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CONCEPTIONS OF LEARNING SCIENCE IN INFORMAL ENVIRONMENTS AMONG PRIMARY SCHOOL STUDENTS IN MAINLAND CHINA

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Abstract. *Previous studies on students' conceptions of learning science (COLS) have focused primarily on formal environments. In these studies, students' COLS were positively associated with their approaches to and outcomes for science learning. However, little research has been conducted to explore students' conceptions of learning science in informal environments (COLSIE), despite its importance to students' academic achievement. To fill this research gap, this study qualitatively and quantitatively explored Chinese primary school students' COLSIE. First, in Study I, interview data gathered from a group of 80 students were analysed using the phenomenographic method, and ten hierarchical categories of COLSIE emerged (e.g., communicating and explaining). Based on these categories, a survey was developed and distributed to another group of 414 students in Study II. Exploratory factor analysis was conducted to validate the survey, which revealed nine factors matching the ten categories except for the initial categories of applying and understanding. This study also revealed the commonalities and uniqueness of COLSIE in comparison with students' COLS in formal environments. The findings suggested that informal science learning experiences may strengthen students' impressions of science practices. Science educators are encouraged to provide their students with opportunities to engage with science practices in informal environments.*

Keywords: *primary school students; Mainland China; conceptions of learning science; informal environments; phenomenographic*

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Introduction

Science learning is a process occurring in both formal and informal environments (Bell et al., 2009; Duschl et al., 2007). Students' experiences of learning science in informal environments include a broad array of activities, such as visiting museums and natural parks, attending science clubs and out-of-school programs, reading science books, and searching for science-related information online (Aubusson et al., 2012; Bell et al., 2009; Lin & Schunn, 2016). These diversified learning experiences have been found to be different from those in formal environments in various aspects (Bell et al., 2009; Falk, 2005; Tal, 2012). Accordingly, students' conceptions of learning science in informal environments (COLSIE) may be different from their conceptions of learning science (COLS) in formal environments, as conceptions of learning have been found to be domain-specific and context-dependent (e.g., Marton et al., 1993; Tsai, 2004).

Previous studies on students' COLS have focused primarily on students in formal learning situations and found that students' COLS were positively associated with their approaches to and outcomes for science learning (e.g., Zheng et al., 2018). However, little research has been conducted to explore students' COLSIE, given the importance of learning science in informal environments to students' academic achievement worldwide (Bell et al., 2009; Shaby & Vedder-Weiss, 2019; Tang & Zhang, 2020). To fill this research gap, this study explored primary school students' COLSIE in Mainland China.

Learning Science in Informal Environments

Students learn science in either formal or informal environments. While formal science learning normally takes place at school and in the classroom, informal environments for learning science include various out-of-school con-

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texts such as museums, science centres, and summer programs (e.g., Bell et al., 2009). Learning science in informal environments is also known as outdoor education, everyday science learning, lifelong learning, and free-choice learning (Ellenbogen, 2003; Falk, 2005; Philip & Azevedo, 2017; Tal, 2012; Vedder-Weiss & Fortus, 2011; Zimmerman et al., 2019). In this study, the term informal science learning is adopted and defined as learning science in organized situations (e.g., participating in science clubs), in everyday life (e.g., reading sciences books), and through the media or web (e.g., watching science-related TV programs and searching for science-related information by using media) (Aubusson et al., 2012; Bell et al., 2009; Lin & Schunn, 2016; Tang & Zhang, 2020). According to the National Research Council, informal science learning is guided by "learner interests, voluntary, personal, ongoing, contextually relevant, collaborative, nonlinear, and open-ended" (Bell et al., 2009, p. 11).

It has been widely recognized that the characteristics of students' experiences of learning science in informal environments are different from those in formal environments. First, informal science learning includes a broad array of activities occurring across various environments, including designed, every-day, or public settings (Anderson & Ellenbogen, 2012; Aubusson et al., 2012; Bell et al., 2009; Lin & Schunn, 2016). Second, with respect to the structure of learning activities, informal science learning seems structureless and nonsequential. However, it provides students with more opportunities to communicate and interact with peers or other adults (Bell et al., 2009). Finally, informal science learning experiences are often believed to be driven by learners' intrinsic motivations and interests (Alexander et al., 2012; Holmes, 2011). That is, learners tend to voluntarily participate in informal science learning activities (Falk, 2005; Tal, 2012).

Recent studies have tried to classify students' informal science learning experiences into finer grain-sized dimensions. For example, according to the object of learning and structure of activity, they were specified into three areas: everyday settings and family activities, designed environments, and after-school and adult programs (Bell et al., 2009). In addition, Lin and Schunn (2016) pointed out that students' informal science learning experiences can be considered from four dimensions, i.e., informal home science, semiformal science, nature, and museum.

Conceptions of Learning Science

Conceptions of learning refer to "a coherent system of knowledge and belief about learning and related phenomena" (Negovan et al., 2015, p. 643). In the science education field, students' COLS were found to be correlated with their science learning process (Chiou et al., 2012; Lee et al., 2008). Lee et al. (2008) reported that high school students who possessed higher-level or constructivist COLS were more likely to adopt deep approaches to learning science. Researchers have also established a close link between students' COLS and self-efficacy in learning science, i.e., an essential factor in predicting their science learning achievement performance (Lee et al., 2019; Tsai et al., 2011). For instance, Tsai et al. (2011) revealed that high school students' higher-level COLS positively predicted their self-efficacy in learning science. In a recent study, Zheng et al. (2018) investigated the interrelationships among students' COLS, their approaches to and the self-efficacy of learning science. They reported that primary school students' higher-level COLS had a positive influence on deep approaches to learning science, and only students' deep approaches to learning science had a positive impact on their self-efficacy of learning science.

The phenomenographic method is often adopted to explore students' conceptions of learning in various topics (Marton et al., 1993; Tsai, 2004; Zhao & Thomas, 2016). The phenomenography was considered "a distinctive qualitative approach" to exploring students' learning (Richardson, 1999, p. 53). It has been utilized by many researchers in Sweden, Australia, Hong Kong, and Taiwan (Chiu et al., 2016; Gao & Watkins, 2002; Saljo, 1979; Tsai, 2004). The phenomenography aimed at describing, analysing, and understanding learning experiences (Marton, 1981) and believed that there are variations in how different people conceive of learning experiences (Marton & Booth, 1997). Variations can be discovered by combining interviews, protocols, and discourse analysis (Richardson, 1999). Within this framework, an outcome space would be established to represent the variations in students' qualitatively different, hierarchically related conceptions of learning (Marton & Booth, 1997; Tsai, 2004). Marton and Booth (1997) defined a hierarchical outcome space, as each successive category is a more complex way of experiencing learning. For example, in a pioneering phenomenographic work, Saljo (1979) revealed five qualitatively different and increasingly comprehensive categories of conceptions of learning:, i.e., (i) *increase of knowledge*, (ii) *memorizing*, (iii) *acquisitions of facts and procedures that can be retained and/or utilized in practice*, (iv) *abstraction of meaning*, and (v) *an interpretative process aimed at the understanding of reality.*

Overall, previous studies have shown that students' conceptions of learning are influenced by various do-

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main-specific and context-dependent factors, e.g., subjects, culture, and educational environments (Boulton-Lewis et al., 2000; Chiu et al., 2016; Marton et al., 1993; Tsai, 2004). First, for instance, students' COLS may be different from learning other subjects. In one of the early studies that applied phenomenographic methods, Tsai (2004) explored Taiwanese high school students' COLS. His study revealed seven increasingly sophisticated categories of COLS: *memorizing*, *testing*, *calculating and practising tutorial problems*, *increasing knowledge*, *applying*, *understanding*, and *seeing in a new way*. Specifically, the origin of the conception of *calculating and practising tutorial problems* was suggested to be related to the nature of school science. That is, science was always presented as a series of numbers, formulas, calculations, and tutorial problem solving in school science texts and tests.

