International Journal of Science Education

ISSN: 0950-0693 (Print) 1464-5289 (Online) Journal homepage: http://www.tandfonline.com/loi/tsed20

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INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, 2016
http://dx.doi.org/10.1080/09500693.2016.1198060

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Undergraduate students' earth science learning: relationships among conceptions, approaches, and learning self-efficacy in Taiwan

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ABSTRACT
In the area of science education research, studies have attempted to investigate conceptions of learning, approaches to learning, and self-efficacy, mainly focusing on science in general or on specific subjects such as biology, physics, and chemistry. However, few empirical studies have probed students' earth science learning. This study aimed to explore the relationships among undergraduates' conceptions of, approaches to, and self-efficacy for learning earth science by adopting the structural equation modeling technique. A total of 268 Taiwanese undergraduates (144 females) participated in this study. Three instruments were modified to assess the students' conceptions of, approaches to, and self-efficacy for learning earth science. The results indicated that students' conceptions of learning made a significant contribution to their approaches to learning, which were consequently correlated with their learning self-efficacy. More specifically, students with stronger agreement that learning earth science involves applying the knowledge and skills learned to unknown problems were prone to possess higher confidence in learning earth science. Moreover, students viewing earth science learning as understanding earth science knowledge were more likely to adopt meaningful strategies to learn earth science, and hence expressed a higher sense of self-efficacy. Based on the results, practical implications and suggestions for future research are discussed.

ARTICLE HISTORY
Received 24 November 2015
Accepted 1 June 2016

KEYWORDS
Conceptions of learning earth science; approaches to learning earth science; self-efficacy

Introduction

Recently, science education researchers have been striving to identify students' conceptions of learning science so as to reveal how they conceptualize and interpret their personal experience of learning science. Tsai (2004) has identified seven conceptions of learning science (i.e. learning science as Memorizing, Preparing for tests, Calculating and Practicing tutorial problems, the Increase of knowledge, Applying, and Understanding and Seeing in a new way) through interviewing high school students. In addition,

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research interest in students' approaches to learning has also increased in the past decade. Students' approaches to learning indicate their ways of academic learning (Biggs, 1994). Researchers have found two major approaches to students' learning (i.e. the deep and the surface approaches), each of which comprises a 'motive–strategy' combination (e.g. Biggs, 1994; Chin & Brown, 2000; Kember, Biggs, & Leung, 2004). Several studies have sought to investigate the relationship between learners' conceptions of learning science and their approaches to learning science (e.g. Chiou, Lee, & Tsai, 2013; Dart et al., 2000; Lee, Johanson, & Tsai, 2008), and have revealed that people holding mature conceptions of learning science are more likely to draw on deep or meaningful approaches to learning science.

Moreover, researchers have suggested that students' self-efficacy plays an important role in their learning process and performance (Britner & Pajares, 2006). Lin and Tsai (2013) and Phan (2011) further revealed the relationships between students' self-efficacy, conceptions of learning science, and approaches to learning. In general, those studies indicated that students with more sophisticated conceptions and deeper approaches tend to have higher self-efficacy for learning. In the area of science education research, researchers have attempted to understand students' science learning profiles. Those studies probing the issue of conceptions of learning, approaches to learning, and self-efficacy have mainly focused on science in general (e.g. Hong & Lin, 2013; Lin, Tan, & Tsai, 2013) or on specific subjects, such as biology (e.g. Chiou, Liang, & Tsai, 2012; Minasian-Batmanian, Lingard, & Prosser, 2006), physics (e.g. Chiou et al., 2013; Gungor, Eryilmaz, & Fakioglu, 2007; Lin, Liang, & Tsai, 2015), and chemistry (e.g. Li, Liang, & Tsai, 2013; Villafañe, Garcia, & Lewis, 2014).

Earth science is an all-embracing subject related to the planet Earth. The formal discipline of earth sciences mainly involves inquiries into the atmosphere, hydrosphere, biosphere, as well as the solid earth. Moreover, earth science is distinctive from other fields of science. Typically, physics and chemistry experts construct the core knowledge by means of emphasizing a series of scientific inquiry methods (i.e. observation, experimentation, and deductive inference). However, when confronted with very large-scale phenomena through time and space, earth science inquiry requires an intellectually holistic comprehension of change through Earth's history across many scales. Furthermore, earth scientists generally utilize instruments on the basis of physics, chemistry, biology, geography, and chronology to construct a comprehensive understanding of how the Earth works, and how it developed to its present condition. In addition, Orion and Ault (2007) also argue that inquiry in earth science has six distinctive features: the historical approach, complex systems, large-scale phenomena, visual representation and spatial reasoning, integration across scales, and retrospective scientific thinking. Accordingly, the nature of earth science pedagogy places importance on application and understanding. To date, studies in the area of earth science education have explored a range of issues such as conceptions of geoscience learning (e.g. Markley, Miller, Kneeshaw, & Herbert, 2009), approaches to learning geoscience (e.g. Kennelly, 2009), and self-efficacy of learning geoscience (e.g. Burton & Mattietti, 2011). However, little research has been conducted to explore the interrelationship among students' conceptions of, approaches to, and self-efficacy for learning earth science simultaneously.

The main purpose of this study was thus to explore the relationships among students' conceptions of learning earth science (COLES), approaches to learning earth science

(ALES), and self-efficacy. Based on our previous series of studies on the conceptions of learning in various domains of science (e.g. biology, physics, and chemistry), three instruments were modified to assess these three aspects of learning earth science, and the structural equation modeling (SEM) technique was utilized to investigate the hypothesized structure model for identifying the relationships.

