International Journal of Science Education

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

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To cite this article: Wen-Min Hsieh & Chin-Chung Tsai (2017) Exploring students' conceptions of science learning via drawing: a cross-sectional analysis, International Journal of Science Education, 39:3, 274-298, DOI: 10.1080/09500693.2017.1280640

To link to this article: https://doi.org/10.1080/09500693.2017.1280640

Published online: 19 Jan 2017.

INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, 2017
VOL. 39, NO. 3, 274–298
http://dx.doi.org/10.1080/09500693.2017.1280640

Exploring students' conceptions of science learning via drawing: a cross-sectional analysis

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ABSTRACT

This cross-sectional study explored students' conceptions of science learning via drawing analysis. A total of 906 Taiwanese students in 4th, 6th, 8th, 10th, and 12th grade were asked to use drawing to illustrate how they conceptualise science learning. Students' drawings were analysed using a coding checklist to determine the presence or absence of specified attributes. Data analysis showed that the majority of students pictured science learning as school-based, involving certain types of experiment or teacher lecturing. In addition, notable cross-sectional differences were found in the 'Activity' and 'Emotions and attitudes' categories in students' drawings. Three major findings were made: (1) lower grade level students conceptualised science learning with a didactic approach, while higher graders might possess a quantitative view of science learning (i.e. how much is learned, not how well it is learned), (2) students' positive and negative emotions and attitudes toward science learning reversed around middle school, and (3) female students expressed significantly more positive emotions and attitudes than their male counterparts. In conclusion, higher graders' unfruitful conceptions of science learning warrant educators' attention. Moreover, further investigation of girls' more positive emotions and attitudes found in this study is needed.

ARTICLE HISTORY
Received 14 May 2016
Accepted 6 January 2017

KEYWORDS
Conceptions of science learning; cross-sectional study; drawing analysis

Introduction

Conceptions of learning refer to a coherent system of knowledge and beliefs about learning and related phenomena (Vermunt & Vermetten, 2004). According to Vermunt and Vermetten (2004), conceptions of learning may include the knowledge and beliefs of how learners think about learning objectives, activities, strategies, tasks, processes, and learning and studying in general. Previous studies have demonstrated that a close tie exists between students' conceptions of learning, approaches to learning, and the quality of their learning outcomes (e.g. Dart et al., 2000; McLean, 2001; Peterson, Brown, & Irving, 2010). For instance, Peterson et al. (2010) found that students who regarded learning as a duty predicted lower achievement, while those who regarded learning as continuing effort predicted higher achievement.

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The body of work researching students' conceptions of learning has also suggested that the learning conceptions held by students might differ according to a number of factors such as culture (e.g. Marton, Watkins, & Tang, 1997; Rosário et al., 2013; Zhu, Valcke, & Schellens, 2008), age (e.g. Klatter, Lodewijks, & Aarnoutse, 2001; McCallum, Hargreaves, & Gipps, 2000), and subject domain (e.g. Eklund-Myrskog, 1998; Marshall, Summer, & Woolnough, 1999; Tsai, 2004; Tsai & Kuo, 2008). Students in Asian countries have consistently performed well in international tests, especially those in the Confucian-influenced cultural circle including Hong Kong, Singapore, South Korea, Japan, and Taiwan (Carless & Lam, 2014). As reported by the Trends in International Mathematics and Science Study (TIMSS) International Science Reports, the top four performing countries in 2003 and 2007 were all Asian countries (Martin, Mullis, & Foy, 2008; Martin, Mullis, Gonzalez, & Chrostowski, 2004). In the TIMSS International Science Report 2011, Asian countries continued to be the top performing among the participating countries (Martin, Mullis, Foy, & Stanco, 2012). Since there is evidence indicating that students' learning outcomes are closely linked to their conceptions of learning, the kind of conceptions of learning held by the students in these top performing countries have thus become an intriguing topic for educational researchers. Taiwan, being regularly ranked among the top performing countries in the TIMSS International Science Reports, thus provides a unique cultural context for researchers to pursue this line of research.

Students' conceptions of science learning

Previous studies have suggested that conceptions of learning are, at least to a certain degree, domain specific (Buehl & Alexander, 2001; Buehl, Alexander, & Murphy, 2002; Tsai, 2006; Hofer, 2000). That is, students might hold different conceptions of different knowledge domains (e.g. science versus history). Building on Buehl and Alexander's (2001) idea of domain-specific epistemological beliefs, Tsai (2004) further differentiated it to include academic domain-specific epistemological beliefs. According to Tsai (2004), domain-specific epistemologies are beliefs about the nature of the domain of knowledge (e.g. science), while academic epistemological beliefs include beliefs about school knowledge and learning (i.e. conceptions of learning). Academic domain-specific epistemological beliefs (e.g. conceptions of science learning) are the results of the interplay between the two. In this sense, students' conceptions of science learning (i.e. academic domain-specific epistemological beliefs) are potentially influenced by their view of the nature of science (domain-specific epistemology) and their view of learning (academic epistemological beliefs). Consequently, exploring students' conceptions of science learning could broaden our understanding of their science learning.

Several researchers have studied the cultural impacts on students' conceptions of learning in Asian countries (e.g. Lee, Johanson, & Tsai, 2008; Tsai, 2004; Tsai & Kuo, 2008). One of these such efforts that explored students' conceptions of science learning is the work done by Tsai (2004), who investigated the conceptions of science learning held by 120 Taiwanese high-school students (11th and 12th graders) using phenomenographic analysis, and derived 7 qualitatively different categories of conceptions of science learning, namely science learning as memorising, preparing for tests, calculating and practicing tutorial problems, the increase of knowledge, applying, understanding, and seeing in a new way. Among the seven conceptual categories, two – 'testing' and 'calculating' – had not been revealed in previous studies. Moreover, Tsai (2004) proposed a framework to map the variations in students' conceptions of science learning using three dimensions: forms of knowledge acquisition ('reproducing' versus 'knowing' versus 'extending and developing'), motivational orientations ('external: fulfilling external requests' versus 'internal: fulfilling personal development'), and standards of evaluating learning outcomes ('quantitative: how much is learned' versus 'qualitative: how well it is learned'). Take 'memorising' for instance; it is oriented to 'reproducing' forms of knowledge acquisition, driven by external motivational factors, and is a quantitative view of science learning. In discussing the findings, Tsai (2004) attributed the origins of the two new categories respectively to the educational environment in Taiwan that values high test scores, and the nature of school science that presents science as problems or questions that ask for accurate answers.

