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Conceptions of learning science among high school students in Taiwan: a phenomenographic analysis

Chin-Chung Tsai ^a

^a Institute of Education and Center for Teacher Education , National Chiao Tung University , Hsinchu, Taiwan E-mail:

^b Center for Teacher Education & Institute of Education , National Chiao Tung University , 1001 Ta Hsuch Rd, Hsinchu 300, Taiwan E-mail:

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RESEARCH REPORT

Conceptions of learning science among high school students in Taiwan: a phenomenographic analysis

Chin-Chung Tsai, Institute of Education and Center for Teacher Education, National Chiao Tung University, Hsinchu, Taiwan; email: cctsai@mail.nctu.edu.tw

Educators and psychologists have evidence that students' conceptions of learning have a profound influence on the learning process, and thus are related to learning outcomes. The purpose of this paper was to explore the conceptions of learning science held by 120 Taiwanese high school students. The interview data gathered from these students, analysed by a phenomenographic method, revealed seven categories of conceptions of learning science, including: learning science as memorizing, preparing for tests, calculating and practising tutorial problems, the increase of knowledge, applying, understanding, and seeing in a new way. The educational contexts or curricular programmes in which these high school students enrolled also played a role in their conceptions of learning science. This study finally proposed a framework to describe the variations of the conceptions of learning science, consisting of the following features: the forms of knowledge acquisition, motivational orientations, and standards of evaluating learning outcomes. How to change students' unfruitful conceptions of learning science was also discussed.

Introduction

Educators and psychologists have been interested in exploring learners' conceptions of learning and epistemological beliefs about the nature of knowledge (Buehl et al. 2002, Duell and Schommer 2001, Hofer 2000). These researchers also show some evidence that these conceptions or beliefs have a profound influence on the learning process (Hofer and Pintrich 1997, Schommer 1998, Sinatra 2001). As a result, research about students' conceptions of learning has received much attention among educators, particularly in respect of higher education (for example, Boulton-Lewis et al. 2001, Marshall et al. 1999, Morris 2001). These studies have revealed that students have a variety of the conceptions of learning that may thus be related to their approaches to learning itself.

Although the earliest research about students' epistemological development in general was Perry's (1970) study, a pioneering work about conceptions of learning was that of Saljo (1979). Based on a more complete and detailed analysis of students' responses to their views about learning, later termed the phenomenographic method by Marton (1981, 1986), Saljo (1979) distinguished five qualitatively different conceptions of learning (table 1). The phenomenographic method, which has combined interview, protocol and discourse analyses, is used to identify students' qualitatively different, hierarchically related, conceptions of learning, and it is frequently employed in this line of research (Richardson 1999). Following Saljo, many researchers have investigated the conceptions of learning held by different

Table 1. Conceptions of learning proposed by educators.

<i>Saljo (1979)</i>	<i>Marton et al. (1993)</i>	<i>Eklund-Myrskog (1998)</i>	<i>Marshall et al. (1999)</i>
Increase of knowledge	Increasing one's knowledge	Remembering	Memorizing
Memorizing	Memorizing	Understanding	Applying equations and procedures
Acquisitions of facts, procedures that can be retained and/or utilized in practice	Applying	Applying knowledge	Making sense of physical concepts and procedures
Abstraction of meaning	Understanding	Getting a new perspective	Seeing in a new way
An interpretative process aimed at the understanding of reality	Seeing something in a different way Changing as a person	Forming a conception of one's own	A change as a person

groups of students in a variety of educational contexts. Table 1 presents a brief review of the categorization of students' conceptions of learning revealed by such studies. Although these studies were conducted with various groups of students, their findings and categories about the conceptions of learning could be viewed as a revised version of those proposed by Saljo (1979).

This study, through analysing the interview data gathered from 120 high school students in Taiwan, was intended to explore their conceptions of learning, particularly toward the subject of science.

Rationales of the study

This study, exploring Taiwanese high school (11th grade and 12th grade) students' conceptions of learning science through a phenomenographic analysis, was undertaken on the basis of the following five rationales.

First, research has revealed that the conceptions of learning are related to learning approaches, which then influence the learning outcomes. For example, the study conducted by Purdie et al. (1996) showed that the Australian and Japanese secondary students having the conception of learning as 'understanding' tended to have better use of self-regulated learning strategies. Dart et al. (2000) found that high school students in Australia who reported qualitative conceptions of learning (such as emphasizing understanding) tended to use deep approaches to learning, whereas students holding quantitative conceptions of learning (such as focusing on memorization) were likely to use surface approaches. Research also suggested that deep approaches to learning were associated with better learning outcomes (Chin and Brown 2000, Trigwell and Prosser 1991). These findings strengthen the need for probing different conceptions of learning held by students, because they are related to students' learning strategies and thus their outcomes.

