, the structural relationships between the factors of the COLB and those of the ALB were evaluated via SEM analysis. The COLB factors were considered as predictor (exogenous) variables, whereas the ALB were deemed as outcome (endogenous) variables. To examine gender differences in the COLB and ALB, *t*-tests were conducted. Then, similar correlations and SEM analyses were undertaken for the female and male student samples, respectively. The female and male SEM models were compared to find gender differences in the way in which the COLB factors might have effects on the ALB factors.

## Results

### *Exploratory Factor Analyses of the COLB and ALB*

The results of the exploratory factor analysis for the COLB questionnaire are shown in Table 1. This study adopted principal component analysis as the extraction method, and used the rotation method of varimax with Kaiser normalization. The factor loading of each item weighed greater than 0.4 on the relevant factor and less than 0.4 on the non-relevant factors in the COLB. Therefore, a total of 37 items were kept in the final version of the COLB (full list items in Appendix 1) and were grouped into the following six factors: ‘Memorizing’, ‘Testing’, ‘Calculating and Practising’, ‘Increasing one’s knowledge’, ‘Application’, and ‘Understanding and seeing in a new way’ (as shown in Table 1). The alpha coefficients of each scale were 0.91, 0.93, 0.93, 0.91, 0.89, and 0.94, respectively, and the overall alpha coefficient was 0.90. These coefficients indicate that the COLB has a sufficient level of internal consistency. In addition, the total variance explained in the COLB is 71.98%.

Table 2 shows the exploratory factor analysis results for the ALB. Similar to the COLB, the ALB used a factor loading greater than 0.4 for retaining the items. Thus, 28 items were kept in the final version of the ALB (full list items in Appendix 2), and the total variance explained is 62.34%. The alpha coefficients of each scale were 0.92, 0.92, 0.85, and 0.86, and the overall alpha coefficient was 0.89, which indicates a satisfactory level of internal consistency.

### *The Correlation between Conceptions of Learning Biology and Approaches to Learning Biology*

To explore the relationships between the students’ COLB and their ALB, we calculated the Pearson’s correlation coefficients between the COLB factors and the ALB factors. As shown in Table 3, on the one hand, statistically significantly positive correlations exist between the three lower-level factors in the COLB, ‘Memorizing’, ‘Testing’, and ‘Calculating and Practising’, and the two surface-level factors in the ALB, ‘Surface Motive’ and ‘Surface Strategy’ (coefficients *r* ranging from 0.11 to 0.58, *p* < 0.05). There are statistically significant negative

Table 1. Rotated factor loadings, Cronbach's alpha values, factor means, and SDs for the six factors of the Conception of Learning Biology (COLB) survey

	Factor 1: Memorizing	Factor 2: Testing	Factor 3: CP	Factor 4: IK	Factor 5: Application	Factor 6: US
Factor 1: Memorizing; $\alpha = 0.91$ ; mean = 4.04; SD = 1.10						
Memorizing 1	0.677					
Memorizing 2	0.832					
Memorizing 3	0.788					
Memorizing 4	0.839					
Memorizing 5	0.797					
Memorizing 6	0.667					
Memorizing 7	0.549					
Factor 2: Testing; $\alpha = 0.93$ ; mean = 3.34; SD = 1.24						
Testing 1		0.708				
Testing 2		0.684				
Testing 3		0.716				
Testing 4		0.702				
Testing 5		0.678				
Testing 6		0.724				
Testing 7		0.653				
Factor 3: Calculating and practising (CP); $\alpha = 0.93$ ; mean = 3.34; SD = 1.28						
CP 1			0.706			
CP 2			0.765			
CP 3			0.779			
CP 4			0.767			
CP 5			0.822			
CP 6			0.790			
Factor 4: Increasing one's knowledge (IK); $\alpha = 0.91$ ; mean = 5.32; SD = 0.94						
IK 1				0.738		
IK 2				0.813		
IK 3				0.771		
IK 4				0.784		
IK 5				0.731		
Factor 5: Application; $\alpha = 0.89$ ; mean = 5.09; SD = 0.88						
Application 1					0.796	
Application 2					0.770	
Application 3					0.786	
Application 4					0.664	
Application 5					0.737	
Application 6					0.589	
Factor 6: Understanding and seeing in a new way (US); $\alpha = 0.94$ ; mean = 5.46; SD = 0.91						
US 1						0.584
US 2						0.730
US 3						0.721
US 4						0.726
US 5						0.720
US 6						0.700

Note. Overall alpha: 0.90; and the total variance explained: 71.98%.