Students' COLS may also be influenced by culture. Initially, it was assumed that there might be some unique conceptions of learning or learning sciences that are "endemic" to a specific culture (Dahlin & Regmi, 1997; Negovan et al., 2015). Previous studies have verified this assumption to some extent (e.g., Marton et al., 1993; Tsai, 2004). For instance, *testing*, a new category of COLS revealed by Tsai (2004), was attributed to Taiwan's prevailing culture of examinations. In a similar vein, Zhao and Thomas (2016) found a new category of COLS, i.e., *listening to their teacher*, among high school students in Mainland China. This category was believed to represent the feature of obedience stressed and reinforced in high schools in Mainland China.

In addition, another series of studies has shown that students' different educational environments could influence their COLS. For example, Tsai and Kuo (2008) explored students' COLS in a cram school, a unique educational context that aims to improve students' exam scores through the repeated practise of tutorial exercises. Their study found that most student participants conceptualized learning science as memorizing school knowledge, preparing for tests, or calculating and practising tutorial problems. In a recent study, Chiu, Lin, and Tsai (2016) adopted the phenomenographic method to investigate Taiwanese university science-major students' COLS in the laboratory and identified six hierarchical categories: *memorizing*, *acquiring manipulative skills*, *obtaining authentic experience*, *examining prior knowledge*, *reviewing prior learning profiles*, and *achieving in-depth understanding*. While the conceptions of *memorizing* and *achieving in-depth understanding* have been previously identified by Tsai (2004) for COLS in general, the remaining four conceptions are unique for COLS in the laboratory.

Boulton-Lewis et al. (2000) expanded their focus to informal environments. They compared students' conceptions of formal and informal learning among 22 Aboriginal and Torres Strait Islander students from three Australian universities. Their study revealed clear differences between students' conceptions of learning in different environments. Specifically, three main conceptions were evident for formal learning, i.e., *acquiring knowledge*, *understanding*, and *personal growth*. In comparison, four conceptions were confirmed for informal learning, i.e., *acquiring skills by observation and imitation*, *acquiring cultural and social knowledge* from family members or elderly individuals, *developing practical skills* by active problem solving, and *seeking information* by finding appropriate resources. Importantly, most students in their study showed inconsistency between their conceptions of formal learning and those of informal learning.

Research Questions

Previous studies have demonstrated that students' conceptions of learning are often affected by different learning environments and their cultural values (Chiu et al., 2016; Tsai, 2004; Zhao & Thomas, 2016). Overall, the apparent differences between students' conceptions of formal and informal learning in general have also been partially evidenced by previous studies (Boulton-Lewis et al., 2000). While COLS have been widely studied in formal environments, little research has been conducted regarding this topic in informal environments. Thus, it is important to explore students' COLS exclusively in informal environments.

The current research aimed to explore primary school students' COLSIE in Mainland China. It consisted of two studies: in Study I, phenomenographic analysis was conducted on students' interview data to qualitatively explore their COLSIE; in Study II, based on the qualitatively different categories of COLSIE obtained in Study I, a COLSIE survey was developed and distributed to a group of primary school students. Later, its reliability and validity were quantitatively assessed. Specifically, this research was conducted to address the following research questions:

1. What are the different categories of descriptions that classify COLSIE held by primary school students in Mainland China?
2. To what extent is the COLSIE survey reliable and valid for assessing primary school students' COLSIE in Mainland China?

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Research Methodology

General Background

In the current study, student participants aged 10 to 12 years were recruited from grades 4 to 6 in seven primary schools in South China. These schools were selected through purposive sampling. Specifically, they varied in terms of students' enrolment, the quality of teachers, the socioeconomic status of students' families, and the socioeconomic level of the local communities. Therefore, the student participants in the study were believed to be representative of the majority of primary school students in Mainland China due to the diverse background information of these schools. It also met the requirements of the participant's variation suggested by the phenomenographic method.

Study I: Qualitative Exploration and Categorization of COLSIE

Participants and Procedures

In Study I, 80 students (41 boys and 39 girls) from three of the seven primary schools voluntarily participated in an individual interview. Prior to the interview, these students were confirmed to have informal science learning experiences. They were interviewed individually in a semistructured way. The individual student interviews were conducted in Chinese. Two researchers majoring in science education conducted the interviews.

Modified from two previous studies on COLS (Chiu et al., 2016; Tsai, 2004), five interview questions were used:

- What do you usually do when learning science in informal environments?
- How do you understand the meaning of learning science in informal environments? Or, in your opinion, what does learning science in informal environments mean to you?
- How do you learn science in informal environments?
- How do you know that you have learned something about science in an informal environment?
- What do you think the purpose of learning science in informal environments is?

Data Analysis

The individual student interviews were electronically recorded. These recorded interviews were transcribed into verbatim transcripts. Two researchers jointly analysed these transcripts following the phenomenographic method (Chiu et al., 2016; Tsai, 2004). First, for each student's transcript data, the most important sentences or keywords were marked to characterize the student's views of learning science in informal environments. Then, by comparing these highlighted sentences and keywords, the similarities and differences across students' responses were carefully investigated and identified. Finally, a hierarchical system composed of qualitatively different conceptions of description was constructed, which provided a framework to classify the student participants' COLSIE.

To illustrate the data analytical procedure in detail, two students' interview data are shown below. Each student was given a numerical identification with three digits, in which the first digit indicates his/her grade level (4, 5, or 6), and the remaining two digits were a sequential identifying number randomly assigned to each student in the same grade group. For example, 429 referred to a fourth-grade student who was also the 29th participant in grade 4. When collecting data from each student, we stored each student's information in one file using his or her three-digit identification number. For example, student 429 had a file named 429, and all his/her answers to the interviews would be recorded there. The interview data presented in the following section were translated from Chinese to English by the authors. An additional bilingual researcher unfamiliar with the current research was asked to translate the English version of the interview data back to Chinese to ensure translation correctness. The back-translated data were then compared against the original data for further revision and refinement. No misinterpretations were detected, and hence, the translation process was finalised.

> 429. Learning science in informal environments is about real experiences. For example, I once *came into contact* with some snails on the grass and *observed* them carefully. I have also *watched* the process of larval metamorphosis into a chrysalis.
>
> 517. I *witnessed* some specimens of microorganisms in a museum. With my mom's assistance, I also performed some

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experiments on oral epithelial cells and shrimp eggs. (A follow-up question was asked: How do you know that you have learned something about science in an informal environment?) I got to *see exactly* what the microorganisms and onion samples look like.