Literature review

Conceptions of learning

Students' conceptions of learning refer to their personal experiences and interpretations of the learning context (Richardson, 1999), indicating how learners frame, interpret, and reflect on their learning experiences (Lee, Lin, & Tsai, 2013). Säljö (1979) pioneered the work of the research on conceptions of learning through the analysis of a series of in-depth, personal interviews, identifying five categories of conceptions of learning: (1) an increase in knowledge, (2) memorizing, (3) an acquisition of facts or principles, (4) an abstraction of meaning, and (5) an interpretive process aimed at understanding reality. Since Säljö's research, there has been a great number of consecutive studies focusing on students' conceptions of learning and their effects, and extending Säljö's assertion to other contexts (Duarte, 2007; Marton, Dall' Alba, & Beaty, 1993; Peterson, Brown, & Irving, 2010; Purdie, Hattie, & Douglas, 1996; Tsai, 2004). For example, Marton et al. (1993) identified a sixth category, and proposed conceptions of learning representing learning as (1) increasing knowledge, (2) memorizing and reproducing, (3) applying, (4) understanding, (5) seeing things in a different way, and (6) changing as a person. In Marton et al.'s (1993) research, the conception of learning as 'changing as a person,' which means that seeing things differently may change you, is not referred to as widely as other conceptions found in the previous studies. Marton et al. (1993) further argued that this conception is only found in a few cases and builds further on the conception as 'seeing things in a different way.'

In addition to these six categories, Tsai (2004) found two further distinct learning conceptions which reflect the cultural impact and the domain-specific feature regarding learning science in Taiwanese culture, namely 'Preparing for tests' and 'Calculating and Practicing tutorial problems.' These new conceptions were identified by means of interviewing 120 high school students. Following the research by Tsai (2004), Lee et al. (2008) developed a questionnaire to explore students' conceptions of learning science. In Lee et al.'s (2008) study, the seven original conceptions of learning science identified by Tsai (2004) resulted in six meaningful factors as a result of merging the factors of 'Understanding' and 'Seeing in a new way' into the single factor of 'Understanding and Seeing in a new way' through a series of factor analyses. Following Lee et al.'s (2008) original study, the questionnaire with six factors has been used in a number of subsequent studies to investigate students' conceptions of learning science (e.g. Chiou et al., 2012; Li et al., 2013). Therefore, Lee et al.'s (2008) questionnaire was adopted and modified in the present study.

Conceptions of learning have been regarded as a hierarchical system (Marton et al., 1993). Different terminologies have been proposed in different studies to classify the conceptions, such as 'lower' or 'higher' level conceptions (Dart et al., 2000);'passive accumulation of external fragmentary information' or 'active transformation of external information into meaningful, understandable, and applicable knowledge' (Marton et al., 1993); the 'reproducing' or 'transforming' orientations (Brownlee, Purdie, & Boulton-Lewis, 2003); and 'reproductive' or 'constructive' conceptions (Lee et al., 2008). In general, the conceptions of 'Memorizing', 'Testing', and 'Calculating and Practicing' are classified into the lower level, while the last three factors, 'Increasing one's Knowledge', 'Applying', and 'Understanding and Seeing in a new way,' are classified into the higher level (Lee et al., 2008). This categorization was confirmed with a large-sample study by Lin, Tsai, and Liang (2012) through investigating 524 senior high school students' conceptions of learning by means of the confirmatory factor analysis (CFA) to find the most appropriate model to illustrate the two-profile categorizations of conceptions of learning science. In the present study, the categorization of 'lower' versus 'higher' was adopted. The lower level conceptions of learning science (i.e. 'Memorizing', 'Testing', and 'Calculating and Practicing') indicate that learning science aims to duplicate what teachers say and what the textbook shows, and then to re-present the perceived information intact. On the other hand, the higher level conceptions of learning science (i.e. 'Increasing one's Knowledge', 'Applying', and 'Understanding and Seeing in a new way') reveal that learning science involves a process of transforming what students have perceived into a meaningful whole.

Moreover, it is argued that conceptions of learning are domain-dependent in the sense that students may have idiosyncratically differing views of learning regarding different domains (Buehl & Alexander, 2001; Hofer, 2000; Tsai, 2006). Recently, researchers have extended this line of research to various domains such as science, marketing, and management, and have contended that students' conceptions of learning may be domain specific (e.g. Edström, Wilhemsson-Macleod, Berggren, Josephson, & Wahlgren, 2015; Lee et al., 2008; Lin & Niu, 2011; Lin & Tsai, 2008). In the science domain, conceptions of learning for the specific subjects of biology, physics, and chemistry have been explored (e.g. Chiou et al., 2013, 2012; Li et al., 2013, 2015). Accordingly, to further understand students' earth science learning, the present study aimed to probe students' COLES.

The relationship between conceptions of and approaches to learning

Studies regarding approaches to learning originated from phenomenographic research, and have attempted to conceptualize students' motives and strategies for learning into deep and surface approaches (Biggs, 1987; Entwistle & Ramsden, 1983). The deep approaches are conceptualized as intending to look for meaning through elaborating or transforming the material studied. Furthermore, the deep approaches are related to intrinsic motivation, interest in the content of the task, focusing on understanding the meaning of the learning material, and attempting to relate newly learned concepts to one's previous knowledge structure (Chin & Brown, 2000). On the other hand, surface approaches are adopted to reproduce learning materials through routine procedures with extrinsic or instrumental motivations (Kember et al., 2004). In addition, the Learning Process Questionnaire (LPQ) (Biggs, 1987) has yielded three categories of student learning approaches, namely the deep, surface, and strategic (or achieving) approaches. The strategic (or achieving) approach is built on an achieving motivation to maximize grades by effectively using time and space. However, Kember et al. (2004) suggested that the 'strategic (or achieving) approach' factor of the LPQ is not as evident as the 'deep approach' and 'surface approach' factors. They further argued that a two-factor (i.e. deep and surface) LPQ more usefully addresses the greatest number of parameters relating to teaching and learning issues. Lee et al. (2008) developed the Approaches to Learning Science questionnaire, which was revised from the Revised Learning Process Questionnaire (Kember et al., 2004), to assess students' approaches to learning science. To realize the relationships between students' ALES, this study followed Kember et al.'s (2004) and Lee et al.'s (2008) works by only adopting the deep/surface approaches to illustrate students' approaches to learning. In this study, the questionnaire by Lee et al. (2008) was modified to assess students' ALES.