Table 2. Rotated factor loadings, Cronbach's alpha values, factor means, and SDs for the four factors of the Approaches to Learning Biology (ALB) survey

	Factor 1: Deep Motive	Factor 2: Deep Strategy	Factor 3: Surface Motive	Factor 4: Surface Strategy
Factor 1: Deep Motive; $\alpha = 0.92$ ; mean = 4.89; SD = 0.89				
Deep Motive 1	0.711			
Deep Motive 2	0.748			
Deep Motive 3	0.816			
Deep Motive 4	0.815			
Deep Motive 5	0.771			
Deep Motive 6	0.741			
Deep Motive 7	0.769			
Deep Motive 8	0.684			
Factor 2: Deep Strategy; $\alpha = 0.92$ ; mean = 5.10; SD = 0.89				
Deep Strategy 1		0.592		
Deep Strategy 2		0.613		
Deep Strategy 3		0.718		
Deep Strategy 4		0.697		
Deep Strategy 5		0.708		
Deep Strategy 6		0.645		
Factor 3: Surface Motive; $\alpha = 0.85$ ; mean = 4.87; SD = 0.98				
Surface Motive 1			0.749	
Surface Motive 2			0.736	
Surface Motive 3			0.732	
Surface Motive 4			0.637	
Surface Motive 5			0.736	
Surface Motive 6			0.746	
Factor 4: Surface Strategy; $\alpha = 0.86$ ; mean = 3.99; SD = 0.98				
Surface Strategy 1				0.610
Surface Strategy 2				0.700
Surface Strategy 3				0.766
Surface Strategy 4				0.793
Surface Strategy 5				0.557
Surface Strategy 6				0.759
Surface Strategy 7				0.786
Surface Strategy 8				0.621

Note. Overall alpha: 0.89; and the total variance explained: 62.34%.

correlations between 'Testing' and the two factors in the ALB, 'Deep Motive' and 'Deep Strategy' ( $r = -0.22$  and  $-0.28$ , respectively,  $p < 0.05$ ), and between 'Calculating and Practising' and 'Deep Strategy' ( $r = -0.17$ ,  $p < 0.05$ ). Moreover, positive correlations can be identified between the three higher-level factors in the COLB, 'Increasing Knowledge', 'Application', and 'Understanding and seeing in a

Table 3. Correlations among the factors between the COLB and the ALB

	Memorizing	Testing	CP	IK	Application	US
Deep Motive	0.02	-0.22*	-0.05	0.43*	0.57*	0.56*
Deep Strategy	-0.02	-0.28*	-0.17*	0.52*	0.52*	0.66*
Surface Motive	0.21*	0.11*	0.15*	0.36*	0.39*	0.39*
Surface Strategy	0.49*	0.58*	0.50*	-0.09*	-0.05	-0.17*

\* $p < 0.05$ .

Note. CP, calculating and practising; IK, increasing one's knowledge; and US, understanding and seeing in a new way.

new way', and the three factors in the ALB, 'Deep Motive', 'Deep Strategy', and 'Surface Motive' (coefficients  $r$  ranging from 0.36 to 0.66,  $p < 0.05$ ). Also, significant negative correlations exist between 'Increasing Knowledge' and 'Surface Strategy' ( $r = -0.09$ ,  $p < 0.05$ ), and between 'Understanding and seeing in a new way', and 'Surface Strategy' ( $r = -0.17$ ,  $p < 0.05$ ).

#### *The Structural Model of the COLB and ALB*

This study utilized the SEM technique to explore the structural relationships between the six factors in the COLB and the four factors in the ALB. Based on the results from the SEM analysis, the COLB factors were considered as predictors, while the ALB factors were viewed as outcome variables. The indexes of overall fit suggest that the model (Figure 1) fits the data reasonably well ( $\chi^2(6) = 308.11$ , GFI = 0.90, CFI = 0.92, NFI = 0.92, and standardized RMR = 0.059). The model indicates several significant associations between the factors in the COLB and those in the ALB. First, 'Memorizing' has a significant influence on 'Surface Strategy'. Second, while 'Testing' significantly contributes to 'Surface Motive' and 'Surface Strategy', it also significantly suppresses 'Deep Motive' and 'Deep Strategy'. Third, 'Calculating and Practising' serves as a significantly positive predictor to 'Deep Motive', 'Surface Motive', and 'Surface Strategy'. Fourth, 'Increasing one's knowledge' has a significant influence on 'Surface Motive'. Fifth, both 'Application' and 'Understanding' exert a significantly positive effect on 'Deep Motive', 'Deep Strategy', and 'Surface Motive'.

#### *Gender Difference in Conceptions of Learning Biology and Approaches to Learning Biology*

Table 4 shows the female and the male students' mean scores for the factors in the COLB and the ALB, as well as the results of the paired  $t$ -tests for examining the gender differences. Regarding the COLB, both the female and the male students scored lower on the first three lower-level factors, 'Memorizing', 'Testing', and 'Calculating and Practising' (the means range from 3.14 to 4.14) than the last three higher-level factors, 'Increasing Knowledge', 'Application' and 'Understanding and seeing in a new way'