In the first part of the interview segment, some keywords indicating the student's views of learning science in informal environments were marked, e.g., "came into contact," "observed," and "watched". In a similar manner, another set of keywords was highlighted in the second example, such as "witnessed" and "see exactly." Next, by looking across these two students' responses, a category of *obtaining authentic experience through activities* emerged to capture the similarity of the keywords mentioned by the two students above. Overall, a total of ten categories in a hierarchical order were identified to represent students' COLSIE, which will be discussed in the results section. These qualitatively different categories presented here could serve as a coding scheme to categorize students' COLSIE.

Previous studies have also revealed that students' conceptions of learning may be across multiple categories (e.g., Lin & Tsai, 2008; Tsai, 2009). Following recent developments, this study used the "main" conceptions proposed in Tsai (2009) to provide a certain representation of the students' major views of COLSIE. Specifically, the main conception referred to the most frequent conception each student expressed in the interview. For example, in the results section, two quotations from student 601 were identified as *applying* and *understanding*. However, in his complete interview data, the conception of *applying* was mentioned only once, whereas the conception of *understanding* was discussed three times. Hence, student 601's main conception was identified as *understanding*. In a similar manner, two researchers classified each student's main conception into one of the ten categories. For students who had two or more conceptions that shared the same highest frequency, the researchers examined their interview transcripts again, discussed case by case, and then determined a final main conception.

Study II: Development and Validation of the COLSIE Survey

Instrument

In line with studies on students' conceptions of learning, some researchers have argued the importance of developing a corresponding instrument to conduct a large-scale investigation, which would provide empirical evidence for the validity of the structure of conceptions of learning derived from interview data (Chiu et al., 2016; Lee et al., 2008; Lin & Tsai, 2013). Therefore, a COLSIE survey was developed in Study II to validate the ten categories of COLSIE identified in Study I.

The ten categories of students' COLSIE identified in Study I served as the guiding framework for the development of the COLSIE survey (see the Appendix). For each of the ten categories, statements or sentences were extracted from the transcripts to represent each category. Concurrently, some items from Lee, Johansson, and Tsai's (2008) Conceptions of Learning Science Inventory and Chiu, Lin, and Tsai's (2016) Conceptions of Learning Science by Laboratory Survey were also adopted. These items modified from previous studies are marked with an asterisk.

For each of the ten categories, three to six five-point Likert-type items ranging from *strongly agree* to *strongly disagree* were constructed. As a result, a 52-item, ten-factor initial version of the COLSIE survey was developed (see the Appendix). The face validity of the survey was first evaluated by two science teachers and nine of their students. Except for minor wording modifications, both teachers and their students agreed that the instrument was suitable for assessing the target student population.

Participants and Procedures

The COLSIE survey was randomly distributed to a group of 413 students (236 boys and 176 girls) from the remaining four schools recruited for the current study. Specifically, the survey was presented in Chinese and distributed by their teachers in a 45-minute free period, which was sufficient for the students to complete the survey.

Data Analysis

After students' survey responses were collected, exploratory factor analysis (EFA) with principal component extraction and oblimin rotation was conducted to explore the structure of the survey. Principal component extraction was chosen to estimate the number of latent factors extracted from the empirical data, which provided

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evidence for the construct validity of the survey. It may also help validate ten categories of the COLSIE identified in Study I. Specifically, the number of factors was determined based on the criteria of eigenvalues greater than 1. Next, oblimin rotation was used to determine the factor structure because it is reasonable to assume that the factors (or the various categories of students' COLSIE) are correlated with each other, as they characterized different aspects of a single construct, i.e., their COLSIE. Meanwhile, correlations between the factors were also estimated. In addition, Cronbach's alpha was calculated to guarantee the reliability of each factor and the entire survey (see Table 2). According to DeVellis (2016), a Cronbach's alpha coefficient of 0.65–0.70 is "minimally acceptable", a coefficient between 0.70 and 0.80 is "respectable", and a coefficient between 0.80 and 0.90 is "very good". The statistical analysis was conducted using IBM SPSS Statistics version 23.

Research Results

Study I: Categories of Chinese Primary School Students' COLSIE

In Study I, through a phenomenographic analysis of students' interview data, ten quantitively different categories of COLSIE were identified, which showed progressively comprehensive views with a hierarchical outcome space of COLSIE. They are described below in detail, with some student interview comments provided.

Category 1: Learning Science in Informal Environments as Memorizing

In the first category, the memorization of scientific phenomena, concepts, and facts was seen as the main feature of learning science in informal environments. In other words, the major purpose of learning science in informal environments for some students was to memorize as much information as possible for later recall, as evidenced by the following student interviews:

> 419: I memorize it so that I immediately know the answer when I am asked a relevant question related to science.
> 518: I always try to recall what I have learned (about science). If I can repeat them, it means I have mastered them.

Here, students emphasized that memorization was an important tool for learning science in informal environments. This rehearsal or rote memorization helped them establish science knowledge in their long-term memory, which could be extracted if required (e.g., to respond to questions and to recall).

Category 2: Learning Science in Informal Environments as Practising Tutorial Problems

Students whose response fell into this category had experience practising many tutorial problems in informal environments. For instance, some students stated that:

> 415: I always assign myself some science sublet exercises at home to check to what degree that I have understood the science knowledge.
> 608: My teacher at the cram school always assigns homework after class. I have to apply a specific concept or principle (e.g., the reaction force) to solve a problem. I can get knowledge from problem-solving exercises.

As revealed in the above example, the sources of tutorial problems may be different, and they could be provided by the students' parents or their teachers at cram school. Some students even take the initiative to find and solve some problems by themselves. They were willing to or asked to practise many tutorial problems because they wanted to excel in learning school science. They also believed that practising tutorial problems can foster their conceptual understanding.

Category 3: Learning Science in Informal Environments as Recording by Way of Notetaking

In this category, recording what they observed, felt, and learned was considered by some students a notable outcome of learning science in informal environments. This conception is consistent with some scientific practices documented earlier in the history of science, e.g., the records of Millikan's oil drop experiment and Galileo's inclined

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plane experiment. The student participants, for example, commented that:

> 424: After visiting the Science and Technology Museum exhibitions, I wrote down some reflections of the trips when I got home.
>
> 502: When doing experiments or reading books, I usually take notes of my thoughts or the new knowledge I have learned.
>
> 615: When learning science outside the classroom, I like to record what I observed. For example, I will draw the details about the plants.

Given these comments, the students stressed the importance of keeping a record of some details and descriptions of the learning process and outcomes. They believed that writing down essential information or their reflections could facilitate their science learning.

It is worth noting that the conceptions of *memorizing* and *recording* emphasize different aspects of learning outcomes. When the students conceptualize COLSIE as *memorizing*, they store some fragmented facts or concepts of science in their brains internally. However, students who consider COLSIE as *recording* tend to use external devices (e.g., a notebook) to help them sort out the information they obtained and to capture all essential details. The students that fell into the category of *recording* may reflect a traditional proverb: "The faintest ink is better than the best memory." In other words, the students in this category value the importance of notetaking.