In another study, Tsai and Kuo (2008) further explored cram school students' conceptions of learning and science learning. Cram schools are the after-school private tutoring systems in Taiwan that provide supplementary or test-preparation programmes on academic subjects to students. It is also known as *Buxiban* in Taiwan, *Juku* in Japan, *Hagwon* in Korea, or private tuition and shadowing education system in the Western worlds (Bray, 2007). In Taiwan, some students choose to attend cram school for additional after-school instruction to enhance their academic performance in the hope to increase their chances to enter schools/colleges with good reputation. Tsai and Kuo (2008) analysis of 45 cram school students' (around 14 years old) conceptions of learning and science learning showed that the majority of those students conceptualised learning or science learning as 'memorising school knowledge', 'preparing for tests', or 'practicing tutorial problems and processing calculations'. Moreover, they seemed to hold a quantitative view of learning (science) (i.e. how much is learned), have extrinsic motivation for learning (e.g. test scores), and employed surface approaches to learning. The above-mentioned studies showed how cultural and educational context could play a role in students' conceptions of science learning.

Apart from the cultural and educational context, Tsai (2004) pointed out that research into students' conceptions of science learning should also be extended to younger learners as they may have already developed their conceptions of learning. Researchers typically rely on phenomenographic analysis (Marton, 1981, 1986) to derive qualitatively different category conceptions from students' verbal data (e.g. Eklund-Myrskog, 1998; Klatter et al., 2001; Marshall et al., 1999; Paakkari, Tynjälä, & Kannas, 2011; Rosário et al., 2013; Tsai, 2004; Tsai & Kuo, 2008). However, as younger learners' ability to verbalise and reflect on abstract ideas is generally less sophisticated than that of more mature learners, a different research method might be needed to probe into the younger students' learning conceptions. One approach suggested by the literature that does not rely heavily on students' verbalisation is the use of drawing.

Drawing as a research tool

Following the seminal work done by Mead and Métraux (1957), Chambers (1983) developed the Draw-A-Scientist-Test (DAST), and administered it to 4807 K-5 students to determine the age at which stereotypical images of scientists developed. In DAST, students' drawings were scored based on the presence/absence of (1) lab coat (usually white), (2) eyeglasses, (3) facial hair (beards, mustaches), (4) symbols of research (scientific instruments), (5) symbols of knowledge (books, and filing cabinets), (6) technology (the products of science), and (7) relevant captions (formulae, 'eureka', etc.). The analysis showed that the standard image of scientists seemed to take root beginning in grade 2, and the number of indicators continued to grow as the students' grade level advanced. In addition, Chambers reported that among the 4807 drawings collected from elementary school children in grade K-5, only 28 drew female scientists in their pictures (all of whom were girls).

One advantage of the DAST is that it does not require the participants to have advanced reading or writing skills, and thus can be administered to both younger and older subjects. Since then, drawing has been extensively used as a way to elicit elementary or middle school students' perceptions of science and scientists (Barman, 1997, 1999; Maoldomhnaigh & Hunt, 1988; Newton & Newton, 1992; She, 1995; Song & Kim, 1999). Later, Finson (2002) in his review of the research utilising the DAST concluded that (1) stereotypical perceptions are persistent, (2) the mythic element (i.e. Frankenstein) has become less and less prevalent, and (3) Caucasian male chemists are the dominant image drawn. Moreover, the stereotypical images are pervasive across grade levels, gender, racial groups, and national borders. The collected work in this area has demonstrated the DAST to be a useful tool for eliciting students' ideas.

More recently, drawing has also been used as a research tool to examine students' conceptions of assessment (e.g. Brown & Wang, 2011; Carless & Lam, 2014; Harris, Brown, & Harnett, 2014; Xiao & Carless, 2013) and learning (e.g. Wang & Tsai, 2012; Hsieh & Tsai, in press). For instance, Hsieh and Tsai (in press) utilised the draw-a-picture technique to examine the learning conceptions held by students in different grade levels, and found that students' conceptions of learning differ in terms of the specificity, human agents, and emotions and attitudes depicted in their drawings. The results of their study showed that (1) younger students tend to hold episodic images of learning compared with more mature students, (2) the human agents involved in learning shifted from others to self, suggesting that students either started to take ownership of their learning or viewed learning as a duty that needs to be fulfilled, and (3) negative emotions and attitudes reached a plateau in grades 6, 8, and 10. Using the draw-a-picture technique, Hsieh and Tsai (in press) were able to elicit different facets of learning conceptions that were traditionally derived from phenomenography.

Purpose of the study

Haney, Russell, and Bebell (2004) argued that drawings of everyday situations of classrooms, schools, and learning have 'unusual power to document and change the educational ecology of classrooms and schools' (p. 242). Previous studies employing the draw-a-picture technique to explore students' learning conceptions not only afforded the researchers new insights but also suggested the technique as a useful tool for eliciting students' emotions and attitudes (e.g. Wang & Tsai, 2012; Hsieh & Tsai, in press). Hence, the purpose of this study is to conduct a cross-sectional exploration of Taiwanese students' conceptions of science learning through the draw-a-picture technique. By comparing and contrasting the conceptions of science learning held by different age group students, we hoped to unveil possible trends that might occur as students gain more experience in schooling, which will in turn add to our understanding of the conceptions of science learning held by students.