Many researchers have focused on studies regarding the relationships between conceptions of and approaches to learning (e.g. Dart et al., 2000; Edmunds & Richardson, 2009; Ferla, Valcke, & Schuyten, 2008; Lee et al., 2008; Minasian-Batmanian et al., 2006). Lee et al. (2008) investigated 474 high school students' conceptions of and approaches to learning science, and pointed out that students holding higher level conceptions of learning science tended to utilize deep approaches to learning science. Recently, the relationships between conceptions of and approaches to learning in different subjects of science have been investigated in many studies. Chiou et al. (2012) investigated undergraduates' biology learning, Li et al. (2013) studied college students' chemistry learning, and Chiou et al. (2013) probed undergraduates' physics learning. In terms of the relationship between conceptions of and approaches to learning, previous studies have revealed that, by and large, students possessing lower level conceptions of learning are more likely to adopt a surface approach to learning, whereas those possessing higher level conceptions tend to adopt a deep approach to learning. However, some context-specific findings could be identified in different areas of science. For example, Li et al. (2013) indicated that the lower level conception 'learning chemistry by memorizing' could positively predict a deep motive to learn, while the higher level conception 'learning chemistry by transforming' was positively correlated to a surface motive for learning chemistry. Kember et al. (2004) also claimed that students might perform differently in each learning domain. As previously mentioned, earth science learning is distinct from other fields of science. However, it is difficult to find empirical studies which simultaneously focus on students' conceptions of and approaches to earth science learning. Accordingly, one purpose of this study was to explore the relationship between students' COLES and ALES.

Research on self-efficacy

Self-efficacy, proposed by Bandura in his well-known social cognitive theory, refers to individuals' judgments of their own academic capabilities to tackle certain learning tasks or actions required to achieve designated types of performance (Bandura, 1997). In accordance with the previous research findings, the self-efficacy belief affects students' learning achievement by means of processes of motivational engagement, affective expression, cognitive engagement, and decision-making (Bandura, 1990; Linnenbrink & Pintrich, 2003; Silvia, 2003; Zimmerman & Bandura, 1994). Regarding motivational engagement, people with higher self-efficacy are more likely to be actively involved in the task than those with lower self-efficacy. In terms of affective expression, people confident in their ability to cope with the potential threats of a task are more willing to work hard when in trouble. As regards cognitive engagement, people possessing higher self-efficacy can be engaged in in-depth thinking and reflection processes by means of drawing on cognitive and metacognitive strategies.

Several studies have investigated the relations between self-efficacy, conceptions of, and approaches to learning (e.g. Chiou & Liang, 2012; Phan, 2007, 2011; Tsai, Ho, Liang, & Lin, 2011). According to Tsai et al. (2011), the results of SEM analysis pointed out that the students' lower level conceptions of learning science (regarding learning science as memorizing, testing, calculating, and practicing) were negatively related to their science learning self-efficacy, whereas their higher level conceptions (regarding learning science as increase in knowledge, applying, understanding, and seeing in a new way) seemed to foster their self-efficacy. Moreover, Phan (2007) argued that undergraduate students' usage of deep learning approaches positively predicted their self-efficacy by means of performing a path analysis. Chiou and Liang (2012) examined the relations among Taiwanese high school students' science self-efficacy, conceptions of learning science, and approaches to learning science by means of the SEM method, and found that the students' approaches to learning science were a significant predictor of their science self-efficacy. By and large, the above studies seem to illustrate the interrelations between students' conceptions, approaches, and self-efficacy of learning. As learning earth science is distinct from learning other fields of science, the major purpose of this study was to explore this relationship to further understand students' earth science learning. Accordingly, the hypothesized model of this study consists of three components: COLES, ALES, and self-efficacy for learning earth science (SELES; Figure 1).

Research purpose

This study, by validating three instruments (i.e. the COLES questionnaire, the ALES questionnaire, and SELES questionnaire), was conducted to examine the relationship among undergraduates' COLES, ALES, and SELES.

Methods

Participants

The participants consisted of 268 undergraduates in Taiwan, of whom 124 were male and 144 were female. Their ages ranged from 19 to 21 years. In addition, all of the participants were non-earth science majors, but had taken a series of earth science courses at junior and senior high school. They were recruited from 'The Introduction to Earth Sciences' course, which is one of the science-related courses undergraduates may take to fulfill the general education requirements at the university. All of the participants were unpaid volunteers,

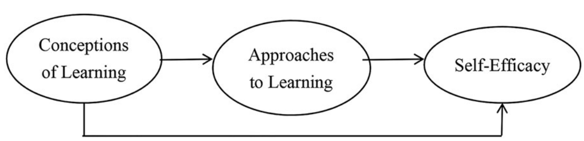

Figure 1. Hypothesized model of structural relations among conceptions of learning, approaches to learning, and self-efficacy regarding earth science.

and they were invited to complete the three instruments: COLES, ALES, and SELES. Although these students were non-earth science majors, they could be expected to embrace a similar perspective of learning earth science from high school to the undergraduate level. In Taiwan, high school students in the ninth and tenth grades (i.e. 15–16 years old) need to take one earth science class per week for one semester. The earth science courses in Taiwanese high schools present a great number of scientific concepts and practical activities such as experiments and field trips (Lee, Chang, & Tsai, 2009). However, the credits of the earth science course in Taiwan are less than those of other science domains (such as physics and chemistry). Although educational administrators have encouraged earth science teachers to conduct practical activities using multiple teaching strategies such as visualization technologies and fieldwork, didactic instructional approaches still dominate (Lee et al., 2009).

Instruments

Three questionnaires (i.e. COLES, ALES, and SELES) measured with a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) were adopted as the survey instruments. The COLES, ALES, and SELES were modified from Conceptions of Learning Science (Lee et al., 2008), Approaches to Learning Science (Lee et al., 2008) and the scale for self-efficacy of learning science (Tsai et al., 2011) to target the earth science-related content. Three experts in science education and earth science examined the content of all the questionnaire items to ensure the validity of the questionnaires. The three questionnaires are provided in the Appendix.