Category 4: Learning Science in Informal Environments as Increasing Knowledge

Increasing knowledge was also reported as a major feature of learning science in informal environments. Some student participants believed that learning science in informal environments is an effective way to broaden the scope of their existing scientific knowledge. In other words, in their opinion, knowledge acquired from informal learning is an extension of that taught by their science teachers in the classroom. For instance, students pointed out:

> 406: We can learn something that our teachers have not taught through learning in informal environments. In this way, we know more about science.
>
> 529: I get to know many modern technologies when visiting the museum of science and technology. I can also learn many things through reading science-related books or doing some experiments by myself.
>
> 620: In addition to learning science at school, I can learn about science and discover science knowledge in my daily life.

Here, these students believed that knowledge learned in informal environments builds on their previous knowledge acquired from formal science classrooms. In some early works, the conception of *increasing knowledge* was classified as reproductive conceptions of learning (Marton et al., 1993; Saljo, 1979). However, some recent empirical studies in science and engineering education have pointed out that the conceptions of *increasing knowledge* should be classified as constructive conceptions of learning. For example, Lin and Tsai (2009) revealed that college students who preferred laboratory inquiry activities and constructive learning environments tended to show more agreement with the conception of *increasing knowledge*. Lin et al. (2012) also provided empirical evidence that the conception of *increasing knowledge* should pertain to constructive conception through confirmatory factor analysis. In informal environments, students' science learning experiences are often driven by their intrinsic motivations and interests (Alexander et al., 2012; Holmes, 2011). As a result, students might favour active accumulation of a certain amount of science knowledge in informal environments, which shapes informal science learning connected with constructive learning. However, the accuracy of knowledge obtained informally may not be guaranteed.

Category 5: Learning Science in Informal Environments as Obtaining Authentic Experience through Activities

Students in this category conceptualized learning science in informal environments as *obtaining authentic experience through activities*. They expected to observe scientific phenomena or items by engaging in real-life experiences, such as directly interacting with plants and animals in the natural environment or visiting science museums. The students, for instance, stated that:

> 429: Learning science in informal environments is about real experiences. For example, I once came into contact with

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some snails on the grass and observed them carefully. I have also watched the process of larval metamorphosis into a chrysalis.

515: I'd like to conduct some experiments mentioned in my textbook or in the lectures, e.g., the buoyancy caused by the buoyant force or the shadow made on a surface when something stands between a light and the surface.

517: I witnessed some specimens of microorganisms in a museum. With my mom's assistance, I also performed some experiments on oral epithelial cells and shrimp eggs. (A follow-up question was asked: How do you know that you have learned something about science in an informal environment?) I got to see exactly what the microorganisms and onion samples look like.

The students in this category claimed that learning science in informal environments allows them to witness something. Some students with this conception may purposefully act out what they previously mentioned in their learning materials (e.g., the textbook mentioned by student 515). However, some other students with this conception may have no presupposed idea about what they are going to learn in informal environments (e.g., the science museum discussed by student 517) and to obtain real-life experience beyond the classroom.

It is worth noting that there is a clear distinction between *recording* and *obtaining authentic experience*. As discussed in the category of *recording*, students may write down their reflections of their authentic experience. To record, they try to capture the exterior details of the objects or phenomena they have observed. In other words, they focus on the learning outcomes or the tangible end product created in the learning process. In comparison, students who consider COLSIE as *obtaining authentic experience* value the process of the activities they participate in informal environments, as well as the mental and emotional experiences provided during the process.

Category 6: Learning Science in Informal Environments as Communicating and Explaining

Students in this category believed that the primary purpose of learning science in informal environments is to engage in a conversation and to share their science-related knowledge with others. To what extent do they fluently talk about this type of knowledge was recognized as a critical indicator for the quality of their scientific understanding. Students responded that:

403: If I can tell what I know about science out loud to someone else, I know I have mastered it.

503: When talking to my parents or classmates, I always share something interesting about science. It also helps me double-check the extent to which I have learned something.

605: As a volunteer, I will first make sure that I understand the exhibits' scientific principles. Then, I can explain the underlying mechanisms and answer follow-up questions from visitors.

The students in this category claimed that informal environments provide them with opportunities to communicate with others or to explain scientific phenomena to others. Through communication and explanation, their understanding of science may be modified and strengthened.

Category 7: Learning Science in Informal Environments as Applying

Students in this category conceptualized learning science in informal environments as applying their established science-related knowledge to solve practical problems. The scope of application of their knowledge may also be extended when they found themselves in similar or dissimilar situations. By doing so, they also tend to create some "scientific inventions," which may be impractical or may already exist. For example, students claimed that:

402: I am interested in informal science learning because I can apply what I learned outside the school to experience new scientific inventions.

521: Visiting the science museum helps me refresh my memory of some science principles that I learned previously. I found it interesting to apply the same principles to conduct a similar experiment using different home materials.

601: I think that learning science in informal environments can expand my knowledge of science, which I can use to solve problems in my real life and thus makes my life easier.

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According to these statements, students in this category emphasized using their own science-related knowledge in informal environments. That is, informal environments provide students with opportunities to apply their knowledge to solve problems in a real situation or to create something they desire.

It is important to discuss the distinctions between this category and two relevant conceptions, i.e., *practising* and *communicating and explaining*. Although both the *practising* and *applying* highlight solving problems, the *practising* is limited to solving familiar and well-structured problems; in contrast, the *applying* is extended to solving unfamiliar and ill-structured problems in the real world. In addition, the *communicating and explaining* and *applying* conceptions are both based on students' previous existing understanding of science. However, notably, *communicating and explaining* emphasizes human interaction, while the conception of *applying* highlights students' interaction with the material world.

Category 8: Learning Science in Informal Environments as Understanding

In this category, learning science in informal environments was viewed as achieving a deep understanding of scientific knowledge. As shown in the following examples, students believe learning science in informal environments facilitates their understanding of scientific phenomena and provides them with new insights into how science-related devices work.

> 417: Using the planetarium as an example, I can observe many scientific phenomena. After listening to the tour guide's information at the planetarium, I get to know the causes of the phenomenon. I can learn how the observation equipment is made.
> 520: Learning science in informal environments allows us to learn the habits of animals in nature and to understand how plants grow or acquire information regarding food chains and food webs.
> 601: When visiting the science museum, I prefer to experience some science-related facilities and figure out how they work.

Here, learning in informal environments helped students understand the development of theories and principles about the natural world (e.g., how plants grow) and engineering design (e.g., observation equipment). In addition to simply knowing what science is, students in this category are eager to explore further and to make sense of some science development. Accordingly, there is a significant difference between this category and the category of *increasing knowledge*: the former highlights students' understanding of science knowledge in depth, whereas the latter focuses on expanding their understanding to build a large pool of information.