Specifically, using the draw-a-picture technique, the current study sought to explore (1) Taiwanese students' conceptions of science learning across different grade levels in terms of the people, locations, activities, and, objectives depicted in their drawings, and (2) the spontaneously expressed emotions and attitudes toward science learning in students' drawings.

Methods

Participants

The purpose of this study was to explore the potential cross-sectional differences in students' conceptions of science learning. In Taiwan, Social Studies, Arts and Humanities, and Science and Technology are combined into one subject called Life Curriculum in grades 1 and 2. From grades 3 to 9, science begins to be separated from other content areas but is still combined with technology to form one subject called Science and Technology. In grades 10–12, science starts to be broken down to the different sciences such as chemistry, physics, biology, and earth science. For the purpose of this study, the potential difference in sciences was not accounted for as the main interest was to explore the common experience students in different academic standings all share – science learning. Since science is not an independent subject in grades 1 and 2 (age 7–8) in Taiwan, data were collected from five grade levels ranging from grades 4 to 12 (age 10–18) with a 1-year gap between each. A total of 906 students from 11 schools across northern, central, and southern Taiwan participated in this study. Participants consisted of 160 students from 4th grade, 198 from 6th grade, 188 from 8th grade, 161 from 10th grade, and 199 from 12th grade. In addition, the numbers of male and female students were nearly balanced. The gender breakdown of the participants in each grade level is shown in Table 1.

Data collection

This study employed the draw-a-picture technique as the primary means of data collection. The participants were asked to draw their conceptions of science learning on a piece of A4 paper. To help them grasp and reflect on the idea of science learning, two prompts were given: 'What is science learning?' and 'What is it like when you are learning science?' A total of 30 minutes was then given to the participants to complete the drawing task in class. It should be emphasised that the students were only informed to use drawings

Table 1. Gender and grade level distribution of the participants.

Gender	Grade 4	Grade 6	Grade 8	Grade 10	Grade 12	Total
Male	85	99	94	81	99	458
Female	75	99	94	80	100	448
Total	160	198	188	161	199	906

to represent their ideas about science learning because we were interested in seeing how they would use natural drawings to represent their ideas. Although the current study tried to elicit students' conceptions of science learning through drawing, a small number of the participants spontaneously opted to use other modes of expression such as annotated text and mind/concept maps. The researcher showed flexibility to the students if they felt more competent using these alternatives to illustrate their ideas. As a result, in addition to students' drawings, annotated text and concept/mind maps were also collected for our data analysis.

Data analysis

The coding checklist

This study is a part of a research project that aimed to explore school children's conceptions of learning via the draw-a-picture technique. The coding checklist developed and consolidated through the emergent analytic coding method (Haney et al., 2004) in Hsieh and Tsai (in press) was adapted to analyse the students' drawings. Hsieh and Tsai's (in press) coding checklist includes six categories: (1) subject domains, (2) people involved, (3) locations, (4) activities, (5) objects, and (6) emotions and attitudes. As the current study focused on the subject of science, the subject domain category was dropped out of the coding checklist, leaving it with five categories: (1) people involved, (2) locations, (3) activities, (4) objects, and (5) emotions and attitudes. Detailed information about the coding checklist is given in Table 2. Drawings have been proven to be a useful tool to elicit students' emotions and attitudes toward the target research area (e.g. Brown & Wang, 2011; Carless & Lam, 2014; Harris et al., 2014; Hsieh & Tsai, in press; Xiao & Carless, 2013). By adopting Hsieh and Tsai's (in press) coding checklist, this study also looked for traces of students' positive and negative emotions and attitudes in students' drawings. Typical drawing expressions of happiness such as

Table 2. Checklist for coding students' drawings.

Categories	Indicators	Indicators
(1) People involved	1.1 Parent	1.4 Student (alone)
	1.2 Teacher	1.5 Peers/Groups
	1.3 Student (with teacher)	1.6 No human drawn
(2) Locations	2.1 Classroom	2.5 Home
	2.2 Laboratory	2.6 Natural environment
	2.3 Outside classroom (on campus)	2.7 Cram school
	2.4 Museum and library	2.8 Unspecified
(3) Activities	3.1 Teacher lecturing	3.7 Physical activity
	3.2 Student output	3.8 Performance/Hands-on
	3.3 Group work	3.9 Writing
	3.4 Reading/Studying	2.10 Off task
	3.5 Experiment	3.11 Unspecified
	3.6 Assessment	
(4) Objects	4.1 Technological products	4.7 Book
	4.2 Blackboard	4.8 Man-made machinery
	4.3 Exam paper	4.9 Animals
	4.4 Stationery	4.10 Plants
	4.5 Sports equipment	4.11 Celestial planets
	4.6 School furniture	4.12 Laboratory equipment
(5) Emotions and attitudes	5.1 Positive	
	5.2 Negative	

smiling faces and textual descriptions indicating enjoyment were coded as positive emotions and attitudes, whereas drawings containing expressions of unhappiness such as downturned mouths, frowning eyebrows, bowed heads, and textual description indicating boredom, sadness, or annoyance were coded as negative. Those that did not contain expressions of positive or negative emotions and attitudes were not coded for the emotions and attitudes category.

Inter-rater training

A coding team of six was assembled to code the student drawings collected in this study. To establish inter-rater reliability for the current study, the coding team convened for a two-hour training session for practice coding and to gain familiarity with the coding checklist. After the training session, the same method that was used in Hsieh and Tsai (in press) to calculate inter-rater reliability was also employed in this study. That is, six subsets of drawings (subset $n = 20$) were randomly selected from the collected student drawings and were numbered. Each coder was responsible for three subsets of student drawings: their corresponding subset, the one before, and the one after. As a result, the same subset of student drawing was coded by three coders, allowing us to compute pairwise rater agreement (Cohen's Kappa) and track down coding incongruences. Details of the inter-rater grouping are listed in Table 3.