The COLES was administered to assess students' COLES. Detailed descriptions of the six hierarchical COLES factors (from lower to higher levels) with a sample item for each are presented in Table 1. The reliability coefficients for the COLES factors were 0.85, 0.87, 0.84, 0.88, 0.85, and 0.89, respectively, representing sufficient reliability.

The ALES consisted of four factors to evaluate students' ALES. Detailed descriptions of the four factors with a sample item for each are presented in Table 2. The reliability coefficients for the ALES factors were 0.83, 0.86, 0.83, and 0.80, respectively.

In addition, the SELES was revised from the scale for self-efficacy of learning science (Tsai et al., 2011) to measure students' self-efficacy of their earth science learning. A sample item is: I believe I will receive an excellent grade in class. In this study, the reliability coefficient for the SELES was 0.88.

Data analysis

Since the major purpose of this study was to explore the structural relationships among students' conceptions of, approaches to, and self-efficacy in learning earth science, the SEM technique was performed in this study. Data screening and correlation analysis were conducted using SPSS version 17.0. LISREL 8.80 was used to implement the CFAand was also employed to test the structural relationships by administering the full-model testing of SEM.

Table 1. The factors, definitions, and sample item of COLES questionnaire.

Factor	Definition	Sample item
Memorizing	Learning earth science is conceptualized as the memorization of definitions, formulae, laws, and special terms.	Learning earth science means memorizing the definitions, formulae, and laws found in the earth science textbook.
Testing	Learning earth science is to pass the examinations or to achieve high scores in earth science tests.	Learning earth science means getting high scores on examinations.
Calculating and practicing	Learning earth science is viewed as a series of calculating and practicing tutorial problems, and manipulating formulae and numbers.	Learning earth science means constantly practicing calculations and problem-solving.
Increase of knowledge	An increase in knowledge is seen as the main feature of learning earth science.	Learning earth science means acquiring knowledge that I did not know before.
Applying	The purpose of learning earth science is the application of received knowledge.	Learning earth science means acquiring knowledge and skills to enhance the quality of our lives.
Understanding and Seeing in a new way	A true understanding is viewed as a major feature of learning earth science, and earth science learning can be characterized as gaining a new perspective.	Learning earth science means understanding earth science knowledge.

Results

Factor analysis of the COLES, ALES, and SELES

To validate the constructs of COLES, ALES, and SELES, confirmatory factor analysis was conducted. As a result, several items from the initial model with cross-loadings were eliminated. Finally, a total of 41 items (including COLES with 24 items for six factors, ALES with 13 items for four factors, and SELES with 4 items) were retained for further analysis. Although the goodness-of-fit index (GFI = 0.80) was somewhat low, the value was still acceptable. The other fit indices (the ratio of chi-square to degrees of freedom = 1.83, CFI = 0.96, RMSEA = 0.056, NFI = 0.92, NNFI = 0.95) showed that the measurement model provided a satisfactory fit to the data. Moreover, the factor loadings, average variance extracted (AVE), and composite reliability (CR) are suggested to evaluate the convergent validity of the constructs (Hair, Black, Babin, Anderson, & Tatham, 2006; Pedhazur, 1997). The CFA results indicated that all of the loading values of the measured items were significant and higher than 0.5 (Table 3). Compared with the cut-off value of 0.60, the CR values of all factors ranging from 0.75 to 0.87 indicated acceptable reliability of the factors (Bagozzi & Yi, 1988). Moreover, the AVE values ranging from 0.47 to 0.64

Table 2. The factors, definitions, and sample item of ALES questionnaire.

Factor	Definition	Sample item
Deep motive	Students show their intrinsic motivation while learning earth science, such as learning earth science driven by their curiosity and own interest.	I always greatly look forward to going to earth science class.
Deep strategy	Students utilize more meaningful strategies to learn earth science, such as making connections and coherent understanding.	I try to understand the meaning of the contents I have read in the earth science textbook.
Surface motive	Students possess extrinsic motivation to learn earth science, such as learning earth science for course grades or others' expectations.	I worry that my performance in earth science class may not satisfy my teacher's expectations.
Surface strategy	Students use more rote-like strategies such as remembering or narrowing targets to learn earth science.	I find the best way to get high scores in earth science exams is to remember the answers to likely questions.

revealed adequate convergent validity of the factors, and the alpha coefficient for all factors ranged from 0.80 to 0.89, representing good reliability.

The relationships among students' COLES, ALES, and SELES

The descriptive statistics and the correlation coefficients of the research variables are presented in Tables 3 and 4, respectively. The results seem to reveal that the lower level COLES factors (i.e. Memorizing, Testing, and Calculating and Practicing) tended to be positively correlated with the surface ALES (i.e. surface motive and strategy). The higher level COLES (i.e. Increase in knowledge, Applying, and Understanding and Seeing in a new way) tended to reveal positive correlations with deep approaches (i.e. deep motive and strategy) and SELES. In addition, the results also indicate a positive correlation between deep approaches and SELES.

To explore the path correlations among COLES, ALES, and SELES, path analysis was conducted using SEM analysis. The path coefficients of the structural model that specified the relationships between the latent constructs (factors) are presented in Figure 2. The fit indices of the structural model show that the model has an acceptable fit (the ratio of chi-square to degrees of freedom = 1.83, CFI = 0.96, RMSEA = 0.056, NFI = 0.92, NNFI = 0.95, and GFI = 0.80).

The structural relationships among COLES, ALES, and SELES are revealed in Figure 2. The conception of learning earth science as 'Memorizing,' 'Testing' and 'Calculating and practicing' has positive relations with 'Surface Strategy' ($\gamma = 0.24$–0.28, $p < .05$). The conception of learning earth science as 'Testing' has negative relations with 'Deep Motive' and 'Deep Strategy' ($\gamma = -0.20$, and -0.17, $p < .05$), whereas it has a positive relation with 'Surface Strategy' ($\gamma = 0.24$, $p < .05$). COLES as 'Calculating and Practicing' and 'Applying' have positive relations with both 'Deep Motive' ($\gamma = 0.33$ and 0.39, $p < .05$) and 'Surface Motive' ($\gamma = 0.44$ and 0.38, $p < .05$), and COLES as 'Understanding and Seeing in a new way' have a positive relation with 'Deep Strategy' ($\gamma = 0.57$, $p < .05$). Moreover, 'Deep Strategy' ($\beta = 0.48$, $p < .05$) has positive relations with SELES. In addition, the conception

Table 3. The CFA for COLES, ALES, and SELES ($n = 268$).