Category 9: Learning Science in Informal Environments as Improving Oneself through Opportunities

In this category, students conceptualized learning science in informal environments as a way of improving themselves. Their goal of learning science in informal environments is to make themselves better people. Improving themselves was further regarded as the foundation of serving family and nation in the long term. For example, students stated that:

> 405: Learning science in informal environments is helpful for my family because it provides me with many career opportunities and choices in the future. In this way, I may serve my country better.
> 416: Learning science in informal environments helps increase my intelligence and abilities.
> 508: When I am learning science in informal environments, I will identify and correct some shortcomings in myself.

Students in this category believed that their intellectual abilities could be improved through learning science in informal environments. Therefore, they will become competitive when entering the job market. Later, they will be able to take care of their family and serve their country better. Interestingly, this view reflected a kind of traditional Chinese culture, namely, Jingshi-zhiyong (经世致用), roughly translated to English as learning should contribute to good governance. Under the influence of traditional culture, students want to improve themselves by learning science in informal environments because they care about their family's well-being and are eager to contribute to their country.

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Category 10: Learning Science in Informal Environments as Seeing in a New Way

In the final category, learning science in informal environments was regarded as obtaining a new way of exploring the natural world. For example, students stated:

> 425: After learning science in informal environments, I now think of the natural world more clearly. I can analyse some phenomena from different perspectives.
> 603: We used to do some science experiments in informal environments. These activities taught me how to understand the nature of science better.

Learning science in informal environments provided students with opportunities to change their epistemology of science. In other words, these informal experiences changed how they approach science phenomena and how they are able to further explore the nature of science from different perspectives.

Distribution of Primary School Students' Main COLSIE

As discussed previously, each student's interview responses were classified into one main individual category, which represented the students' major views of COLSIE. In other words, each student's strongest conception, i.e., the most frequent conception expressed in their interview data, was selected to represent their main conceptions. The distribution of these primary school students' main conceptions is shown below in Table 1.

Table 1
Distribution of Students' Main Conceptions of Learning Science in Informal Environments (n=80).

Category	Main conceptions *n* (%)
Memorizing	0
Practising tutorial problems	1 (1.25)
Recording by way of notetaking	2 (2.50)
Increasing knowledge	34 (42.50)
Obtaining authentic experience through activities	35 (43.75)
Communicating and explaining	1 (1.25)
Applying	2 (2.50)
Understanding	3 (3.75)
Improving oneself through opportunities	2 (2.50)
Seeing in a new way	0

Notes: The frequencies of *memorizing* and *seeing in a new way* were 0 because no one took them as their main conceptions. Using student 518 as an example, while a quotation from him was identified as *memorizing* in Category 1, his main conception was identified as *increasing knowledge* because, in his complete interview data, the conception of *increasing knowledge* was discussed the most frequently (three times). In contrast, the conception of *memorizing* was mentioned only once. Similarly, students' main conceptions were classified into the remaining eight categories because the categories of *memorizing* and *seeing in a new way* were discussed at the lowest frequency in their interview data.

As shown in Table 1, among the 80 interviewed students, the major feature of learning science in informal environments was found to be *obtaining authentic experience through activities* category (*n*=35), followed by *increasing knowledge* (*n*=34). However, interestingly, the frequencies for the remaining categories of COLSIE were relatively low.

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Study II: Development and Validation of the COLSIE Survey

In Study II, students' responses to the COLSIE survey were analysed using exploratory factor analysis (EFA) with principal component extraction and oblimin rotation methods. Afterwards, Cronbach's alpha was calculated to assess each factor's reliability and the final version of the COLSIE survey, as suggested by the EFA results. In addition, the correlations between the factors were also estimated. The EFA results and the reliability of the COLSIE survey are shown below in Table 2.

Exploratory Factor Analysis and Reliability of the COLSIE Survey

First, sampling adequacy for EFA was examined using Bartlett's test of sphericity and KMO measurements. The results indicated that the samples were appropriate for EFA ($\chi^2(666)=5436.874$ $p<.001$, and KMO=0.928). During the analysis, items with a factor loading of less than 0.4 were subject to elimination (Netemeyer et al., 2003). As a result, a total of 37 items were retained and formed a nine-factor structure, which explained 59.935% of the cumulative variance, as presented in Table 2. The final version of the COLSIE Survey is listed in the Appendix, in which some items were underlined, as they were suggested to be dropped based on the EFA results.

As shown in Table 2, the nine factors retained were labelled in the order of appearance, such as *memorizing* (ME), *practising tutorial problems* (PP), *recording by way of notetaking* (RE), *increasing knowledge* (IK), *obtaining authentic experience through activities* (OA), *communicating and explaining* (CE), *applying and understanding* (AU), *improving oneself through opportunities* (IO), and *seeing in a new way* (SE). Overall, these nine factors were similar to the ten categories of COLSIE identified in the findings of Study I.

The retained items of the seventh factor (AU), in particular, consisted of original items from *applying* and *understanding*. As shown previously in Study 1, the original categories of *applying* and *understanding* were suggested to be adjacent in the hierarchical outcome space of COLSIE. Accordingly, it seemed reasonable to group both the *applying* category and *understanding* category into a single factor entitled "*applying and understanding*" (AU). Previously, these two categories were grouped into a single factor in studying university students' conceptions of learning chemistry (Li et al., 2013). For instance, students may link the two items derived from the *applying* category, labelled AU1 and AU2 in the Appendix, to *understanding* items. It is possible that applying knowledge in informal environments provides students with a better transfer of learning, which helps them achieve a deeper understanding of science.

The reliability coefficients revealed by Cronbach's alpha values ranged from 0.688 to 0.834 for the subscales and were 0.950 for the whole scale of the COLSIE survey, which all exceeded the lower limit criterion of 0.65 (DeVellis, 2016). Accordingly, the COLSIE survey, with nine factors (scales), was considered sufficiently reliable and acceptable for assessing primary students' COLSIE.

Table 2

Rotated Factor Loadings and Reliability of the Nine Factors of the COLSIE Survey (n=414).

	F1	F2	F3	F4	F5	F6	F7	F8	F9	Cronbach's alpha
ME1	.661									
ME2	.603									
ME3	.609									.745
ME4	.735									
ME5	.548									
PP1		-.781								.740
PP2		-.710								
RE1			-.571							
RE2			-.555							.688
RE3			-.544							

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	F1	F2	F3	F4	F5	F6	F7	F8	F9	Cronbach's alpha
IK1				.618						
IK2				.588						.767
IK3				.520						
IK4				.611						
IK5				.596						
OA1					.742					.803
OA2					.771					
OA3					.596					
CE1						-.789				
CE2						-.877				.761
CE3						-.413				
AU1							-.512			
AU2							-.498			
AU3							-.473			.822
AU4							-.569			
AU5							-.729			
AU6							-.625			
IO1								.705		
IO2								.589		
IO3								.535		.791
IO4								.402		
IO5								.421		
SE1									.587	
SE2									.747	
SE3									.662	.834
SE4									.728	
SE5									.635	

Notes: ME: *memorizing*; PP: *practising tutorial problems*; RE: *recording by way of notetaking*; IK: *increasing knowledge*; OA: *obtaining authentic experience through activities*; CE: *communicating and explaining*; AU: *applying* and *understanding*; IO: *improving oneself through opportunities*; and SE: *seeing in a new way*.