An average pairwise inter-rater agreement of 0.65 was obtained after the first cycle of inter-rater training. A Kappa value of 0.65 indicates that coders have substantial agreement (Landis & Koch, 1977). The coding team was sent out to code the remaining student drawings after reaching a strong inter-rater agreement.

Data analysis procedure

Students' drawings were analysed in two parts: the analysis of the drawings, and the analysis of the drawing captions. For the analysis of the students' drawings, the coding checklist was used to determine if a particular attribute was present or not in the drawings. It should be noted that multiple coding of the same category in our data analysis was accepted, as multiple attributes might exist simultaneously in the students' drawings. However, the same indicator was only counted once in the same drawing. For instance, even if a drawing contained four peer figures, under the 'Peers/Groups' indicator it would be counted as one because we were mainly interested to see if a certain feature was present or not. Correspondingly, if students' drawing portrayed more than one scene (e.g. using a cartoon-type presentation with split frames), all the indicators in the different frames were recorded but again the same indicator was

Table 3. Inter-rater training coding groups.

Drawings	Coder
Subset 1 ($n = 20$)	C1, C6, C2
Subset 2 ($n = 20$)	C2, C1, C3
Subset 3 ($n = 20$)	C3, C2, C4
Subset 4 ($n = 20$)	C4, C3, C5
Subset 5 ($n = 20$)	C5, C4, C6
Subset 6 ($n = 20$)	C6, C5, C1
Total $N = 120$	

only recorded once. For example, if a student's drawing contained studying scenes at school and home, both locations were being recorded for the same student drawing but the school furniture in the two locations was only counted once. A coded example of a student's drawing is shown in Figure 1. In Figure 1, the student is conducting '3.5 experiment' with '1.5 Peers' in a '2.2 Laboratory'. The objects drawn are '4.6 School furniture' and '4.12 Laboratory equipment'. The two students in the drawing are showing '5.1 Positive emotions and attitudes'.

In addition, Carless and Lam (2014) suggested that the captions in students' drawings might be useful for revealing responses to areas of interest. Therefore, for those drawings containing textual descriptions, the word frequency method was used to analyse the captions and text in the students' drawings (Carless & Lam, 2014). Because of the large quantity of student drawings collected, a Chinese word cloud generator was adopted to facilitate word frequency analysis. Plain text in students' drawings was extracted and fed into a Chinese word cloud generator to obtain frequency word lists by grade. The top five word lists were then translated into English and the results are reported in the next section.

Results

Results from the coding checklist

The student drawings were analysed with reference to the coding checklist in Table 2. A total of 848 (male: 428, female: 420) of 906 drawings were considered valid, while 58 were not. Drawings that did not address the prompts, or those which contained random or unintelligible drawing were counted as invalid. Table 4 shows the tabulated results of the frequency and percentages of students' drawing contents. The following first four

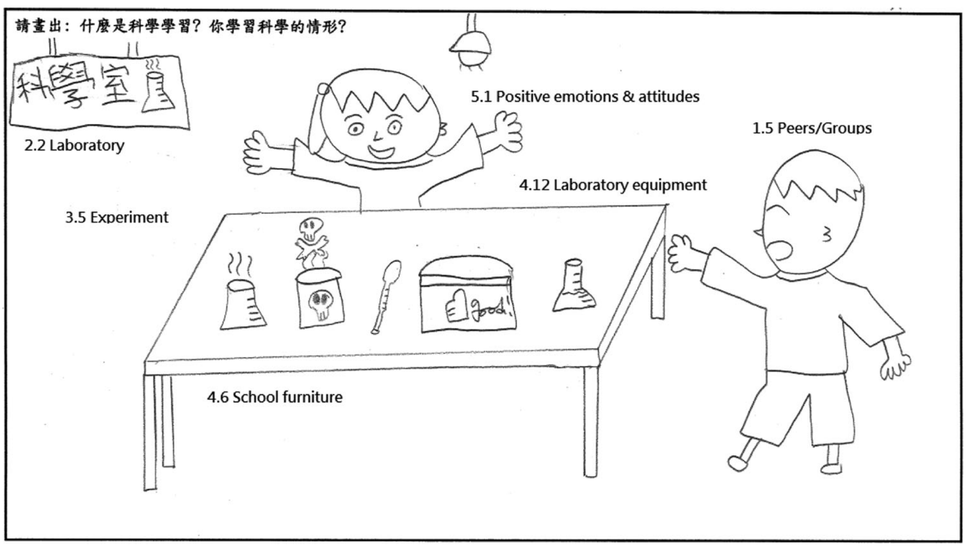


Figure 1. An example of a coded student drawing by a fourth grader. (Chinese prompts in upper left: What is science learning? What is it like when you are learning science?)

Table 4. Distribution of students' drawing contents.