Second, students' conceptions of learning are influenced by culture. Purdie et al. (1996) showed that Australian and Japanese students had quite different conceptions of learning. Educators have asserted that using the phenomenographic method can explore conceptions that may be influenced by cultures, as it enhances the possibility of revealing some conceptions that are 'endemic' to the culture (Dahlin and Regmi 1997: 473). Many recent studies about the conceptions of learning for a variety of cultural groups have used the phenomenographic method (Boulton-Lewis et al. 2000, 2004, Richardson 1999). As the sample in this study included a group of high school students in Taiwan, who were educated in an Eastern culture, the phenomenographic method was utilized in this study. The study conducted by Marton et al. (1997) exploring high school students' conceptions of learning in Hong Kong also used the phenomenographic approach. Marton et al. (1997) also highlighted the importance of studying Asian (particularly Chinese-related) students' conceptions of learning, as there were seemingly paradoxical results between two stereotypes of 'the brainy Asian' and 'the Asian learner as a rote learner'. The current study investigating Taiwanese students' conceptions of learning science may provide some insights for the stereotypes.

Third, the conceptions of learning are related to educational contexts. The studies by Eklund-Myrskog (1997, 1998) and Marshall et al. (1999) supported this claim, and they found students with different majors or educational contexts, such as nursing, engineering or science, expressed quite different conceptions of learning. As these studies examined the role of educational contexts or majors on students' conceptions of learning, they were usually conducted with higher education students who had a clearer focus on the field of learning. In Taiwan, high school students, from the beginning of the 11th grade, are required to choose a major either in the field of science or art and then they are educated with different types of curricula. Because the sample in this study consisted of Taiwanese 11th and 12th graders, it provided a particular opportunity to examine the role of educational contexts or curricular programs on the conceptions of learning. Therefore, one important feature of this study was the fact that it was a *comparative* study across two subject domains (science versus art) within the high school educational background of Taiwan. This part of the exploration may also expand the findings gathered from higher education students to younger learners.

Fourth, the conceptions of learning, to some extent, are domain dependent. In other words, an individual student may have different conceptions toward different domains of learning (e.g. science versus history). The review by Buehl and Alexander (2001) and studies by Hofer (2000), Lonka *et al.* (1996) and Prosser et al. (1996) shared this view. Buehl and Alexander (2001) called these conceptions as domain-specific epistemological beliefs. This study further differentiated the domain-specific epistemological beliefs as 'academic domain-specific epistemological beliefs', as shown in figure 1. In figure 1, the conceptions of learning are viewed as academic (school) epistemological beliefs, representing student beliefs about school knowledge and learning. However, these conceptions or beliefs are probably related to domain-specific epistemologies. For example, students may have quite different views about the nature of science and the nature of history, and then guide them to different conceptions about learning science and learning history. That is, students' views about the nature of the knowledge domain still play a role in their conceptions of learning toward the specific domain of knowledge. Research in science education exploring students' views about the nature of science also has

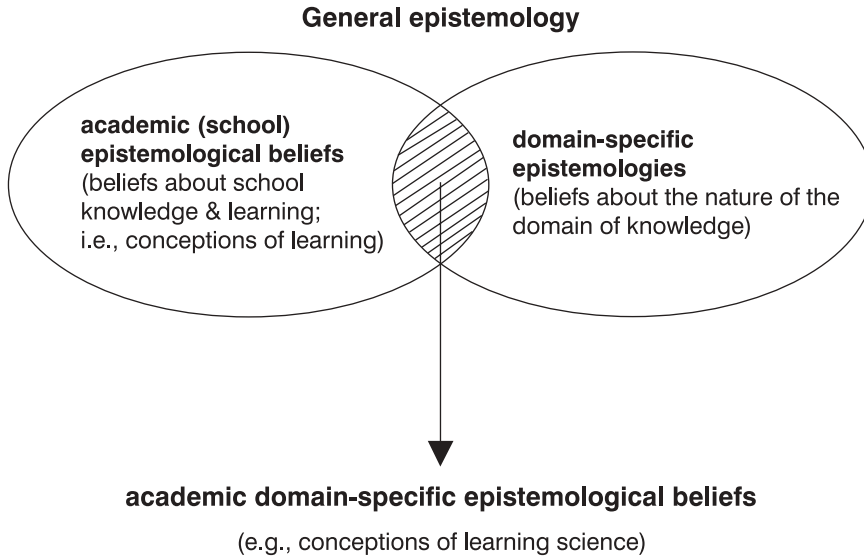


Figure 1. The academic domain-specific epistemological beliefs, an interplay between academic epistemological beliefs and domain-specific epistemologies.

suggested that students' epistemological beliefs about science are related to their approaches to learning science (Lederman 1992, Tsai 1998a, 1998b, 1999, 2000a). Therefore, instead of probing students' conceptions of learning in general, this study was intended to reveal students' conceptions of learning science in particular. That is, the purpose of this study was to explore students' academic domain-specific epistemological beliefs in science, as illustrated in figure 1.