Primary School Students' Scores on the Nine Scales of the COLSIE Survey

The average scores and standard deviations of the nine scales of the survey in Study II are presented in Table 3. These statistics describe the degree of students' recognition of the nine scales of COLSIE.

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Table 3
Descriptive Statistics and Correlation of Students' Scores on the COLSIE Scales (n=414).

Scale	M	SD	ME	PP	RE	IK	OA	CO	AU	IO
ME	3.434	0.891								
PP	3.628	1.128	.463*							
RE	3.868	0.894	.381*	.331*						
IK	3.875	0.811	.435*	.388*	.528*					
OA	3.765	0.984	.317*	.223*	.478*	.481*				
CE	3.554	0.969	.423*	.358*	.489*	.445*	.468*			
AU	3.672	0.834	.444*	.411*	.462*	.563*	.514*	.540*		
IO	3.718	0.900	.360*	.360*	.426*	.507*	.401*	.458*	.595*	
SE	3.804	0.878	.366*	.328*	.434*	.535*	.456*	.464*	.569*	.624*

Notes: ME: *memorizing*; PP: *practising tutorial problems*; RE: *recording by way of notetaking*; IK: *increasing knowledge*; OA: *obtaining authentic experience through activities*; CE: *communicating and explaining*; AU: *applying* and *understanding*; IO: *improving oneself through opportunities*; SE: *seeing in a new way*; M: mean; and SD: standard deviation. *$p<.01$.

As shown in Table 3, these students scored highest on the scale of *increasing knowledge* (M = 3.875), followed by the scales of *recording by way of notetaking* (M =3.868), *seeing in a new way* (M= 3.804), and *obtaining authentic experience through activities* (M = 3.765). The lowest score was *memorizing* (M = 3.434). Notably, the most frequently chosen main conceptions (*increasing knowledge* and *obtaining authentic experience through activities*) revealed in Study I were confirmed to be widely appreciated by the quantitative analysis in Study II.

Relationships Among Subscales of the COLSIE Survey

Pearson correlation analysis was also conducted for each pair of factors to examine the relationship among students' COLSIE. The results are presented in Table 3. The relationships among the nine subscales of the COLSIE were significantly positively correlated with each other, ranging from 0.223 to 0.624. These significant correlations suggested adequate convergent validity for the COLSIE survey (Netemeyer et al., 2003). That is, the nine subscales revealed by the survey contribute to a common latent construct, i.e., the primary school students' COLSIE.

Discussion

In this study, students' COLSIE were found to be different from the COLS in general and in the laboratory, as evidenced by previous studies (Chiu et al., 2016; Tsai, 2004; Zhao & Thomas, 2016). For easy comparisons, the categories of COLS in various environments are summarized in Figure S.1 in the Appendix, and they are given almost identical names after careful examinations of their original meanings. As shown in Figure S.1, the ten categories identified in the current study showed great commonalities and possessed unique features in comparison with COLS in general and in the laboratory. In the following section, the commonalities and uniqueness of COLSIE among primary school students in Mainland China will be discussed in detail.

Commonalities of COLS

As shown in Figure S.1, this study identified eight common categories of COLSIE that have been revealed in previous studies (Chiu et al., 2016; Tsai, 2004; Zhao & Thomas, 2016). These categories can be classified into three subgroups according to the possible influencing factors.

First, this study found six categories of COLS, i.e., *memorizing*, *practising tutorial problems*, *increasing knowledge*, *applying*, *understanding*, and *seeing in a new way* (see Figure S.1 in the Appendix), which first appeared in Tsai (2004) on Taiwanese high school students' COLS. Accordingly, they are perhaps the essential characteristics of learning science in either formal or informal environments and are thus worth further exploration.

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In addition, the category of *improving oneself through opportunities* was found in this study. This category was first identified in Zhao and Thomas (2016), who investigated Mainland Chinese high school students' COLS. The researchers connected this conception to students' cultural backgrounds. In particular, they believed that students who want to improve themselves when learning science were perhaps influenced by Confucian culture. Collectively, this study also suggested that students' cultural backgrounds should be taken into consideration when analysing students' COLS in both formal and informal environments. As stated earlier, some students reported that learning science in either formal or informal environments was a helpful way to cultivate their abilities and morals to serve well their family and country. Their conceptions were likely influenced by their Chinese cultural background, in particular, Confucianism's advocacy for learning should contribute to good governance. Students from other cultures probably will not associate their learning of science with the goal of serving their family or making contributions to their country. Further studies are encouraged to explore different culturally oriented contexts to better reveal the role of culture on students' views of learning science.

Furthermore, this study found another conception, i.e., *obtaining authentic experience through activities*, which has already been revealed by Chiu et al. (2016) on Taiwan college students' COLS in the laboratory. They argued that learning science in the laboratory could provide students with multisensory experiences, such as observation and operation; thus, students conceptualized learning science as a way of *obtaining authentic experience* (Millar et al., 2003). Lin and Schunn (2016) also suggested that informal environments could provide students with similar experiences. Echoing their study, the category of *obtaining authentic experience through activities* also emerged in the current study. Hence, it is important to promote science learning through various learning contexts and to encourage students to take advantage of observing scientific phenomena or items by engaging in real-life experiences themselves in informal environments.

Uniqueness of COLSIE

This study identified two new categories of COLSIE that had not been revealed in previous studies: *recording by way of notetaking* and *communicating and explaining*. The origins of these two new categories could be related to the way students learning science in informal environments is self-directed, collaborative, nonlinear, and open-ended (Bell et al., 2009; Falk, 2005; Tal, 2012). In other words, these features of informal environments provided students with ample freedom and interaction to engage in science practices, such as "obtaining, evaluating, and communicating information" (National Research Council, 2013, p. 382).

First, students conceptualize learning science in informal environments as *recording by way of notetaking*, perhaps because they can have a high degree of autonomy in an informal learning context. Scientific investigation and observation may be conducted in the laboratory or in the field. A primary goal of scientific investigation and observation of the world is to systematically describe the world, which requires identifying what is to be recorded (National Research Council, 2012). Students can fully experience the learning process by recording the subjects and results of their investigations in informal environments because of their high degree of autonomy, which they may find difficult to receive in a formal classroom environment. Therefore, students may conceptualize learning science in informal environments as *recording by way of notetaking*.

In addition, students value *communicating and explaining* in learning science in informal environments, as "scientific disciplinary knowledge is constructed, communicated, and assessed through language" (Reveles et al., 2007, p. 469). Science education examines how people learn to talk and write the language of science and meaningfully and cooperatively engage in various activities (Lemke, 2001). The collaborative nature of learning science in informal environments provided students with ample opportunities to communicate their ideas clearly and persuasively in oral and written languages. In this study, students reported that they were able to share their science-related knowledge freely with others, which was something that they rarely do in formal classroom settings. The practice of communication also helps students' understanding of science. Thus, these ideas may strengthen students' impression that learning science in informal environments involves *communicating and explaining*.