Categories	Grade 4 n(% = n/152)	Grade 6 n(% = n/190)	Grade 8 n(% = n/175)	Grade 10 n(% = n/148)	Grade 12 n(% = n/183)	Total n(% = n/848)
People involved						
Parent	3 (2)	1 (0.5)	4 (2.3)	0 (0)	0 (0)	8 (0.9)
Teacher	**42 (27.63)**^{3}	33 (17.37)	**51 (29.14)**^{2}	17 (11.49)	25 (13.66)	168 (19.81)
Student (with teacher)	11 (7.24)	13 (6.84)	17 (9.71)	3 (2.03)	5 (2.73)	49 (5.78)
Student (alone)	**65 (42.76)**^{1}	**62 (32.63)**^{2}	**59 (33.71)**^{1}	**52 (35.14)**^{2}	**85 (46.45)**^{1}	**323 (38.09)**^{1}
Peers/Groups	**56 (36.84)**^{2}	**67 (35.26)**^{1}	**48 (27.43)**^{3}	**20 (13.51)**^{3}	**32 (17.49)**^{3}	**223 (26.3)**^{3}
No human drawn	22 (14.47)	**59 (31.05)**^{3}	47 (26.86)	**76 (51.35)**^{1}	**73 (39.89)**^{2}	**277 (32.67)**^{2}
Locations						
Classroom	**17 (11.18)**^{3}	**12 (6.32)**^{3}	**42 (24)**^{3}	**19 (12.8)**^{3}	**21 (11.5)**^{3}	**111 (13.09)**^{3}
Laboratory	**71 (46.71)**^{1}	**102 (53.68)**^{1}	**67 (38.29)**^{1}	**37 (28.96)**^{2}	**53 (28.96)**^{2}	**330 (38.92)**^{2}
Outside classroom (on campus)	5 (3.29)	2 (1.05)	0 (0)	0 (0)	0 (0)	7 (0.83)
Museum and library	2 (1.32)	1 (0.53)	1 (0.57)	0 (0)	1 (0.55)	5 (0.59)
Home	7 (4.61)	1 (0.53)	3 (1.71)	3 (2.03)	4 (2.19)	18 (2.12)
Natural environment	8 (5.26)	6 (3.16)	8 (4.57)	3 (2.03)	19 (10.04)	44(5.19)
Cram school	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Unspecified	**49 (32.24)**^{2}	**64 (33.68)**^{2}	**63 (36)**^{2}	**80 (54.05)**^{1}	**96 (52.46)**^{1}	**352 (41.51)**^{1}
Activities						
Teacher lecturing	**33 (21.71)**^{2}	**29 (15.26)**^{3}	**37 (21.14)**^{3}	18 (12.16)	23 (12.57)	**140 (16.51)**^{3}
Student output	10 (6.58)	10 (5.26)	12 (6.86)	11 (7.43)	27 (14.8)	70 (8.26)
Group work	1 (0.66)	3 (1.58)	6 (3.43)	6 (4.05)	3 (1.64)	19 (2.24)
Reading/Studying	5 (3.29)	12 (6.32)	6 (3.43)	**24 (16.2)**^{3}	**27 (14.8)**^{3}	74 (8.73)
Experiment	**78 (51.32)**^{1}	**122 (64.21)**^{1}	**85 (48.57)**^{1}	**44 (29.73)**^{2}	**66 (36.07)**^{1}	**395 (46.58)**^{1}
Writing	5 (3.29)	8 (4.21)	5 (2.86)	6 (4.05)	8 (4.37)	32 (3.77)
Physical activity	0 (0)	3 (1.58)	0 (0)	0 (0)	0 (0)	3 (0.35)
Performance/Hands-on	29 (19.1)	13 (6.84)	12 (6.86)	9 (6.08)	18 (9.84)	81 (9.55)
Assessment	2 (1.32)	5 (2.63)	4 (2.29)	5 (3.38)	6 (3.28)	22 (2.59)
Off task	1 (0.66)	8 (4.21)	11 (6.29)	10 (6.76)	9 (4.92)	39 (4.6)
Unspecified	**32 (21.05)**^{3}	**33 (17.37)**^{2}	**43 (24.57)**^{2}	**50 (33.78)**^{1}	**56 (30.6)**^{2}	**214 (25.24)**^{2}
Objects						
Technological products	16 (10.5)	19 (10)	10 (5.71)	12 (8.11)	16 (8.74)	73 (8.61)
Blackboard	**30 (19.74)**^{3}	19 (10)	**45 (25.71)**^{3}	16 (10.81)	22 (12.02)	132 (15.57)
Exam paper	2 (1.32)	3 (1.58)	3 (1.71)	2 (1.35)	5 (2.73)	15 (1.77)
Stationery	7 (4.61)	10 (5.26)	12 (6.86)	7 (4.73)	10 (5.46)	46 (5.42)
Sports equipment	0 (0)	1 (0.53)	0 (0)	1 (0.68)	0 (0)	2 (0.24)
School furniture	**86 (56.58)**^{2}	**97 (51.05)**^{2}	**91 (52)**^{2}	**30 (20.27)**^{3}	**40 (21.86)**^{3}	**344 (40.57)**^{2}
Book	21 (13.82)	**25 (13.16)**^{3}	30 (17.14)	**38 (25.68)**^{2}	**42 (22.95)**^{2}	**156 (18.4)**^{3}
Man-made machinery	9 (5.92)	12 (6.32)	4 (2.29)	5 (3.38)	11 (6.01)	41 (4.83)
Animals	20 (13.2)	21 (11.1)	4 (2.29)	3 (2.03)	3 (1.64)	51 (6.01)
Plants	13 (8.55)	10 (5.26)	7 (4)	2 (1.35)	14 (7.65)	46 (5.42)
Celestial planets	9 (5.92)	11 (5.79)	13 (7.43)	14 (9.46)	30 (16.4)	77 (9.08)
Laboratory equipment	**98 (64.47)**^{1}	**143 (75.26)**^{1}	**105 (60)**^{1}	**56 (37.84)**^{1}	**87 (47.54)**^{1}	**489 (57.67)**^{1}
Emotions & attitudes						
Positive	80 (52.63)	56 (29.47)	27 (15.43)	27 (18.24)	33 (18.03)	223 (26.3)
Negative	13 (8.55)	36 (18.95)	39 (22.29)	31 (20.95)	34 (18.58)	153 (18.04)