Finally, many studies in this line of research have focused on college students (for example, Boulton-Lewis et al. 2001, Marshall et al. 1999, Morris 2001), with only a few exceptions on high school students (Marton et al. 1997). This type of research should not be limited to higher education, as younger students have already developed their conceptions of learning (or learning science). A careful investigation about relatively young students' conceptions of learning can provide more insights for the existing research literature. Hence, this study chose high school students as the target subjects for research.

Based on the aforementioned rationales, this study explored 120 Taiwanese high school students' conceptions of learning science. As these conceptions may be highly related to cultures, the phenomenographic method was utilized in this study. Moreover, how their majors may play a role in their conceptions of learning science was also examined.

Method

Sample

The sample in this study included 120 11th and 12th graders (62 males and 58 females) in Taiwan. The educational environments in Taiwan may represent those typically found in Eastern countries and cultures. For instance, Taiwan basically

employs nationwide curricula or curricular standards. For entry to high schools and colleges, certain nationwide standard examinations are required for students. As a result, students, teachers, and parents in Taiwan focus on or experience high pressure related to the scores on the nationwide standard tests. The class size in high schools is usually large (around 50 per class) and the teaching method generally is more traditionally oriented (such as lecturing and textbook reading). In addition, intensive practice for tutorial problems and using a variety of in-class quizzes, particularly for science and mathematics, are commonly viewed as being very helpful in improving students' test scores.

The selected students in this study came from 12 high schools across different demographic areas in Taiwan. For each participating school, a total of 10 students were selected for interviews about their conceptions of learning science. In Taiwan's high school system, at the end of 10th grade study, every student is required to choose a major either from science or art, thus leading to two different types of curricular programmes. The science-major programme is designed for students who wish to continue their (college) study in the fields of natural sciences, medicine, and engineering, whereas the art-major programme is for students intending to pursue advanced study in the fields of art and social studies. Therefore, these two programmes have different foci of curricula, and, certainly, the science-major programme includes more courses related to mathematics and natural sciences (such as physics and chemistry). Students' choice of major at this stage is fairly important, as they will have different subject examinations in nationwide College Entrance Examinations. In addition to some core subject tests, such as Chinese, English and mathematics, the science-major students should take the subject tests such as physics, chemistry, and biology, while the art-major students should take those of history and geography. Their scores on the subject tests will influence their qualification of entering the college departments. In general, only science-major students can enter science-related, medicine-related or engineering-related departments in colleges, and, similarly, only art-major students can get in some art-related or social science-related college departments. Since this study will examine the role of educational contexts (or majors) on students' conceptions of science, such a major grouping for these students has provided a particular opportunity to explore this issue at the high school level. Among the 120 students selected, 60 students were enrolled in the science-major programme and the other 60 students were in the art-major programme.

Data collection

The research data were gathered by interviewing the sample students. Each student was interviewed individually by a trained researcher. The interview was conducted in a semi-structured way. The guiding interview questions were mainly modified from the studies done by Marshall et al. (1999) and Tsai (1998b), as follows:

- What do you understand by 'learning science'?
- How do you know when you have learned something about science?
- How do you learn science?

All of the individual interviews were tape-recorded. The interviews were conducted in Chinese and then fully transcribed for further analyses. The verbatim transcripts of student interviews were the major data of analysing students' conceptions of learning science.

Data analysis

The analysis of the verbatim transcripts of student interviews was undertaken by the phenomenographic method. Similar to the method used by Eklund-Myrskog (1998), for each student's interview transcripts, the researcher first underlined the most important sentences and marked some keywords that characterized the student's views of learning science. By comparing the sentences underlined and the keywords derived from the interview transcripts, the content-specific similarities and differences between students' interview replies about their views about learning science were explored and summarized. Then, the researcher constructed 'qualitatively different' categories of description that were used to classify the conceptions of learning science held by students. For instance, the researcher selected the following sentences that were perceived as the most important to describe one student's conceptions of learning science:

When learning science, I usually need to memorize a lot of formula, definitions, and laws to solve the problems. All of these are very abstract to me, and I often don't know how to remember and recall them in an effective way.

The researcher then underlined some keywords such as 'memorize', 'remember', and 'recall' that characterized the student's main ideas about learning science. The other student had the following responses:

When learning science, I need to memorize many concepts, facts, symbols, and equations ... There are often a lot to be remembered. I often need to rehearse these concepts and equations again and again to keep them strictly in my mind.

The researcher again marked some keywords to illustrate the student's conceptions in learning science, such as 'memorize', 'remember', and 'rehearse'. By comparing the similarities and differences between students, some categories for the conceptions of learning science emerged. For example, the keywords of 'memorize', 'recall', 'remember', and 'rehearse' shared a high degree of resemblance, but these keywords were quite different from others. Consequently, a category of 'learning science as memorizing' was gradually developed by the researcher. In other words, when analysing the interview data gathered for the phenomenographic approach, the researcher explored consistencies and differences essentially across rather than within the students' responses (Marton et al. 1997).