Instrument	Factors	# of item	Mean (SD)	Factor Loading	*t*-value	AVE	CR	Alpha value
COLES	M	4	2.91 (0.85)	0.64–0.91	11.31*–15.53*	0.64	0.87	0.85
	T	5	2.63 (0.81)	0.66–0.83	12.01*–16.80*	0.58	0.87	0.87
	CP	3	2.38 (0.83)	0.72–0.79	13.88*–15.07*	0.58	0.80	0.84
	IK	4	3.68 (0.80)	0.70–0.78	14.26*–16.19*	0.56	0.84	0.88
	A	3	3.39 (0.77)	0.67–0.81	13.17*–18.27*	0.53	0.77	0.85
	US	5	3.72 (0.73)	0.63–0.74	14.29*–16.00*	0.48	0.82	0.89
ALES	DM	3	3.04 (0.78)	0.65–0.77	11.77*–11.49*	0.51	0.75	0.83
	DS	3	3.45 (0.80)	0.68–0.82	13.16*–14.25*	0.56	0.79	0.86
	SM	4	2.87 (0.76)	0.50–0.83	08.80*–09.48*	0.51	0.80	0.83
	SS	3	2.94 (0.83)	0.61–0.84	09.72*–11.95*	0.57	0.79	0.80
SELES	SE	4	3.33 (0.73)	0.64–0.74	13.24*–13.63*	0.47	0.78	0.88

COLES, conceptions of learning earth science; ALES, approaches to learning earth science; SELES, self-efficacy for learning earth science; CR, composite reliability; AVE, average variance extracted; M, memorizing; T, testing; CP, calculating and practicing; IK, increasing one's knowledge; A, applying; US, understanding and seeing in a new way; SM, surface motive; SS, surface strategy; DM, deep motive; DS, deep strategy; SE, self-efficacy.

*$p < .05$.

Table 4. The correlation results of the research variables.

	1	2	3	4	5	6	7	8	9	10
M										
T	.42**									
CP	.26**	.44**								
IK	−.05	−.33**	−.31**							
A	.14*	−.20**	−.06	.45**						
US	.04	−.32**	−.30**	.74**	.62**					
DM	.02	−.14*	.12*	.15*	.35**	.26**				
DS	.02	−.34**	−.15*	.46**	.40**	.57**	.47**			
SM	.21**	.08	.32**	−.05	.30**	.09	.40**	.21**		
SS	.40**	.42**	.33**	−.06	.07	−.05	.03	−.09	.24**	
SE	.14*	−.23**	−.12	.34**	.40**	.41**	.34**	.52**	.18**	−.03

M, memorizing; T, testing; CP, calculating and practicing; IK, increasing one's knowledge; A, applying; US, understanding and seeing in a new way; SM, surface motive; SS, surface strategy; DM, deep motive; DS, deep strategy; SE, self-efficacy
*$p < .05$.
**$p < .01$.

of learning earth science as 'Applying' also has a positive relation with SELES ($\gamma = 0.25$, $p < .05$).

In summary, the conception of 'Applying' directly links to SELES, while the conceptions of 'Testing' and 'Understanding and Seeing in new way' are indirectly correlated with self-efficacy via deep strategies for learning earth science. In addition, the conception

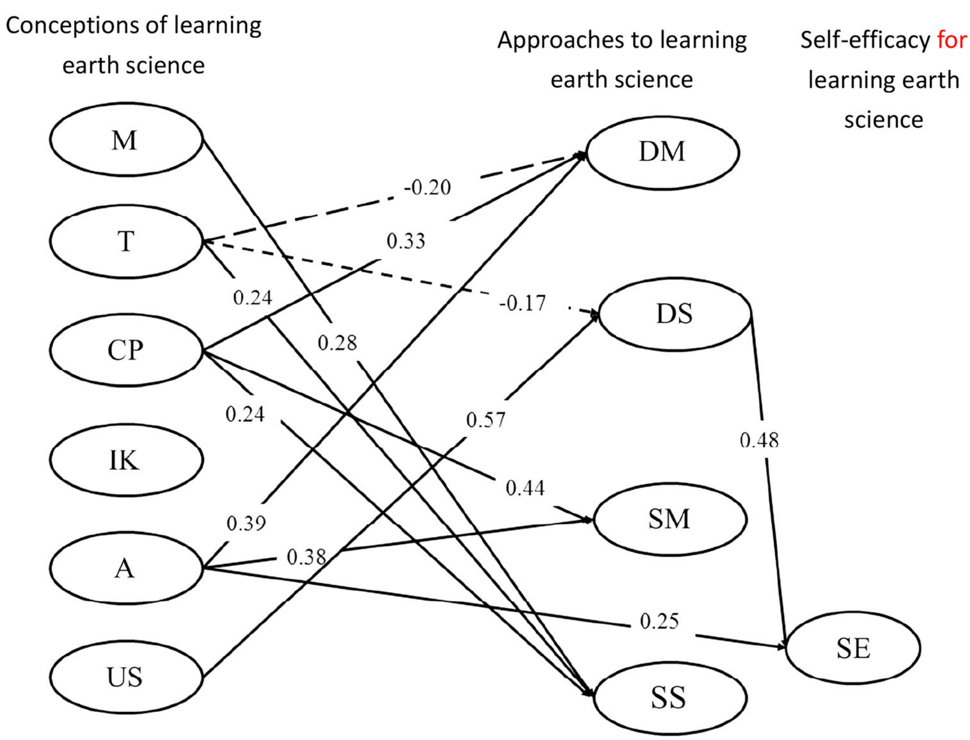

Figure 2. The path coefficients of the structural relations among COLES, ALES, and SELES. Note: M: memorizing; T: testing; CP: calculating and practicing; IK: increasing one's knowledge; A: applying; US: understanding and seeing in a new way; SM: surface motive; SS: surface strategy; DM: deep motive; DS: deep strategy; SE: self-efficacy.