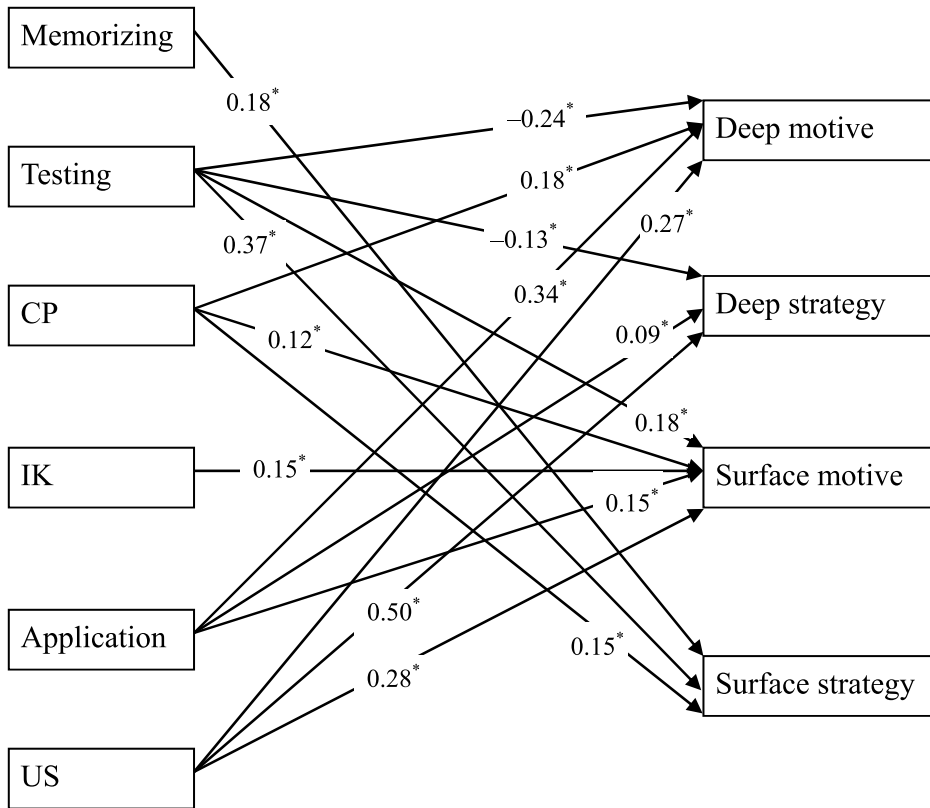


Figure 1. The structural equation model between conceptions of learning biology and approaches to learning biology

\* $p < 0.05$ .

Note. CP, calculating and practising; IK, increasing one's knowledge; and US, understanding and seeing in a new way. Good of fitness indices:  $\chi^2(6) = 308.11$ ; Goodness of Fit Index = 0.90; Comparative Fit Index = 0.92; Normed Fit Index = 0.92; and Standardized RMR = 0.059.

(the means range from 5.08 to 5.55). However, while the male students scored significantly higher on the three lower-level factors, 'Memorizing' ( $t = -2.41, p < 0.05$ ), 'Testing' ( $t = -3.73, p < 0.05$ ) and 'Calculating and Practising' ( $t = -2.32, p < 0.05$ ), the female students scored significantly higher on two of the higher-level factors, 'Increasing Knowledge' ( $t = 2.30, p < 0.05$ ) and 'Understanding and seeing in a new way' ( $t = 2.32, p < 0.05$ ).

In addition, with respect to the ALB, there was no significant difference between the female and the male students' scores on both the 'Deep Motive' and 'Deep Strategy' factors. However, the female students scored significantly higher on the 'Surface Motive' factor ( $t = 2.18, p < 0.05$ ) and significantly lower on the 'Surface Strategy' factor ( $t = -3.00, p < 0.05$ ) than the male students.

Table 4. Analyses of gender differences on the subscales of the COLB and the ALB

	Female (mean, SD)	Male (mean, SD)	<i>t</i> -test
Memorizing	3.92 (1.10)	4.14 (1.10)	-2.41*
Testing	3.14 (1.26)	3.52 (1.20)	-3.73*
Calculating and practising	3.21 (1.27)	3.45 (1.28)	-2.32*
Increasing one's knowledge	5.41 (0.95)	5.23 (0.91)	2.30*
Application	5.10 (0.89)	5.08 (0.87)	0.23
Understanding and seeing in a new way	5.55 (0.89)	5.38 (0.92)	2.32*
Deep Motive	4.91 (0.91)	4.88 (0.86)	0.44
Deep Strategy	5.16 (0.85)	5.05 (0.93)	1.54
Surface Motive	4.96 (1.00)	4.78 (0.96)	2.18*
Surface Strategy	3.86 (0.97)	4.10 (0.97)	-3.00*

\**p* < 0.05.