Moreover, as asserted by Eklund-Myrskog (1998), the 'qualitatively different' categories indicated different ways of conceiving the phenomenon in focus (i.e. the conceptions of learning science in this study) — not in terms of the amount of detail provided, but rather in relation to their structural meanings. Each category was intended to show a unique way of understanding the phenomenon being researched. Therefore, the purpose of such a phenomenographic analysis in this study was to reveal some categories of description that could characterize the qualitatively different perspectives in which learning science was conceptualized or experienced by the selected students.

Findings

Conceptions of learning science

Through a phenomenographic analysis of students' interview results, seven qualitatively different conceptions of learning science were identified in this study. By

presenting the interview transcripts in the following,¹ each student is given an identification, including one letter and one number. The letter indicated his/her major: 'A' for art majors and 'S' for science majors. The number is a sequential identifying number for each individual in a major group. The seven categories about the conceptions of learning science are now described, with some student interview quotations provided.²

Learning science as memorizing (called 'memorizing'). In the first category, learning science was characterized as the memorization of definitions, formulae, laws, and special terms. The purpose of learning science was to store all of these information bits in an effective way. For example, students stated that:

- A17: When learning science, I usually need to memorize a lot of formula, definitions, and laws to solve the problems. All of these are very abstract to me, and I often don't know how to remember and recall them in an effective way.
- A22: I just have an impression that in science classes, the teachers often state many special terms and formula in which I am supposed to memorize. These terms and formulae are foreign to me, but I need to try to store in my mind to answer the teachers' questions, homework assignments and tests.
- S41: When learning science, I need to memorize many concepts, facts, symbols, and equations. Sometimes, I feel that I am learning social studies such as history and language while learning science. There are often a lot to be remembered. I often need to rehearse these concepts and equations again and again to keep them strictly in my mind.

The students in this category probably learned science by reproducing knowledge through a rehearsal or rote memorization technique. In this way, they could memorize scientific information, an important criterion in showing their learning of science.

Learning science as preparing for tests (called 'testing'). Students in the second category conceptualized learning science as preparing for tests. Their purpose of science learning was to pass the examinations or to achieve high scores in science tests. For example, students responded that:

- A9: The major purpose of learning science is to pass the exams and have high exam scores, and then get into good colleges.
- A11: Learning science involves the recall of scientific facts to correctly answer the questions in the tests. If there are no tests, I will not learn science.
- A50: I cannot see other benefits of learning science, except for getting good scores in the tests. In fact, I can live well without knowing the scientific facts.
- A55: Learning science is preparing for the tests. I often think why we need science. The existence of scientific knowledge is just for testing us.
- S31: Learning science is preparing for tests. Science, for us, is a major subject for the College Entrance Examination.³
- S53: Learning science indicates a process of getting familiarity of test materials. Sometimes, I try to memorize the codified procedures of solving certain science tutorial problems without understanding their meanings, because these problems frequently appear in the tests.⁴

Students in this category highly valued the importance of the success in tests. One student even claimed that 'the existence of scientific knowledge is just for testing us'. The standard of evaluating learning outcomes was mainly dependent on the test scores.

Learning science as calculating and practising tutorial problems (called 'calculating'). In the third category, science learning was viewed as a series of calculating, practising

tutorial problems, and manipulating formulae and numbers. The process of calculation and tutorial problem-solving was oriented to compute a correct answer. Students, for example, replied that:

- A1: Learning science involves a series of calculations, and problem-solving. It often requires a very complicated sequence of problem-solving procedures to finish a problem.
- A26: Science always gives a lot of situations and numbers. Then, we need to use these numbers, with some formula, to calculate an answer, which is still a number. Therefore, good math ability is required to learn science well.
- A41: When learning science, I am often required to fill numbers into some formulae, and then to get a final result. It is a stuff of calculations and manipulations of formulae and laws.
- S10: Learning science involves the application or rearrangement of certain formulae to compute a right answer.

The ‘calculating’ conception of learning science may have been shaped by the way in which school science is presented. School science texts as well as instructional activities often present scientific knowledge in terms of formulae, equations, and calculations. Many students may have good proficiency in computing a right answer with which to solve a science problem, but they may not really understand the meaning of the answer or the nature of the problem. For these students, learning science was viewed as a process of obtaining familiarity with algorithmic procedures and formalism.

Learning science as the increase of knowledge (called ‘increase’). In this category, an increase of knowledge was seen as the main feature of learning science. The acquisition and accumulation of (correct) scientific knowledge were the major purposes of learning science. For instance, students stated that:

- A10: Learning science indicates the acquisition of scientific knowledge. I have more knowledge derived from science instruction.
- A5: The purpose of learning science is to acquire more knowledge about natural phenomena and living things.
- S25: Learning science is to increase knowledge in science. The increase of knowledge can enlarge the life scope.
- S45: Learning science indicates the increase of correct scientific knowledge to know how the nature works.