Categories of COLS which were Not Revealed in this Study

This section examines some categories of COLS that were revealed by previous studies but did not emerge in this study. First, *testing* and *working hard* were identified in Tsai (2004) and Zhao and Thomas (2016) but were absent in the current study. In their studies, participants were high school students who worked extremely hard because

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they hoped to achieve a proficient performance in the college entrance examination. However, in the current study, participants were primary school students who were not exam driven because they did not have to take high-stakes entrance examinations when attending middle school as a result of the nine-year compulsory education policy in Mainland China. It also explains why primary students showed significantly lower academic stress (e.g., stresses of learning content and examination) than secondary school students in Mainland China (Long et al., 2013).

In addition, *listening to the teacher* was previously identified in the formal science learning environment (Zhao & Thomas, 2016). However, in informal environments, students learn science in a self-directed manner, in which guidance from adults (e.g., teachers) is always ruled out (Bell et al., 2009). Thus, it seems reasonable that this category was absent in this study.

Finally, three categories of COLS in the laboratory, *examining prior knowledge*, *reviewing prior learning profiles*, and *acquiring manipulative skills,* were not identified in the current study (Chiu et al., 2016). Their absence could be explained by the apparent student age differences and the indirect connection between formal and informal environments. *Examining prior knowledge* and *reviewing prior learning profiles* were considered metacognitively orientated, which referred to an individual's capacity to connect with prior knowledge and other experiences, as well as to examine the gap between theory and practice (Chiu et al., 2016). However, primary school students in this study do not have these two metacognitively oriented categories because they are at the stage of having a lower level of metacognition (Vukman, 2005) compared with the college students investigated by Chiu et al. (2016). It is also possible that these students find it challenging to tap into knowledge they learned previously in the science classroom. There is a direct linkage between the science classroom and laboratory, and students can easily connect with prior declarative and procedural knowledge and their experience in the laboratory. However, primary school students may struggle to make this connection because of the nonlinear and open-ended manner of informal science learning (Bell et al., 2009).

Limitations and Suggestions for Future Studies

In this study, the ten categories of COLSIE emerged through interview data gathered from students in three primary schools located in South China. During the sampling process, these schools were selected purposively to meet the requirement of diverse responses. However, careful consideration is necessary when generalizing the results of this study to other student populations in Mainland China. In addition, this study did not analyse the relationship between students' prior experience of informal science learning and their COLSIE. It would be beneficial to provide evidence for cross validation, i.e., do students who have more experience of informal science learning tend to hold more constructivist COLSIE?

Some suggestions derived from this study could also warrant future study. First, the ten qualitatively different categories of COLSIE found in this study could serve as a foundation for researchers to conduct relevant studies. Guided by this framework, future studies are encouraged to further investigate students' COLSIE in diverse specific informal environments, e.g., informal home science, semiformal science, nature, and museums (Lin & Schunn, 2016). Second, the COLSIE survey developed in the current study can be used to explore the relationships among students' conceptions, approaches, and outcomes of learning science in informal environments (e.g., Lee et al., 2008; Zheng et al., 2018). Finally, it will be beneficial to conduct research investigating the relationships between students' COLSIE and other adults' COLSIE, e.g., their parents and tour guides in the museum (Lin et al., 2014).

Conclusions

Given the importance of learning science in informal environments to students' academic achievement, this study explored COLSIE among a group of primary school students in Mainland China. Overall, ten hierarchical categories of COLSIE were identified in Study I through phenomenographic analysis. Notably, many of these primary school students perceived their COLSIE as *increasing knowledge* and *obtaining authentic experience through activities*. To assess students' COLSIE, a specific survey with sufficient reliability and validity was developed in Study II. Exploratory factor analysis revealed nine factors that matched the ten categories except for the initial categories of *applying* and *understanding*. Overall, the initial ten categories were supported by the quantitative analysis in Study II.

It is worth mentioning that, in different environments, students may show different degrees of agreement with the eight common categories of COLS. According to Study I, students expressed their main conceptions in *obtaining authentic experience through activities* and *increasing knowledge*, which may not necessarily be the same as their main conceptions in formal environments. In other words, a student may show more agreement with a conception

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in informal environments than they do in formal environments or vice versa. Accordingly, researchers are encouraged to incorporate the COLSIE survey developed in the current study to better investigate students' COLS in both formal and informal environments.

Furthermore, the current study identified two new categories of COLSIE that had not been revealed in previous studies: *recording by way of notetaking* and *communicating and explaining*. Notably, these two unique conceptions highlight the benefits of learning science in informal environments for strengthening students' impressions and values of science practices. Informed by the results of this study, future studies can explore whether students who show more agreement with these two conceptions tend to prefer doing practical work and participating in science inquiry activities.

Previous studies have primarily focused on students' science learning in formal environments. The current study provided an additional perspective regarding students' science learning by providing an in-depth description of students' views of learning science in informal environments. Overall, the findings draw attention to the complex outcomes of students' COLS in different environments. Students' COLS, originally developed in different environments, may eventually form a coherent mind system of learning science, which will play an essential role in students' subsequent approaches to and outcomes of learning science.

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Declaration of Interest

Authors declare no competing interest.

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Appendix

Conceptions of Learning Science in Informal Environments Survey

Items presented in the following were translated from Chinese to English by the authors. An additional bilingual researcher unfamiliar with the current research was asked to translate the English version of the survey back to Chinese to ensure translation correctness. The back-translated survey was then compared against the original survey for further revision and refinement. No misinterpretations were detected, and hence, the translation process was finalised. The items modified from previous studies are marked with an asterisk (*). In addition, some items were underlined, as they were suggested to be dropped based on EFA results.

Memorizing

ME1*. Learning science in informal environments means memorizing some concepts and facts relevant to science.

ME2*. Learning science in informal environments means memorizing some science terminologies and being able to use them to answer questions from others.

ME3. Learning science in informal environments means memorizing the procedures and the results of the experiments.

ME4. Learning science in informal environments means memorizing the knowledge by heart and being able to repeat it.

ME5. Learning science in informal environments means learning by heart and leaving a powerful mark on my memories.

<u>ME6</u>. Learning science in informal environments means memorizing what someone else said.

Practising tutorial problems

PP1. Learning science in informal environments means practising tutorial problems to check how well I master certain knowledge

PP2*. Learning science in informal environments means practising tutorial problems to strengthen what I learned.

<u>PP3</u>*. Learning science in informal environments means participating in various calculating and tutorial problem-solving activities.

<u>PP4</u>*. Learning science in informal environments means repeatedly doing calculation and practising tutorial problems.

<u>PP5</u>. Learning science in informal environments means finishing exam sheets or homework assigned by others.

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Recording by way of notetaking

RE1. Learning science in informal environments means taking notes of what I observed.
RE2. Learning science in informal environments means taking notes of the results.
RE3. Learning science in informal environments means taking notes of some important information.
RE4. Learning science in informal environments means taking notes of what interests me.
RE5. Learning science in informal environments means recording my reflection.

Increasing knowledge

IK1*. Learning science in informal environments means learning something new.
IK2. Learning science in informal environments means obtaining various types of science-related knowledge.
IK3. Learning science in informal environments means supplementing what I learned in classroom learning.
IK4. Learning science in informal environments means obtaining knowledge about modern technology.
IK5. Learning science in informal environments means learning extra knowledge beyond the classroom.
IK6. Learning science in informal environments means obtaining knowledge about animals and plants.