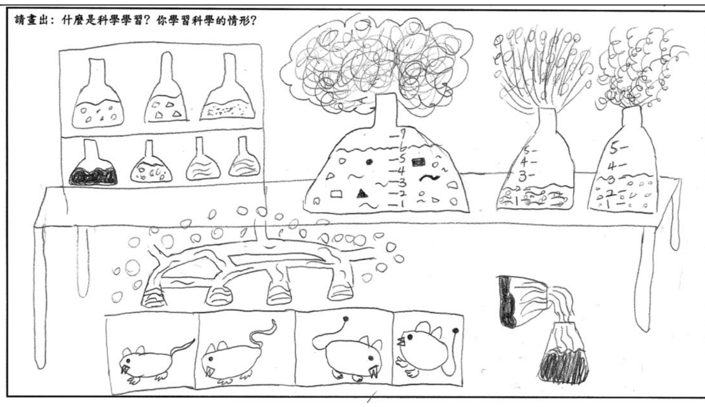
Note. The % in each cell is calculated within the grade level. The top three subcategories are marked in bold face, and the superscript denotes ranking within each category.

subsections (people, locations, activities, and objectives) address the first research purpose, while the last subsection (emotions and attitudes) tackles the second.

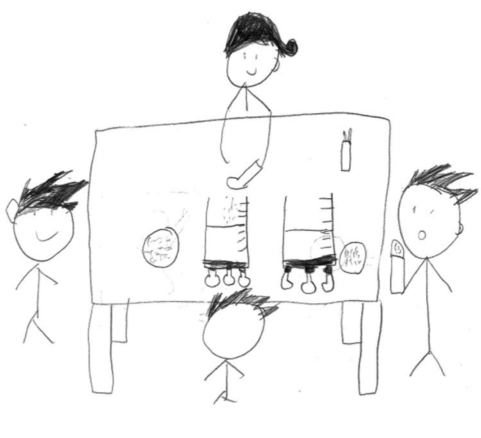
People involved in science learning

In the 'People involved' category, the most commonly drawn human figures are 'Student alone' (38.09%) followed by 'No human drawn' (32.67%), and 'Peers/Groups' (26.3%). Figure 2 shows some sample drawings of the top three ranked subcategories. 'Student alone' consistently ranks first or second across grades: it ranks first in grade 4 (42.76%), grade 8 (33.71%), and grade 12 (46.45%), and second in grade 6 (32.63%) and grade 10 (35.14%). While there is no clear trend for the 'No human drawn' subcategory, an interesting one can be found in the 'Peers/Groups' subcategory. The presence of peers/groups in students' drawings showed a significant difference by grade level (χ^2 (4, $N = 848$) = 36.525, $p < .05$). For instance, the percentage of 'Peers/Groups' in grade 4 is 36.84%, in

"Student (alone)" by a 6th grader



"No human drawn" by a 6th grader



"Peers/Group" by a 4th grader

Figure 2. Examples of the top three subcategories in the 'people involved' category.

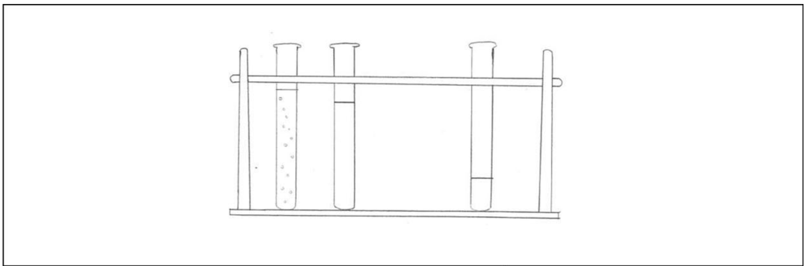
grade 6 it is 35.26%, but it drops steadily to 17.49% in grade 12. This suggests that the presence of peers/groups decreases as the grade level becomes higher. Finally, although 'Teacher' is not among the top three overall ranking, it enters the top three ranking in grades 4 and 8 (ranks third in grade 4 (27.63%) and second in grade 8 (29.14%)), but does not appear to have as much presence in other grade levels (grade 6: 17.37%, grade 10: 11.49%, and grade 12: 13.66%) (χ^2 (4, $N = 848$) = 26.971, $p < .05$). This might imply that grades 4 and 8 students view the teacher as an important figure in learning science, whereas students in other grade levels see learning science as more related to themselves or their peers.

Learning locations

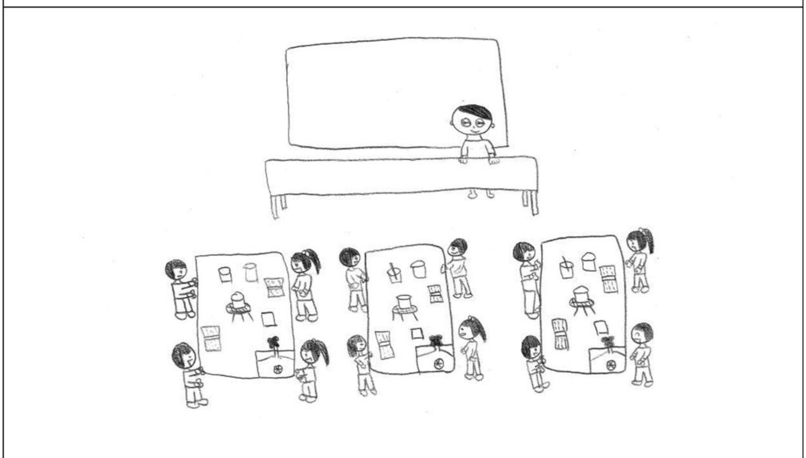
Regarding the locations the students depicted in their drawings of science learning, overall, 'Unspecified' (41.51%) takes the first place with 'Laboratory' (38.92%) and 'Classroom' (13.09%) in second and third. Sample student drawings illustrating different locations are shown in Figure 3. The percentage of 'Unspecified' location in students' drawings differs significantly by grade level (χ^2 (4, $N = 848$) = 30.922, $p < .05$). The percentage of 'Unspecified' in grade 4 is 32.24%, 33.68% in grade 6, and 36% in grade 8, but it accounts for more than half of the instances in grade 10 (54.05%) and grade 12 (52.46%). This suggests that when higher grade level students draw, they tend not to specify the location of science learning in comparison with lower grade level students. When students did specify the learning location, the percentage of 'Laboratory' also shows a significant difference by grade (χ^2 (4, $N = 848$) = 41.032, $p < .05$). In other words, the percentage of 'Laboratory' in students' drawings is higher among younger learners (grade 4: 46.71%, grade 6: 53.68%, grade 8: 38.29) compared to more mature learners (grade 10: 25%, and grade 12: 28.96%). Finally, 'Classroom' consistently ranks as the third most drawn location for science learning across grade levels.