Clearly, students classified in this category emphasized an increase of scientific knowledge when learning. Their views also implied that learning science involved a careful accumulation of accurate scientific knowledge.

Learning science as applying (called ‘applying’). Students in this category stressed the importance of applying science to practical situations. Consequently, the purpose of science learning was the application of received knowledge. Students, for example, responded that:

- A2: Learning science is to acquire some knowledge and skills to solve real-life problems. Science needs to be applied to solve practical problems.
- S13: Learning science helps us obtain knowledge. The knowledge can be applied to invent more products to improve the quality of our life.
- S47: Learning science is not just getting the knowledge, facts or definitions. It involves some methods of exploring questions. I can apply the methods to examine some unknown or interesting questions.

Based on these interview responses, for some of these students (e.g. S47) learning science was not only applying knowledge to solve a variety of problems or to improve life quality, but also involving the ability to apply the methods of exploring science questions to other situations.

Learning science as understanding (called 'understanding'). In this category, a true understanding was conceptualized as the major feature of learning science. Moreover, students characterized in this category highlighted the ability to construct integrated and theoretically consistent knowledge structures in science. For instance, students stated that:

- A32: Learning science needs a deep understanding of scientific knowledge. If you do not really understand, you will encounter a lot of conflict. And, you will not make sense of its concepts.
- S18: Learning science is to understand how the nature works. The understanding is not just for tests. I can use it to interpret and relate other knowledge and information.
- S6: Learning science requires a true understanding. Understand what the scientific laws and knowledge mean. And, when I really understand, I do not need to memorize many details.
- S59: The most interesting and particular thing for leaning is a request for understanding. When I really understand, all of the scientific concepts are consistent. And, I can easily use them to make sense of natural phenomena and to solve problems.

Students in this category evaluated the learning science on their ability to make sense of natural phenomena based on acquired scientific knowledge. Some of them (e.g. S6) claimed that learning science did not need to rely on memorization when a true understanding was achieved. This view was probably an opposite view to the first category, which conceptualized science learning as memorizing.

Learning science as seeing in a new way (called 'seeing in a new way'). In the final category, science learning was viewed in terms of getting a new perspective. The acquisition of scientific knowledge was to obtain a new way to interpret natural phenomena. Students, for instance, replied that:

- A56: Learning science helps me look at many things and phenomena in new ways. But, sometimes, the new ways are pretty abstract.
- S39: Learning science brings new ways to see natural phenomena for me. Often, the scientific knowledge challenges my intuitions, and I finally know that I was incorrect in seeing something.

Although these students believed that learning science helped them acquire a new way of seeing nature, the new way, to some extent, was abstract and challenging for a few of them.

Distribution of students' conceptions of learning science

Based upon the seven categories revealed, each student's interview response was classified into one individual category that mainly represented his/her conception of learning science. Such categorization process was undertaken by the author, and was further validated by a second independent researcher, who actually viewed the verbatim interview transcripts.⁵ The distribution of students' conceptions of learning among the seven categories is presented in table 2 ($n = 120$).

Table 2. Students' conceptions of learning science ($n = 120$).

<i>Conception</i>	<i>n</i>	<i>Percentage</i>
Memorizing	7	5.8
Testing	19	15.8
Calculating	23	19.2
Increase	24	20
Applying	17	14.2
Understanding	23	19.2
Seeing in a new way	7	5.8

Table 2 shows that about 20% of the students, respectively, viewed learning science as 'calculating and practising tutorial problems', 'the increase of knowledge', and 'understanding'. However, few students conceptualized learning simply as 'memorization' (5.8%), whereas still few students perceived learning science as 'seeing in a new way' (5.8%).

The role of educational contexts (or majors)

This study further examined the role of educational contexts in students' conceptions of learning science. As 60 high school students in this study were science majors, and the other 60 were art majors, this study allowed for an opportunity to analyse students' conceptions of learning science by different educational contexts. Table 3 presents this part of findings.

Table 3 shows that more art-major high school students conceptualized learning science as 'calculating and practising tutorial problems' (26.7%) than science-major students (11.7%). On the other hand, more science-major students expressed the conception of learning science as 'applying' or 'understanding' (20% and 26.7%, respectively) than art-major students (8.3% and 11.7%, respectively). A chi-square test revealed that these two groups of students did have statistically different distributions across the seven conceptions of learning science (chi-square = 13.14, degrees of freedom = 6, $p = 0.041$). These findings also advanced those informed by previous studies on college students (for example, Eklund-Myrskog 1997, 1998,

Table 3. Students' conceptions of learning science, sorted by majors.