Obtaining authentic experience through activities

OA1. Learning science in informal environments means obtaining hands-on experience.
OA2. Learning science in informal environments means gaining authentic experience of science phenomena.
OA3*. Learning science in informal environments means observing the process and the results of science experiments.
OA4*. Learning science in informal environments is to acquire practical experience by doing experiments.

Communicating and explaining

CE1. Learning science in informal environments means communicating with peers.
CE2. Learning science in informal environments enables me to communicate with classmates better.
CE3. Learning science in informal environments means sharing scientific knowledge with my classmates.

Applying and Understanding

AU1*. Learning science in informal environments means applying what I already know to problems that I have never encountered before.
AU2. Learning science in informal environments means explaining new science phenomena using what I learned.
AU3*. Learning science in informal environments helps me understand how science knowledge was developed.
AU4. Learning science in informal environments provides me with a profound understanding of science.
AU5*. Learning science in informal environments helps me understand the essence of science knowledge.
AU6*. Learning science in informal environments helps me explore the process by which scientists made scientific discoveries.
AU7. Learning science in informal environments means applying what I already know to problems that I encountered in real life.
AU8. Learning science in informal environments means practising my knowledge to solve practical problems.
AU9. Learning science in informal environments means applying scientific knowledge to make something new.
AU10. * Learning science in informal environments helps me understand the connections between scientific concepts.
AU11. * Learning science in informal environments helps me understand the meanings of scientific theories and formulas.

Improving oneself through opportunities

IO1. Learning science in informal environments helps boost my intelligence (IQ) and ability.
IO2. Learning science in informal environments helps me identify my shortcomings and find ways to cope with them.
IO3. Learning science in informal environments helps me build good study habits towards learning science.
IO4. Learning science in informal environments means bringing self-improvement and benefits to my family in the future.

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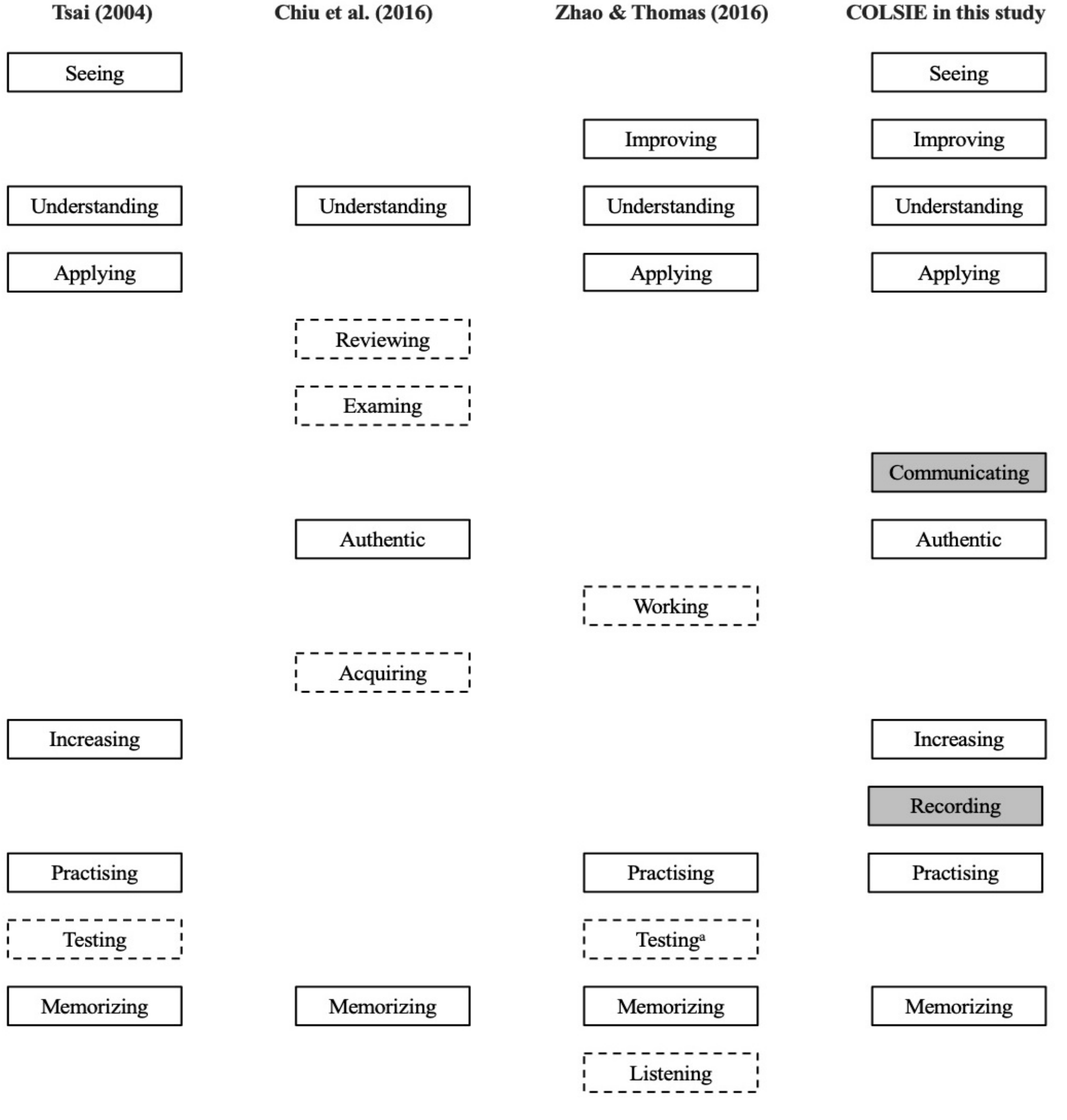
IO5. Learning science in informal environments means better serving my country when I grow up.
IO6. Learning science in informal environments means making global contributions when I grow up.

Seeing in a new way

SE1. Learning science in informal environments expands my vision for the world.
SE2. Learning science in informal environments changed my insights about science.
SE3. Learning science in informal environments helps me explore the world.
SE4*. Learning science in informal environments changed the ways I look at nature.
SE5. Learning science in informal environments enabled me to approach science phenomena from different perspectives.
SE6. * Learning science in informal environments brought me new ways of observing natural phenomena.

Figure S.1
Commonalities and Uniqueness of COLS Revealed by Different Studies



Note: White squares plotted with a solid line (e.g., *memorizing*) represent the categories of COLSIE that have been revealed by previous studies (common conceptions); grey squares plotted with a solid line (e.g., *recording by way of notetaking*) show the

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unique categories of COLSIE that have not been revealed in previous studies; and white squares plotted with a dotted line (e.g., *testing*) are the categories that have been revealed by previous studies but not in COLSIE. In Zhao and Thomas's (2016) study, the category of COLS named *learning science as attending to exams* is similar to the conception of *testing* in other studies. In Zhao and Thomas's (2016) study, there was a category of COLS named *doing problems*, which include few subcategories, e.g., *doing problems as practising* (*practising*) and *doing problems as applying* (*applying*).

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