of ‘Testing’ has a negative relation with deep strategies for learning earth science, whereas the conception of ‘Understanding and Seeing in new way’ has a positive relation with students’ deep strategies for learning earth science. The results also indicate that the lower level COLES (i.e. Memorizing, Testing, and Calculating and Practicing) have positively structured relations with surface strategies. The learning conception of ‘Testing’ was shown to be a strong predictor of the surface ALES. Moreover, the COLES ‘Calculating and Practicing’ and ‘Applying’ were revealed as being significant positive predictors of the ‘mixed’ motives pattern of the ALES.

Discussion

This study advances the research literature on students’ earth science learning by testing the relationships among Taiwanese undergraduates’ COLES, ALES, and SELES. This study adopted the SEM technique via the implementation of the CFA to test the measurement model of the questionnaires, and path analysis for testing the structural model of the research variables. The acceptable model fit index indicated that the construct model provided an acceptable fit to the data. For the measurement model, the three questionnaires modified for this study have good reliability and convergent validity to examine undergraduates’ COLES, ALES, and SELES. The results of the structural model proposed in this study have specified the relationships among students’ COLES, ALES, and SELES. That is, students’ COLES made a significant contribution to their ALES, which consequently exerted an effect on their SELES.

To provide a graphical illustration and to delineate more clearly the results of the SEM analysis, the structural model is simplified and divided into four figures as shown in Figures 3 and 4.

The structural relations between students’ COLES and approaches to learning science are presented in Figure 3. Students with lower level COLES (i.e. Memorizing, Testing, and Calculating and Practicing) may employ surface strategies (Figure 3 (a)). That is, if students regarded learning earth science as memorizing the definitions and specific terms found in the textbook, preparing for the test, or practicing the tutorial problems, they were more likely to learn earth science by rote repetition. Consequently, they were also less likely to try to understand the knowledge in the course, relate the information being studied to knowledge they had learned before, or learn earth science in an active and positive manner. These findings also confirm the relationships found in previous studies either in general domain learning (e.g. Dart et al., 2000; Ferla et al., 2008), in domain-specific science learning (e.g. Lee et al., 2008), or in the specific science subjects of biology, physics, and chemistry (e.g. Chiou et al., 2013, 2012; Li et al., 2013).

Additionally, the conception of ‘Testing’ is negatively related to Deep Motive and Deep Strategy, but positively related to Surface Strategy (Figure 3 (b)). To be more specific, when students view earth science learning as preparing for testing, they would be likely to engage in surface learning strategies, and be unlikely to utilize meaningful strategies to learn earth science enthusiastically and with interest. In science learning, this seems commonplace, and some empirical studies also support this perspective (e.g. Chiou et al., 2012, 2013; Li et al., 2013). In Taiwan, tests not only play a diagnostic evaluation role for teachers to understand students’ weaknesses and difficulties in learning, but also play a driving role for students to engage in constant rote learning (i.e. memorizing and practicing) as

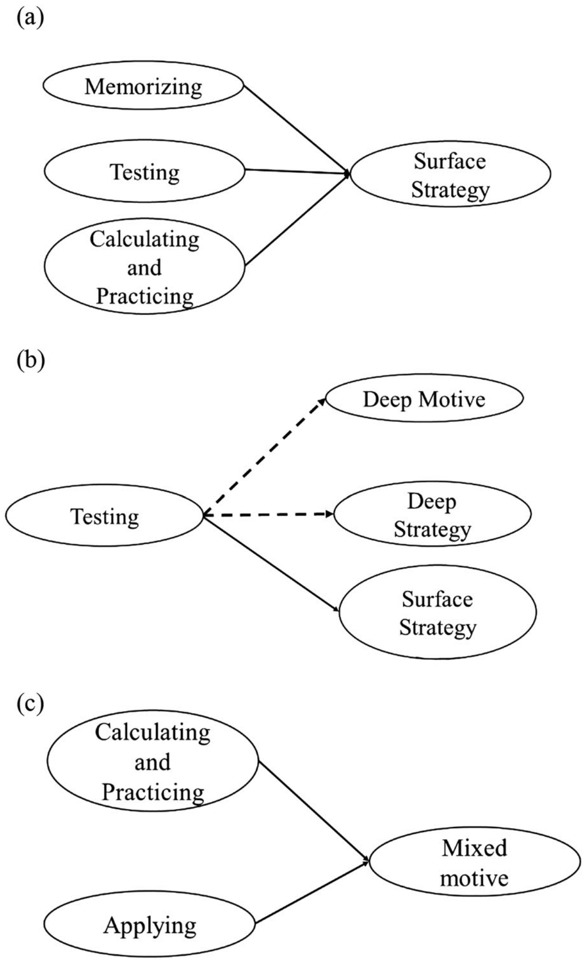

Figure 3. (a) The positive relation between lower level COLES and surface strategies for learning earth science; (b) the relationships between the conception of learning earth science factor 'Testing' and factors of ALES; (c) the positive relations among the conception of learning earth science factors 'Calculating and Practicing' and 'Applying' and mixed motives for learning earth science. Note: The dotted line represents a negative prediction. Mixed motive: both deep motive and surface motive for learning earth science.