*Gender Differences in the Correlations between Conceptions of Learning Biology and Approaches to Learning Biology*

The gender differences in the correlations between the COLB and the ALB can be identified by comparing Tables 5 and 6, presenting the correlations of the female and the male students, respectively. While Tables 5 and 6 appear to be similar at first glance, there are some differences between them. For example, Table 6 (males) indicates two significantly positive correlations between 'Memorizing' and 'Deep Motive' (*r* = 0.11, *p* < 0.05) and between 'Testing' and 'Surface Motive' (*r* = 0.16, *p* < 0.05), whereas Table 5 (females) does not verify these two correlations. Moreover, Table 5 points out three significantly negative correlations between 'Increasing Knowledge' and 'Surface Strategy' (*r* = -0.21, *p* < 0.05), between 'Application' and 'Surface Strategy' (*r* = -0.15, *p* < 0.05), and between 'Understanding and seeing in a new way' and 'Surface Strategy' (*r* = -0.27, *p* < 0.05), while Table 6 fails to find these correlations.

Table 5. The correlations among the factors between the COLB and the ALB for female students

	Memorizing	Testing	CP	IK	Application	US
Deep Motive	-0.07	-0.25*	-0.04	0.49*	0.59*	0.57*
Deep Strategy	-0.08	-0.29*	-0.13*	0.59*	0.49*	0.66*
Surface Motive	0.19*	0.10	0.14*	0.36*	0.31*	0.36*
Surface Strategy	0.49*	0.62*	0.52*	-0.21*	-0.15*	-0.27*

\**p* < 0.05.

Note. CP, calculating and practising; IK, increasing one's knowledge; and US, understanding and seeing in a new way.

Table 6. The correlations among the factors between the COLB and the ALB for male students

	Memorizing	Testing	CP	IK	Application	US
Deep Motive	0.11*	-0.20*	-0.06	0.37*	0.56*	0.55*
Deep Strategy	0.05	-0.27*	-0.20*	0.45*	0.54*	0.65*
Surface Motive	0.26*	0.16*	0.18*	0.35*	0.47*	0.40*
Surface Strategy	0.48*	0.53*	0.47*	0.04	0.04	-0.07

\* $p < 0.05$ .

Note. CP, calculating and practising; IK, increasing one's knowledge; and US, understanding and seeing in a new way.

### *Gender Differences in the Structural Models of the COLB and ALB*

Given that there are significant gender differences in the correlations between the COLB and the ALB, this study further utilized the SEM technique to examine the gender differences in the structural models of the COLB and the ALB. That is, the structural models between the COLB and the ALB were conducted respectively for the female and the male student samples, and the differences between these two models were examined. The indexes of overall fit suggest that the two models adequately fit the two datasets: regarding the female model,  $\chi^2(6) = 141.10$ , GFI = .91, CFI = .93, NFI = .93, and standardized RMR = 0.057; with respect to the male model,  $\chi^2(6) = 177.63$ , GFI = .90, CFI = .90, NFI = .90, and standardized RMR = 0.061.

As shown in Table 7, there are some gender differences between the female and the male students' structural models (shown by grey block). First, 'Memorizing' has a significant effect only on the male students' 'Deep Motive' and 'Deep Strategy', but not on the same approaches for the female students. Second, 'Testing' has a significant, negative effect only on the male students' adoption of 'Deep Strategy', but not on that of the female students. Third, while 'Calculating and Practising' influences the male students to have 'Surface Motive' and to adopt the 'Surface Strategy', it has no significant influence on the female students. Fourth, 'Increasing one's knowledge' appears to exert a significant and positive effect only on the female students' 'Deep Motive', 'Deep Strategy', and 'Surface Motive', though none of these effects are significant for the male students. Last, 'Application' has a significant, positive influence on the male students' adoption of the 'Deep Strategy' and the arousal of their 'Surface Motive', but these influences cannot be identified for the female students.

## **Discussion**

### *Conceptions of Learning Biology, Approaches to Learning Biology, and their Relationships*

The two questionnaires developed in this study, the COLB and the ALB, have been shown to be able to adequately investigate students' COLB and ALB, respectively.

Table 7. Gender differences in the structural models of the COLB and the ALB

	Deep Motive		Deep Strategy		Surface Motive		Surface Strategy	
	Female	Male	Female	Male	Female	Male	Female	Male
Memorizing	-0.01	0.17*	-0.02	0.12*	0.03	0.04	0.14*	0.19*
Testing	-0.20*	-0.25*	-0.08	-0.15*	0.24*	0.17*	0.43*	0.32*
CP	0.22*	0.14*	0.12	0.00	0.08	0.14*	0.12	0.18*
IK	0.14*	-0.09	0.23*	-0.02	0.24*	0.06	0.01	0.04
Application	0.35*	0.31*	0.03	0.14*	0.03	0.28*	-0.05	0.00
US	0.20*	0.35*	0.46*	0.52*	0.29*	0.26*	0.00	0.06

\* $p < 0.05$ .

*Note.* CP, calculating and practising; IK, increasing one's knowledge; and US, understanding and seeing in a new way. Good of fitness indices for female students model:  $\chi^2(6) = 141.10$ ; Goodness of Fit Index = 0.91; Comparative Fit Index = 0.93; Normed Fit Index = 0.93; Standardized RMR = 0.057. Good of fitness indices for male students model:  $\chi^2(6) = 177.63$ ; Goodness of Fit Index = 0.90; Comparative Fit Index = 0.90; Normed Fit Index = 0.90; Standardized RMR = 0.061.