Science learning activities

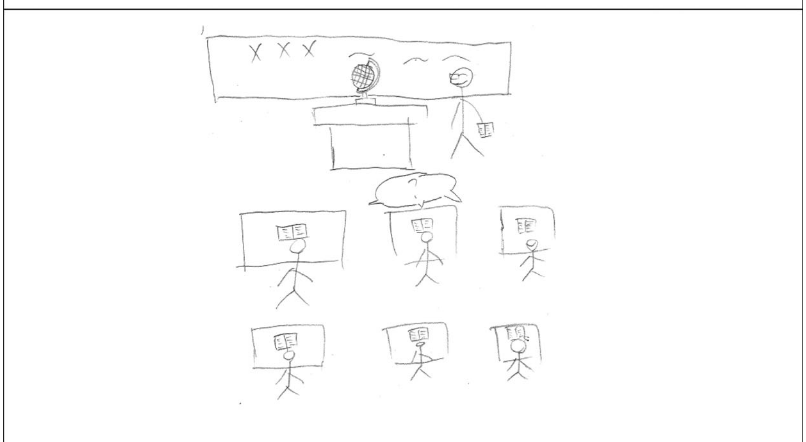
In terms of the 'Activities' category, the three most drawn activities across grade levels are: 'Experiment' (46.58%), 'Unspecified' (25.24%), and 'Teacher lecturing' (16.51%). A closer look into the percentage distribution reveals cross-grade differences for 'Experiment' and 'Teacher lecturing'. 'Experiment' ranks first in every grade level except grade 10. Furthermore, the distribution of its percentages shows significant difference by grade level (χ^2 (4, $N = 848$) = 50.402, $p < .05$). For example, the percentage of 'Experiment' in grade 4 is 51.32%, in grade 6 it is 64.21%, but it drops to well below half in grade 10 (29.73%) and grade 12 (36.07%). There seems to be a trend that as students gain more experience in schooling, the less they associate science learning with 'Experiment'. 'Teacher lecturing' also shows significant difference by grade (χ^2 (4, $N = 848$) = 10.014, $p < .05$). Although 'Teacher lecturing' ranks second in grade 4 (21.71%), and third in grade 6 (15.26%), and 8 (21.14%), it does not enter the top three ranking in grade 10 (12.16%) or grade 12 (12.57%). Instead, 'Reading/Studying' emerges as the third most drawn activity in grade 10 (16.2%) and grade 12 (14.8%). It is also worth noting that 'Reading/Studying' has relatively low percentages in lower grade levels (grade 4: 3.29%, grade 6:6.32%, grade 8: 3.43%). Taken together, when students did specify the activities relating to science learning in their drawings, changes in the percentage distribution in these



"Unspecified location" by a 6th grader



"Laboratory" by an 8th grader



"Classroom" by a 10th grader

Figure 3. Examples of the top three subcategories in the 'locations' category.

categories suggest very different conceptualisations of science learning activities by different age groups. Grades 4, 6, and 8 students' drawings appear to exhibit similar patterns ('Experiment' and 'Teacher lecturing'), whereas grades 10 and 12 form another group with similar patterns ('Experiment' and 'Readying/Studying'). This suggests a cross-sectional change in the major science learning activities portrayed in students' drawings from 'Teacher lecturing' to 'Reading/Studying'.

Objects relating to science learning

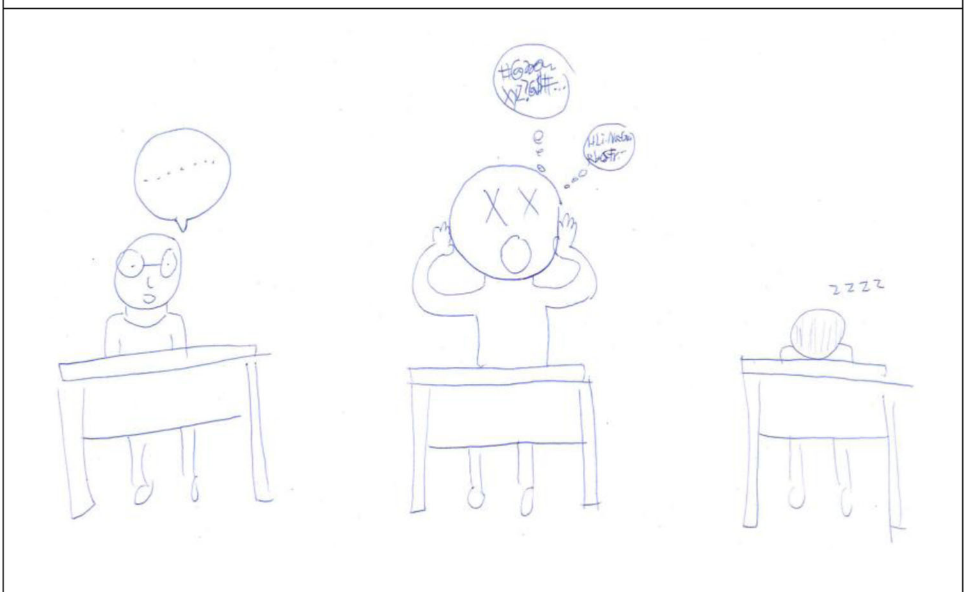
With regard to the 'Objects' category, on the whole, 'Scientific equipment' (57.67%) ranks first, followed by 'School furniture' (40.57%) and 'Book' (18.4%). While 'Laboratory equipment' and 'School furniture' consistently enter the top three rankings across grade levels, a different pattern can be found for 'Book'. There is a significant difference in 'Book' by grade (χ^2 (4, N = 848) = 13.533, $p < .05$). The occurrence of 'Book' in students' drawings ranks the second in grades 10 (25.68%) and 12 (22.95%) and yet the occurrence is much less in grades 4–8 (grade 4: 13.82%, grade 6: 13.16%, and grade 8: 17.14%). One other subcategory worth mentioning is that of 'Blackboard'. The percentage of 'Blackboard' shows significant difference by grade level as well (χ^2 (4, N = 848) = 24.499, $p < .05$). 'Blackboard' has relatively low percentages in grade 6 (10%), 10 (10.81%), and grade 12 (12.02%), and yet it has much higher percentages and ranks the third in grade 4 (19.74%) and grade 8 (25.71%). The pattern found in 'Book' and 'Blackboard' corresponds to the findings in the 'People involved' and 'Activities' category: 'Teacher', 'Teacher lecturing', and 'Blackboard' are the more prominent attributes that seem to be associated with grades 4 and 8, whereas 'Reading/Studying' and 'Book' are linked to grades 10 and 12.