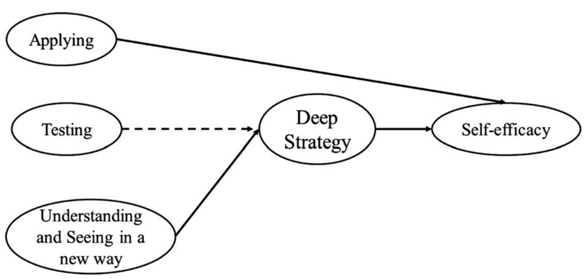

Figure 4. The direct and indirect relations among COLES, ALES, and SELES. Note: The dotted line represents a negative correlation.

a result of the emphasis on standard answers in tests. From elementary school through to high school, the key point of school education is to focus on training students to get better scores in the high-stakes college entrance examinations. Even at the college stage, when students are no longer confronted with the pressure of various burdensome tests, they still regard learning as preparing for tests. The results of this study may indicate that students' main purpose for enrolling in this earth science course is to get credits to fulfill the general education requirements of the university. In addition, many studies (e.g. Chiou et al., 2012) have also indicated that students who express lower level conceptions (i.e. Memorizing and Preparing for Tests) are unlikely to adopt deep approaches (i.e. Deep motive and Deep strategy) to learning. The present study echoes Chiou et al.'s (2012) research findings.

Moreover, if the meaning of learning earth science for students is to acquire knowledge of how to apply previously learned methods to unknown problems, and constantly practice tutorial tasks and problem-solving, students would concurrently possess both deep and surface motives (i.e. mixed motives) for learning (Figure 3(c)). To be more specific, the two conceptions of 'Applying' and 'Calculating and Practicing' trigger both deep and surface motives in earth science learning. According to Orion and Ault (2007), earth science is a subject which emphasizes knowledge integration, application, and problem-solving as a result of multiple content knowledge. Accordingly, earth science learning emphasizes application, calculating, and problem-solving. Moreover, with regard to goal orientation, Krapp, Hidi, and Renninger (1992) suggested that students may be intrinsically interested in a subject, but they may also value it because of its importance for completing their degree. These differential interests and value beliefs could bring about both intrinsic (i.e. Deep motive) and extrinsic (i.e. Surface motive) goal orientations. Given that participants in the present study are non-earth science majors, they may be interested in understanding the earth (deep motive), but they may well also possess a surface attitude to learn about it as they need to fulfill a course requirement and pass the examination so as to get the degree.

Compared with other studies on conceptions of and approaches to learning different subjects of science, the mixed learning motive seems commonplace. Chiou et al. (2012) found that students possessing the conceptions of 'Calculating and Practicing', 'Applying', and 'Understanding and Seeing in a new way' are more likely to hold mixed motives when learning biology, and Li et al. (2013) pointed out that students viewing chemistry learning as 'Memorizing' and 'Transforming' are prone to have mixed motives. In their study, the 'Transforming' conception refers to the higher level conceptions, such as Increasing one's Knowledge, Application, and Understanding and Seeing in a new way. Similarly, Chiou et al. (2013) also revealed that students regarding physics learning as 'Applying' and 'Understanding and Seeing in a new way' are inclined to possess mixed motives. By and large, from the results of the above studies and this current study, even if students have mature learning conceptions (i.e. applying), they may have mixed motives for learning the subject. Certainly, further studies are recommended to verify the role of the learning conception 'applying' in students' science learning.

In the present study, it is hypothesized that students' COLES are correlated with ALES, ALES is related to SELES, and consequently COLES are associated with SELES. These results reveal that this proposed model provided a statistically satisfactory fit for the data obtained in this study. The conceptions of 'Testing' and 'Understanding and Seeing in new way' are indirectly correlated to self-efficacy via deep strategies for learning earth science (Figure 4). Moreover, the conception of 'Applying' directly links to SELES. To be more specific, students' COLES (i.e. 'Testing' and 'Understanding and Seeing in a new way') made a significant contribution to their approaches to learning (i.e. Deep strategy), both negatively and positively, which were consequently positively connected with their self-efficacy for earth science. In other words, if students realize that true understanding and getting a new perspective are major features of learning earth science, they may adopt deep strategies to learn and be more prone to express a stronger sense of earth science learning self-efficacy. Nevertheless, if students still regard the major purpose of learning earth science as getting more familiar with test materials, they are likely to engage in a cycle of rote learning, and will thus fail to attain advanced self-efficacy. Moreover, the conception of 'Applying' plays an important role in students' self-efficacy in earth science learning. As mentioned above, earth science learning aims to explore the source of the development of the earth, and highlights the importance of the integration and application of knowledge. As a result, if students could realize that learning earth science is to learn how to apply knowledge or skills they have learned to solve problems, they would be more likely to express a stronger sense of earth science self-efficacy.

Based on the assumption that students' academic self-efficacy is related to their performance of science learning activities (Capa Aydin & Uzuntiryaki, 2009), teachers may need to help students relate new material to what is already known about the topic or apply knowledge to problem-solving and encourage them to adopt deep learning strategies, which might promote their advanced self-efficacy, and further produce good learning performance. Accordingly, if earth science education puts more emphasis on real-life application, truly understanding the connections among the different contents, and what students encounter in the surrounding world, it will encourage students to adopt deep strategies for learning earth science, in turn facilitating their advanced self-efficacy. For example, King (2008) proposed that earth science fieldwork presents important practical opportunities for the application of outdoor investigational skills and related techniques. Meanwhile, by the process of evaluation and interpretation of evidence found in the fieldwork, students should realize that earth science learning has to be conducted via Understanding and Applying. As natural disasters occur frequently in Taiwan (e.g. typhoons, earthquakes, and debris flows), these educational practices are important in earth science instruction. This study found evidence that the 'Understanding and Seeing in a new way' and 'Applying' conceptions play an important role in students' earth science learning, especially for students not majoring in earth science. Researchers and practitioners should invest efforts in this area in the future.

Conclusions and implications

This study provides more comprehensive insights into students' conceptions of, approaches to, and self-efficacy in earth science learning. The findings of the study indicated that the COLES of 'Understanding and Seeing in a new way' and 'Applying' play an important role in this relationship. More specifically, students who only view earth science learning as understanding the connection between earth science concepts, and who avoid emphasizing testing in the course could adopt deep strategies for learning, and further express a stronger sense of earth science self-efficacy. In addition, students with the learning conception of 'Applying' have advanced SELES.