<i>Conception</i>	<i>Science majors [n (%)]</i>	<i>Art majors [n (%)]</i>
Memorizing	2 (3.3)	5 (8.3)
Testing	8 (13.3)	11 (18.3)
Calculating	7 (11.7)	16 (26.7)
Increase	13 (21.7)	11 (18.3)
Applying	12 (20)	5 (8.3)
Understanding	16 (26.7)	7 (11.7)
Seeing in a new way	2 (3.3)	5 (8.3)

Note: Pearson chi-square = 13.14, degrees of freedom = 6, $p = 0.041$ ($p < 0.05$).

Marshall et al. 1999), and concluded that students' conceptions of learning (science) were related to educational contexts or majors, even at younger ages, such as at the high school level.

Nevertheless, how educational contexts and conceptions of learning (science) interact or influence each other may still need further exploration. For example, there may be a possibility that the educational contexts influence students' conceptions of learning science. Or, *vice versa*, students with certain conceptions of learning science may guide them to choose different educational contexts. For instance, for those students who view learning science simply as practicing tutorial problems, they may decide not to become science majors (because they will feel bored for the calculation and problem-practising activities). On the other hand, students who conceptualize learning science as 'applying knowledge' or 'understanding' may more recognize the merits of scientific knowledge and learning science, and then choose science as their major. The interplay between students' conceptions of learning and their selection of educational contexts is an interesting issue for educators to conduct investigations.

Discussion and conclusions

The categories identified in this study suggested a description about students' conceptions of learning science as a hierarchical system (i.e. from 'memorizing' to 'seeing in a new way'), which concurred with the purpose of using the phenomenographic method as asserted by Marton (1994). Many students in this study held the 'calculating', 'increase', and 'understanding' conceptions of learning science, while few students expressed those of 'memorizing' and 'seeing in a new way'. The results seemingly suggested that many of the sampled students reflected a stereotype of 'Asian learner as a rote learner', showing their conceptions of learning science as 'calculating and practising tutorial problems'. Still many other students might express another stereotype of 'the brainy Asian', who conceptualized learning science as 'understanding'.

Furthermore, on the basis of the review presented in table 1, there were two categories — 'testing' and 'calculating' — that had not been revealed in previous studies. The origins of these two new categories may be related to the educational environments in Taiwan and the nature of school science. In Taiwan, a variety of tests in school and national levels are still playing an important role in representing students' performance, and then influence the opportunities for advanced study. Test scores are usually highlighted by the teachers, parents, and students. Moreover, science is often a school subject in which it is difficult to succeed in tests. The connection between learning science and test scores (which are often low) is strong for many students. Therefore, students may conceptualize learning science simply as preparing for tests. Besides, school science texts and tests often present science as a series of numbers, formulae, calculations, and tutorial problem-solving. Many problems or questions shown in science texts ask for an accurate answer in terms of numbers, perhaps without a deep understanding. These may strengthen students' impression that learning science merely involves a series of calculations and practising tutorial problems. The studies presented in table 1 only explored students' conceptions of learning (in general); therefore, the 'calculating' conception was not explicitly revealed. One may argue that these two new categories may be part of existing category; for instance, the 'testing' category may be overlapped with the

category of ‘memorizing’, since many students used memorization to fulfill the needs of tests. However, given the particular educational environments in Taiwan and the unique feature of school science as already described, this study believes that these two categories are new. These findings were also consistent with the assertion proposed by Marton et al. (1997) that students’ conceptions of learning could be characterized in terms of similar overall structure across cultures; there were thus some common elements, but some other elements were emphasized in certain cultures. This study also revealed that some new elements about the conceptions of learning might be found when a particular domain such as science was chosen for deep exploration.

Moreover, the seven categories about the conceptions of learning science can be developed with the following contrasts:

- Forms of knowledge acquisition: ‘reproducing’ versus ‘knowing’ versus ‘extending and developing’.⁶
- Motivational orientations: ‘external’ (fulfilling external requests or pressures) versus ‘internal’ (fulfilling personal development).
- Standards of evaluating learning outcomes: ‘quantitative’ (how much is learned) versus ‘qualitative’ (how well it is learned).⁷

These seven categories, then, can be conceptualized into a map as illustrated in figure 2. The ‘memorizing’ and, perhaps, ‘increase’ conceptions of learning science are more oriented to the ‘reproducing’ form of knowledge acquisition, while ‘applying’ and ‘seeing in a new way’ are more aligned with the form of ‘extending and developing’. In terms of motivational orientations, the conceptions of ‘memorizing’, ‘calculating’ and, particularly, ‘testing’ are probably inspired by external factors (such as, to pass the examinations or to search for better scores),⁸ whereas the rest of the four categories are more likely to be related to students’ internal or personal desire for learning.