With respect to the COLB, the six extracted factors are the same as those obtained by Lee et al. (2008) and Liang and Tsai (2010). As shown in Tables 1 and 4, while the students scored higher on the last three factors, 'Increasing one's knowledge', 'Application', and 'Understanding and seeing a new way', they scored lower on the first three factors, 'Memorizing', 'Testing', and 'Calculating and Practising'. This result reveals that the students prefer to view learning biology from a higher-level perspective rather than a lower-level perspective. Based upon these results, the students tend to possess more sophisticated, higher-level COLB (e.g., Lee et al., 2008; Tsai, 2004). Given that the students in this study were biology-related majors and had studied some advanced courses in biology, this finding concurs with Marton et al.'s (1993) proposal that people's conceptions of learning gradually develop toward being more sophisticated based on their accumulating experience of learning.

With respect to the ALB, the four extracted factors, 'Deep Motive', 'Deep Strategy', 'Surface Motive', and 'Surface Strategy', are the same as those suggested by Kember et al. (2004) and Lee et al. (2008). That is, students' ALB can be categorized as deep and surface approaches, and both approaches have a predisposition (motive) and a process (strategy) component. As shown in Table 2, while the students in this study obtained similar scores on both the 'Surface Motive' and 'Deep Motive', they scored higher on the 'Deep Strategy' than on the 'Surface Strategy'. This result agrees with Zeegers's (2001) finding that more experienced students tend to use deep strategies to process their learning tasks in science. Moreover, the similar scores on the 'Deep Motive' and 'Surface Motive' may reveal the fact that these college-level students do not have a stable, or fixed, predisposition for learning biology. Instead, they might have a dual motivation for learning biology. The students'

motivation for learning biology might depend on the nature and demands of the learning tasks (Biggs, 2001; Marton & Säljö, 2005; Ramsden, 1992). For example, when students' learning loads are heavy or when the learning tasks require only rote-based processes, the surface motive is more likely to be triggered for conducting the related learning tasks. But their selection of biology-related majors may provide some indications for their intrinsic motivation toward learning biology. The students might just have both types of motivations at the same time (Lee et al., 2008). That is, although they might study biology for passing an examination, they might also take advantage of this opportunity to pursue a comprehensive understanding of the learning materials.

The SEM produced by this study supports our hypothesis that students' COLB can be used to predict their ALB. The most salient associations are those between the lower-level/higher-level COLB and surface/deep ALB. That is, lower-level COLB have an effect on the surface approach to learning in biology, and higher-level COLB have an influence on the deep approach to learning in biology. For example, on the one hand, students who possess the two lower-level COLB, 'Testing' and 'Calculating and Practising', tend to have a surface motive and to adopt the surface strategy to learn biology. The students who regard biology as 'Memorizing' also tend to utilize the surface strategy to learn biology. On the other hand, the students who possess the two higher-level COLB, 'Application' and 'Understanding and seeing in a new way', tend to have a deep motive and to adopt the deep strategy for learning biology. These findings confirm the associations identified by earlier studies (e.g., Dart et al., 2000; Edmunds & Richardson, 2009; Ferla et al., 2008; Lee et al., 2008; Minasian-Batmanian et al., 2006; van Rossum & Schenk, 1984). These associations make good sense given that how students approach their learning tasks partially depends on what they know about the learning of the tasks. For example, those students who consider learning biology as memorizing would learn biology directly through the rote processes of rehearsing related facts and principles. Similarly, those students who treat learning biology as understanding would attempt to comprehend the learning materials through relating what they already know to the materials. Therefore, these associations can be used to support both the dichotomies between the lower-level and higher-level COLB, and between the surface and deep ALB.

However, there are some other associations contradicting the 'lower-level versus surface' and the 'higher-level versus deep' relationships between the COLB and the ALB. First, the lower-level conception of learning biology, 'Calculating and Practising', has a significant effect on 'Deep Motive'. Interestingly, the students who possess this conception also tend to have a surface motive and to adopt a surface strategy. That is, although the students who treat learning biology as calculating and practising prefer to engage in biology learning using surface strategies, this conception could trigger both the surface and the deep motive to learn biology. We argue that it is the dual nature of the 'Calculating and Practising' conception that can trigger both of these motives. On the one hand, the students who view learning biology as 'Calculating and Practising' might treat the calculation and practice of biological

questions as a rote process, just like following a standardized set of steps and formulae to obtain the preset answer. In this sense, 'Calculating and Practising' relies more on the repeated memorization of relevant sequences and formulae to solve a biology problem, and thus the students who possess this view tend to learn biology based on an extrinsic pressure such as pass an examination. On the other hand, 'Calculating and Practising' might refer to a process of self-challenging and self-testing. That is, practising diverse tutorial questions could help the students examine whether they could successfully apply related formulae to other questions. In this sense, the students who refer to learning biology as calculating and practising tend to learn biology based on an intrinsic motive, such as achieving a real understanding of the related formulae.