The findings of this study provide some theoretical suggestions for future research and practical instruction design. First, students' COLES and ALES could adequately serve as two major components in their belief system of science self-efficacy. However, limited by the research method, the present study only revealed the relationships among COLES, ALES, and SELES. There is a need for research on the psychological mechanism among COLES, ALES, and SELES to explain the interactions by means of the experimental method. Second, Marton et al. (1993) proposed that students' conceptions of learning show a developmental and hierarchical trend, which moves from the lower to the higher level. Moreover, the present study revealed that 'Understanding and Seeing in a new way' and 'Applying' are significant factors in earth science learning. There is a need for further exploration into whether students' conceptions of learning could be changed to a higher level through specific teaching strategies. For example, teaching strategies using earth science fieldwork and inquiry-based instruction may allow students to experience the application of outdoor investigational skills and the processes of the evaluation and interpretation of evidence found in the fieldwork. Researchers should invest efforts into exploring this issue to examine whether the strategies improve students' higher level conceptions of learning in the future. Third, as previously mentioned, it is suggested that earth science teachers may need to provide students with much more learning experience of application, understanding, and getting new perspectives, and not overemphasize 'Testing' in the earth science course. They also need to design an environment which encourages students to learn earth science with deep understanding and in a meaningful manner. For example, technology-enhanced learning, earth science fieldwork, or inquiry-based instruction may provide ways for students to apply what they have learned and transfer it to multiple contexts. Moreover, Gummer and Shepardson (2001) have suggested that changing students' conceptions of learning is not only about obtaining more advanced conceptions of learning, but also includes seeking coherence between learning and assessment. Accordingly, so as to not overemphasize 'Testing' in the earth science course, teachers may need to construct assessments which can encourage students to evaluate information and transform their knowledge, such as peer and authentic assessment. Fourth, compared with the previous studies of conceptions of learning in different domains of science (e.g. physics, chemistry, and biology), the present results imply that non-earth science majors may employ a similar view of learning earth science as that regarding learning in other areas of science. The present findings may have potential contributions and implications for earth science teachers in terms of non-earth science major students' earth science learning. Researchers have urged the need to conduct a study to explore earth science major students' conceptions of, approaches to, and self-efficacy of learning earth science and to examine the differences in those variables between earth science majors and non-earth science majors. Furthermore, to understand the similarities and differences in students' conceptions of learning in different domains of science, future research may need to empirically examine students' conceptions of learning in different domains of science simultaneously. Fifth, as students' conceptions are influenced by culture (e.g. Tsai, 2004), it is suggested that other researchers conduct comparative studies for different countries. Finally, further studies are recommended to verify the role of the learning conception 'applying' in students' science learning. And, as aforementioned, in addition to the deep and surface approaches to learning, further studies are suggested to examine the role of 'strategic approach' in students' science learning.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Ministry of Science and Technology, Taiwan [100-2511-S-110-010-MY3, 102-2511-S-110-003-MY5].

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Appendix

Conceptions of learning earth science (COLES)

Memorizing

1 Learning earth science means memorizing the definitions, formulae, and laws found in the earth science textbook.
2 Learning earth science means memorizing the proper nouns found in the earth science textbook that can help solve the teacher's questions.
3 Learning earth science means memorizing earth science symbols, concepts, and facts.
4 In learning earth science, just like in learning history or geography, the most important thing is to memorize the content of the text book.

Testing

1 Learning earth science means getting high scores on examinations.
2 If there were no tests, I would not learn earth science.
3 The major purpose of learning earth science is to get more familiar with test materials.
4 I learn earth science so that I can do well on earth science-related tests.
5 There is a close relationship between learning earth science and taking tests.

Calculating and practicing

1 Learning earth science means constantly practicing calculations and problem-solving.
2 Learning earth science means knowing how to use the correct formulae when solving problems.
3 The way to learn earth science well is to constantly practice calculations and problem-solving.

Increasing one's knowledge

1 Learning earth science mainly means acquiring knowledge about earth science.
2 Learning earth science means acquiring knowledge that I did not know before.
3 I am learning earth science when the teacher tells me earth science facts that I did not know before.
4 I am learning earth science when I increase my knowledge of natural phenomena and topics related to nature.

Applying

1 The purpose of learning earth science is learning how to apply methods I already know to unknown problems.
2 Learning earth science means learning how to apply knowledge and skills I already know to unknown problems.
3 Learning earth science means acquiring knowledge and skills to enhance the quality of our lives.

Understanding and Seeing in a new way

1 Learning earth science means understanding earth science knowledge.
2 Learning earth science means understanding the connection between earth science concepts.
3 Learning earth science means expanding my knowledge and views.
4 Learning earth science helps me view natural phenomena and topics related to nature in new ways.
5 I can learn more ways of thinking about natural phenomena or topics related to nature by learning earth science.

Approach to learning earth science (ALES)

Deep approach

Deep motive

(1) I always greatly look forward to going to earth science class.
(2) I spend a lot of my free time finding out more about interesting topics which were discussed in earth science class.
(3) I come to earth science class with questions in my mind that I want to be answered.

Deep strategy

(1) I try to relate new material to what I already know about the topic when I am studying earth science.
(2) I try to understand the meaning of the contents I have read in earth science textbooks.
(3) I can ask myself possibly to understand the subject matter I have learned in earth science class.

Surface approach

Surface motive

(1) I worry that my performance in earth science class may not satisfy my teacher's expectations.
(2) No matter whether I like it or not, I know that getting a good achievement in earth science could help me to get an ideal job in the future.
(3) I want to have good achievement in earth science so that I can get a better job in the future.
(4) I want to do well in earth science so I can please my family and the teacher.

Surface strategy

(1) I find the best way to get high scores in earth science exams is to remember the answers to likely questions.
(2) I find that memorizing the most important contents of earth science makes me get high scores in earth science exams instead of understanding it.
(3) I will notice and memorize the parts that will appear in the exams when I learn earth science.

Self-Efficacy for learning earth science (SELES)

Self-efficacy

(1) I believe I will receive an excellent grade in class.
(2) I expect to do well in this class.
(3) I'm certain I can master the skills being taught in this class.
(4) Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.