Furthermore, the conceptions of ‘memorizing’, ‘testing’, ‘calculating’, and ‘increase’ are more related to a quantitative view of learning science, as these conceptions probably emphasize more on how much is learned. The quantitative view also implies that learning science is a process of accumulation of new and accurate information in memory. The view embodied in the quantitative perspective suggests an ‘atomized’ view about science in which science is seen as a set of separate facts and procedures to be learned with little integrating framework. Students who conceptualize learning science as ‘understanding’, ‘applying’, and ‘seeing in a new way’ may try to integrate and refine scientific knowledge and then extend it to other situations. Therefore, their standard for evaluating the outcomes of learning science is mainly placed on how well they learn about science, a qualitative view of learning science. The qualitative view also implies that learning science involves qualitative re-organizations of existing knowledge structures, and it reflects a desire to understand, explain and relate separate phenomena and procedures. In Marton’s terminology (Marton et al. 1993, 1997), the quantitative view is oriented to a focus on ‘the signs’ (i.e. simply on the details of learning materials), while the qualitative view is more oriented to the focus going beyond the signs (i.e. ‘the signified’), that to which the learning materials refer.

These three aforementioned features (forms of knowledge acquisition, motivational orientations and standards of evaluating learning outcomes) can effectively map the categories about the conceptions of learning or learning science. In the

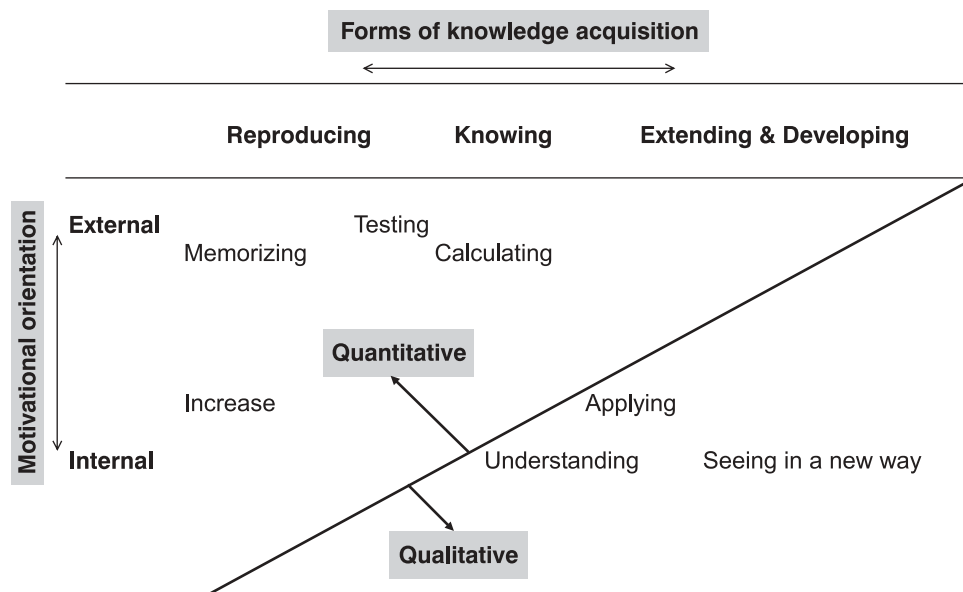


Figure 2. A framework describing the variations of students' conceptions of learning science.

future, if researchers reveal additional categories, these features can help them locate or compare a variety of conceptions about learning or learning science.

In addition, based on the results in table 3, one-half of science-major students had a qualitative view about learning science (combining the students of 'applying', 'understanding', and 'seeing in a new way' conceptions), whereas only 28.3% of art majors held a similar view and certainly many of them had a quantitative view of learning science. Dart et al. (2000) found that students asserting a qualitative conception of learning (such as emphasizing understanding) tended to use deep approaches to learning, whereas students who reported a quantitative conception of learning (such as focusing on memorization) were likely to use surface approaches. If the findings proposed by Dart et al. can be applied to those of the present study, it is anticipated that many science majors seem to engage more in deep approaches to learning science, while many art majors may learn science through surface approaches. Research also suggested that deep approaches to learning science were associated with better learning outcomes (Chin and Brown 2000).

The qualitative view of learning science is consistent with the constructivist view proposed by contemporary educators.⁹ The constructivist view of learning science asserts the following:

- The curriculum and instruction should emphasize the depth, not the breadth of scientific knowledge. A true understanding is better than the memorization of a collection of scientific facts (Brooks and Brooks 1993).
- Learning science involves the ability to apply the scientific knowledge to numerous situations and authentic contexts (Black and McClintock 1996, Roth 1997, Tsai 2001).

- Science or scientific knowledge is a way of knowing, but not the only way. Learners should view science as a way of exploring natural phenomena (Tsai 1998c, 2000b).
- Learning science involves active restructuring of existing conceptions (Dole and Sinatra 1998, Driver and Oldham 1986, Posner et al. 1982).