Second, the first higher-level conception of learning biology, 'Increasing one's knowledge', has only one effect on the 'Surface Motive', but not on the 'Deep Motive' and 'Deep Strategy'. As suggested by Tsai (2004) and Lee et al. (2008), viewing learning biology as 'Increasing one's knowledge' also implies a dual perspective. On the one hand, 'Increasing one's knowledge' refers to the acquisition and accumulation of knowledge (Marton et al., 1993), and thus represents a reproductive, lower-level conception of learning biology. On the other hand, 'Increasing one's knowledge' can be conceived as the discovery of what is unknown, and thus shares the essence of a constructive, higher-level conception of learning biology. Under this dual perspective, 'Increasing one's knowledge' does not completely belong to either the lower-level or the higher-level conception of learning biology, a similar finding revealed by Lin and Tsai (2009) for college engineering students' conceptions of learning engineering. Therefore, the surface motive to learn biology might be triggered by the 'lower-level' side of 'Increasing one's knowledge'. That is, the students who view learning biology merely as the accumulation of knowledge tend to learn biology out of an external requirement.

Last, two of the higher-level COLB, 'Application' and 'Understanding and seeing in a new way', have an influence on the 'Surface Motive' in addition to the 'Deep Motive' and 'Deep Strategy'. These SEM results reveal that, although these two COLB can induce the adoption of the deep strategy, the motivation beneath this strategy may not be persistent. As discussed earlier, these two COLB trigger a dual motive. On the one hand, while the students who conceptualize learning biology as 'Application' and 'Understanding and seeing in a new way' tend to adopt the deep strategy to learn biology, they might do this partially just for passing an examination or fulfilling a course requirement. On the other hand, there is also a high probability that they adopt the deep strategy to learn biology out of a deep motivation, given that the learning tasks intrigue the students' intrinsic interest in learning biology.

#### *Gender Differences in the COLB, ALB and their Structural Models*

The results of this study reveal many gender differences in the students' COLB, their ALB, and the structural models inter-relating them in this subject. However,



since few studies have investigated gender differences in Taiwanese students' conceptions to learning and approaches to learning in biology, it is difficult to explain how these were formed. In recognition of this limitation, in the following discussion, we will cautiously use findings about gender differences from studies conducted in other countries to speculate on the underpinning of the gender differences found in this present study.

Regarding the COLB, Table 4 indicates that the male students scored higher on all three of the lower-level COLB, 'Memorizing', 'Testing', and 'Calculating and Practising'. They also scored lower on two higher-level conceptions, 'Increase of knowledge' and 'Understanding and seeing in a new way'. That is, the male students, in general, had less sophisticated COLB than female students. Consequently, it is not surprising to learn that male students had been found to have less favourable academic performance in biology in some large-scale surveys from different countries (e.g., National Center for Education Statistics, 2008; Taiwan College Entrance Examination Center, 2007).

With respect to the ALB, Table 4 indicates two gender differences in the students' surface ALB. On the one hand, the female students scored higher on the 'Surface Motive'. This means that they were more likely to rely on extrinsic motivation to trigger their biology learning, and had a stronger desire to receive better grades than the male students. As suggested by some studies from different countries (e.g., Duff, 2002; Miller et al., 1990), the likelihood of the females' preference for surface motive might be explained by their higher tendency to fear failure. On the other hand, the male students obtained higher scores on the 'Surface Strategy'. As mentioned above, there was a higher possibility for the males to adopt the surface strategy just because they also preferred the lower-level COLB. Moreover, this correlation could serve as another piece of evidence to support the causal relationship between the lower-level COLB and the surface ALB.

Some salient gender differences emerge when making comparisons between the female and the male students' SEMs of the COLB and ALB (Table 7). First, the male students who treated learning biology as 'Memorizing' were more likely to have a deep motive and adopt the deep strategy to learn biology than the female students. As suggested by Marton, Watkins, and Tang (1997), Asian students may treat memorization as fundamental to real understanding; that is, there is a tendency for Asian students to use memorization as a basis of deep strategy. From this perspective, the probable effect of 'Memorization' on the male students' deep strategy might result from their tendency toward adopting memorization as a crucial component of the deep strategy. Furthermore, this tendency might help to form an efficient learning strategy which could provide a deep motive for the male students to learning biology as suggest by van Etten, Pressley, McInerney, and Liem (2008).

Second, there was a higher probability for the male students who possessed the lower-level conception of learning biology, 'Testing', to prohibit the deep strategy. Although there was a general tendency for the conception 'Testing' to induce the 'Surface Approach' and to suppress the 'Deep Approach' for both the female and the male students, this conception had a significantly negative effect on 'Deep Strategy'



only for the male students. That is, if the male students thought learning biology is just for passing a test, they were less likely to adopt the deep strategy for learning biology.