The first three assertions correspond to three conceptions of learning science, which are categorized as a qualitative view. The first assertion is clearly related to the ‘understanding’ conception of learning science, the second is consistent with the ‘applying’ conceptions, and the third assertion is in agreement with the ‘seeing in a new way’ conception. The final assertion, which displays the fundamental merits of constructivism, also concurs with the qualitative view of learning as a whole, suggesting that learning science involves active and qualitative reorganization of knowledge structures. The qualitative view or constructivist-oriented view of learning science is encouraged by many contemporary science educators. It is expected that having such a view can help students engage in deep approaches and meaningful learning about science.

Educators, then, face an important issue; that is, how to change students’ unfruitful conceptions of learning science, such as those of ‘memorizing’, ‘testing’, and ‘calculating’. Studies on changing students’ conceptions of learning may reveal some insights for this issue. For instance, Boulton-Lewis et al. (2001) have found that education at university, where there is some need to understand and explain phenomena in relation to a variety of theories, can probably help students construct more appropriate conceptions of learning. Similarly, if science instruction can encourage students to interpret natural phenomena or observations in terms of different theoretical perspectives, students’ conceptions of learning science may be improved. Marton et al. (1997) also considered the conceptions of learning that changed over time for individual students. The ‘stability’ of the conceptions, as well as how to change students’ inappropriate conceptions of learning, may need more research.

Finally, science teachers’ conceptions of learning and teaching may also play a role in students’ conceptions of learning science. Although there has been no direct investigation into this research topic, it is intuitively plausible to assume that science teachers’ conceptions of learning (and teaching) will guide their instructional approaches and then shape students’ conceptions of learning science.¹⁰ Donnelly (1999) and Tsai (2002, 2003) have shown that many science teachers may hold inappropriate conceptions about science instruction. For example, Tsai (2002) found that more than one-half of the teachers in his sample expressed the conceptions of learning and teaching science similar to the ‘memorizing’ and ‘calculating’ conceptions revealed in this study. These conceptions may influence their strategies of science instruction, such as conducting many teaching activities on memorization of scientific facts or on extensive practice for tutorial problems, and then misguide students’ conceptions of learning.¹¹ Science teacher education programs need to carefully address these, and need to help preservice and practising teachers shape more advanced conceptions about teaching and learning science. Therefore, the obvious study that now needs to be carried out is one that compares science teachers’ views of learning science with those of their students. If there is a strong correlation between these two, changing

the students' conceptions may simply be a matter of changing their teachers' conceptions.

This study explored students' conceptions of learning science. However, this study does not deeply probe into why the individual students felt one way or the other about their science learning; that is, how the view of science that they articulated fit into their view of the school. Moreover, researchers are encouraged to probe students' conceptions of learning toward other knowledge domains, such as mathematics and history. Consequently, the similarities as well as the differences across various academic domains of epistemological beliefs held by students can be further revealed.

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Notes

1. The interview transcripts presented in this paper were translated by the author, and were validated by a second independent researcher.
2. The interview quotations presented are those perceived as the most representative or fruitful ideas expressed by the interviewed students.
3. The College Entrance Examination is a nationwide test that determines many Taiwanese high school students' entrance for college study.
4. For S53, his conception for learning was somewhat across the first three categories ('memorization', 'testing', and 'calculating'). However, his conception was toward a target, the tests.
5. In some cases, the students might express mixed views across different categories. This situation was also revealed in a previous study (Marton et al. 1993). In order to provide a more direct and clear analysis for students' conceptions, this study, similar to the method utilized by Tsai (2002) and Koballa et al. (2000), used the most dominant or fundamental category as perceived by the researchers to represent each student's interview data (e.g. the case of S53, described in note 4). Two researchers have classified the students' conceptions of learning science into one of the seven categories. For the interview data that did not have the researchers' agreed categorization, the researchers reviewed the interview transcripts again and discussed case by case, and then determined a final categorization. In other words, the reliability check for categorization was undertaken.
6. This feature is similar to that proposed by Dahlin and Regmi (1997) for categorizing students' conceptions of learning. Dahlin and Regmi viewed conceptions of learning as three levels of depth about knowledge, including acquiring, knowing, and applying.
7. This feature is modified from Dart et al. (2000).
8. It is plausible to believe that students categorized in 'memorizing' and 'calculating' may be motivated by external factors (e.g. tests), as the assessment of science learning often involves a recall of scientific facts or a series of calculations.
9. Although constructivism is still a controversial topic in science education (Matthews 2000, Niaz et al. 2003, Osborne 1996), the position of this paper, as that proposed by Staver (1998) and Tobin (1993), asserts that constructivism is a sound theory to help science educators understand how students learn science, as well as to explicate the practice of science and science teaching.
10. A probably related study was conducted by Trigwell et al. (1999), reporting that science teachers' approaches to teaching were associated with their students' approaches to learning science.
11. Certainly, some science teachers would argue that the conceptions they have are the most instrumentally functional when confronted by the summative assessment for which they must prepare their students.

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