Third, the conception ‘Calculating and Practising’ was more likely to have an influence on ‘Surface Motive’ and ‘Surface Strategy’ for the male than for the female students. The male students who viewed learning biology as ‘Calculating and Practising’ might focus more on the formulae and definitions related to biology and thus tend to tackle corresponding problems by rote. Moreover, focusing on the rote side of the calculations and practices might reinforce these male students to conduct the calculations and practice just for the purpose of passing examinations and gaining better grades. Though conducted in a different country, Meece, Glienke, and Burg’s (2006) findings that male students had higher self-efficacy in learning mathematics could shed light on the reason that only the male students had this tendency to connect ‘Calculating and Practising’ with the surface motive. That is, since the male students had more confidence in their ability to perform calculations and algorithms, once they conceived learning biology as calculating and practising, they just tended to take advantage of their possible strength in mathematics, and thus tended to adopt a surface approach to conducting the required calculating tasks. Of course, this hypothesis needs to be examined by further research.

Fourth, the female students who possessed the ‘Increasing one’s knowledge’ view of learning biology were more likely than the male students to have both the ‘Deep Motive’ and ‘Surface Motive’, and to adopt the ‘Deep Strategy’. As discussed earlier, the conception ‘Increasing one’s knowledge’ also implies a belief that an increase in knowledge can open an avenue to make sense of what used to be unknown. One possible reason for the females’ greater willingness to accumulate biology-related knowledge, as suggest by Miller et al. (2006), was that they had a greater desire to engage in life-related disciplines and to be capable of taking care of others. In this sense, there was a higher probability that the learning conception ‘Increasing one’s knowledge’ could invoke the female students to adopt a deep strategy for learning biology. Regarding their predisposition to learning biology, since the female students who treated learning biology as ‘Increasing one’s knowledge’ tended to trigger both the deep and surface motives, as discussed earlier, it appeared that they attempted to increase their biological knowledge to fulfil not only their inner interest in biology, but also the external course requirements. However, there was also a high probability that the way in which the ‘Increasing one’s knowledge’ conception affected the female students’ motivation for learning biology depended on the demands of the learning tasks and on their learning load (Biggs, 1993; Marton & Säljö, 1976a, 1976b). For example, a demand for a thorough understanding and a lighter learning load might result in a better chance for the female students to induce the deep motive.

Last, the conception of learning biology, ‘Application’, had a higher probability of triggering the ‘Surface Motive’ and ‘Deep Strategy’ only for the male students. As discussed earlier, although there was a general trend that ‘Application’, a higher-level conception of learning biology, had a significantly positive effect on the deep

approach to learning in biology, this effect was not exerted equally on the female and the male students. That is, while both the female and the male students who possessed the 'Application' conception tended to have an intrinsic motivation for learning biology, only the male students who possessed this conception were more likely to adopt the deep strategy for learning biology. This finding suggests that when seeking the application of biological knowledge, the male students had a higher chance of gaining a full understanding of the learning materials and integrating what they already knew with the materials. However, given that the 'Application' conception also had a significant positive effect on the 'Surface Motive' for the male students, some of the male students were more likely to seek applications of biological knowledge just for the purpose of passing an examination or fulfilling the course requirements and external expectations.

### *Future Research*

The findings of this investigation offer some suggestions for future research. First, while this study confirms the structural relationships between the undergraduate students' conceptions of and their approaches to learning biology, whether some intermediate factors exist between these two constructs deserves further exploration. Second, it should be noted that the gender differences found in this study are solely based on statistical significance: their education significance has not been explored. To interpret the gender differences identified in this study, future studies are encouraged to discover the potential factors that influence these gender differences, and to explore how these factors affect the development of both female and male students' conceptions of and their approaches to learning biology. Third, whether the structural relationships illustrated in this study can account for students' learning in other scientific areas, such as physics, chemistry, and earth science, needs further examination. Fourth, how students' conceptions of learning and approaches to learning in biology develop with age and experience remains unclear. Future research can tackle this fundamental issue by conducting cross-sectional studies to enrich our understanding of the development of, and the causal relationships between, students' conceptions of learning and approaches to learning in biology. Last but not least, given that students' conceptions of learning and approaches to learning are culture-dependent (Lee et al., 2008; Marton et al., 2007; Tsai, 2004), future research can pay more attention to the interdependence among culture, conceptions of learning and approaches to learning in biology. This culture issue can be addressed by comparing studies from different countries, and can further shed light on the explanation of gender differences in the causal relationships between conceptions of learning and approaches to learning in biology.

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## Appendix 1. The Questionnaire Items on the COLB

### *Memorizing*

- (1) Learning biology means memorizing the definitions, formulae, and laws found in biology textbook.
- (2) Learning biology means memorizing the important concepts found in biology textbook.
- (3) Learning biology means memorizing the proper nouns found in biology textbook that can help solve the teacher's questions.
- (4) Learning biology means remembering what the teacher lectures about in biology class.
- (5) Learning biology means memorizing biological symbols, biological concepts, and facts.
- (6) Learning biology, just like learning history or geography, the most important thing is to memorize the content of the text book.
- (7) When learning biology, I need to memorize the biological definition and formulae well or I will forget them.

### *Testing*

- (1) Learning biology means getting high scores on examinations.
- (2) If there are no tests, I will not learn biology.
- (3) There are no benefits to learning biology other than getting high scores on examinations. In fact, I can get along well without knowing many biological facts.
- (4) The major purpose of learning biology is to get more familiar with test materials.
- (5) I learn biology so that I can do well on biology-related tests.
- (6) There is a close relationship between learning biology and taking tests.
- (7) Learning biology means answering the questions correctly in the examination.

### *Calculating and Practising*

- (1) Learning biology involves a series of calculations and problem-solving.
- (2) I think that learning calculation or problem-solving will help me improve my performance in biology courses.
- (3) Learning biology means knowing how to use the correct formulae when solving problems.
- (4) The way to learn biology well is to constantly practice calculations and problem-solving.
- (5) There is a close relationship between learning biology, being good at calculations, and constant practice.
- (6) Learning biology means constantly practising calculations and problem-solving.



*Increasing one's Knowledge*

- (1) Learning biology means acquiring knowledge that I did not know before.
- (2) I am learning biology when the teacher tells me biological facts that I did not know before.
- (3) Learning biology means acquiring more knowledge about natural phenomena and topics related to nature.
- (4) Learning biology helps me acquire more facts about nature.
- (5) I am learning biology when I increase my knowledge of natural phenomena and topics related to nature.

*Applying*

- (1) The purpose of learning biology is learning how to apply methods I already know to unknown problems.
- (2) Learning biology means learning how to apply knowledge and skills I already know to unknown problems.
- (3) We learn biology to improve the quality of our lives.
- (4) Learning biology means solving or explaining unknown questions and phenomena.
- (5) Learning biology means acquiring knowledge and skills to solve the problems happened in the real life.
- (6) Learning biology means acquiring knowledge and skills to enhance the quality of our lives.

*Understanding and Seeing in a New Way*

- (1) Learning biology means understanding biological knowledge.
- (2) Learning biology means expanding my knowledge and views.
- (3) Learning biology means understanding more natural phenomena and knowledge.
- (4) Learning biology helps me view natural phenomena and topics related to nature in new ways.
- (5) Learning biology means changing my way of viewing natural phenomena and topics related to nature.
- (6) I can learn more ways about thinking about natural phenomena or topics related to nature by learning biology.



## Appendix 2. The Questionnaire Items on the ALB

### *Deep Approach*

#### *Deep motive*

- (1) I find that at times studying biology makes me feel really happy and satisfied.
- (2) I feel that biology topics can be highly interesting once I get into them.
- (3) I work hard at studying biology because I find the material interesting.
- (4) I always greatly look forward to go to biology class.
- (5) I spend a lot of my free time finding out more about interesting topics which were discussed in biology class.
- (6) I come to biology class with questions in my mind that I want to be answered.
- (7) I find that I continually go over my biology class work in my mind even when- ever I am not in biology class.
- (8) I like to work on biology topics by myself so that I can form my own conclusions and feel satisfied.

#### *Deep strategy*

- (1) I try to relate what I have learned in biology subjects to what I learn in other subjects.
- (2) I like constructing theories to fit odd things together when I am learning biology topics.
- (3) I try to find the relationship between the contents of what I have learned in biol- ogy subjects
- (4) I try to relate new material to what I already know about the topic when I am studying biology.
- (5) I try to understand the meaning of the contents I have read in biology textbooks.
- (6) I can ask myself possibly to understand the subject matter I have learned in biol- ogy class.

### *Surface Approach*

#### *Surface motive*

- (1) I am discouraged by a poor mark on biology tests and worry about how I will do on the next text.
- (2) Even when I have studied hard for a biology text, I worry that I may not be able to do well on it.
- (3) I worry that my performance in biology class may not satisfy my teacher's expec- tations.
- (4) I want to get a good achievement in biology subject so that I can get a better job in the future.
- (5) I want to do well in biology subjects so I can please my family and the teacher.

- (6) No matter I like it or not, I know that getting a good achievement in biology subject could help me to get an ideal job in the future.

*Surface strategy*

- (1) I see no point in learning biology materials that are not likely to be on the examinations.
- (2) As long as I feel I am doing well enough to pass the examination, I devote as little time as I can to studying biology subjects. There are many more interesting things to do with my time.
- (3) I generally will restrict my study to what is specially set as I think it is unnecessary to do anything extra in learning a biology topic.
- (4) I find that studying each topic in depth is not helpful or necessary when I am learning biology. There are too many examinations to pass and too many subjects to be learned.
- (5) I find the best way to pass biology examinations is to try to remember the answers to likely questions.
- (6) When learning biology, I try to memorize the content again and again till I remember it very well.
- (7) I find that memorizing the most important content makes me get high scores in the examinations instead of understanding it.