Emotions and attitudes in science learning

As emotions and attitudes are the other important focus of this study, this subsection attends to the second research purpose of the current study that attempted to explore the spontaneously expressed emotions and attitudes in student drawings. In the 'Emotions and attitudes' category, significant difference was found in both the positive and negative emotions and attitudes subcategories across grade levels. Sample drawings of positive and negative emotions and attitudes are shown in Figure 4. The percentages and trends of students' emotions and attitudes at different grade levels are shown in Figure 5. The percentage of the positive emotions and attitudes expressed in the students' drawings starts out fairly high at 52.63% in grade 4, then drops steeply to 29.47% in grade 6, continues to dip to the lowest point of 15.43% in grade 8, before climbing slightly to 18.24% and 18.03% in grades 10 and 12 (χ^2 (4, N = 848) = 77.444, $p < .05$). In contrast, the negative emotions and attitudes expressed in the students' drawings start out low at 8.55% in grade 4, then climb to 18.95% in grade 6, before reaching their highest point of 22.29% in grade 8, and then dropping slightly to 20.95% and 18.58% in grades 10 and 12 (χ^2 (4, N = 848) = 12.373, $p < .05$). It should be highlighted that students' negative emotions and attitudes expressed in their drawings exceeded positive emotions and attitudes from grade 8 on, and reached around the same point as positive emotions and attitudes, around 18%, in grade 12.

In addition to the cross-sectional differences in students' drawings of science learning, gender differences were found in the 'No human drawn' and 'Positive emotions and attitudes' subcategories. Specifically, a gender difference exists in 'No human drawn' (χ^2 (1, N = 848) = 4.321, $p < .05$) of the 'People involved' category (male: 35.98%, female: 29.29%). It appears that male students are less likely to draw human agents involved in science learning than their female counterparts. For the 'Positive emotions and attitudes' subcategory, the female students drew significantly more positive expressions of emotions and attitudes in their drawings than did the male students (female: 32.28%, male: 20.33%, χ^2 (1, N = 848) = 15.891, $p < .05$). Moreover, as

"Positive emotions and attitudes" by a 4th grader



"Negative emotions and attitudes" (middle figure: stressed out) by a 8th grader

Figure 4. Examples of 'positive and negative emotions and attitudes' drawn by students.

illustrated in Figure 6, the percentages of positive emotions and attitudes in the female students' drawings are higher than those of the male students' drawings at every grade level. The greatest gap (24.65%) in positive emotions and attitudes can be observed in grade 6 (male: 17.02%, female: 41.67%), while the smallest difference (2.3%) is in grade 12 (male: 16.85%, female: 19.15%).

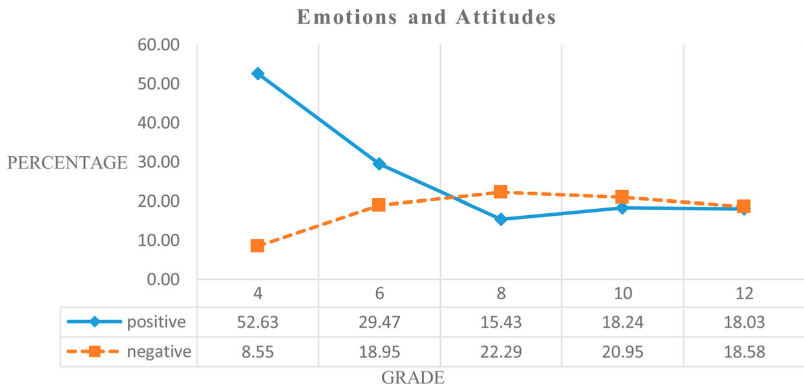


Figure 5. Students' positive and negative emotions and attitudes by grade.

Results of the word frequency analysis

In addition to the analysis of student drawings, the analysis of students' drawing captions was also conducted. The frequency word lists were obtained by feeding the text in the students' drawings into a Mandarin Chinese word cloud generator. After obtaining the word lists, phrases such as 'science' and 'learning' were manually removed because we were interested in seeing what concepts are associated with science learning. Owing to the relatively small amount of text in grade 8, only the top three most frequently used phrases are reported. In addition, those with frequency lower than four are also not reported. The top five word lists in each grade level are shown in Table 5. In brief, the top five most frequently used phrases are: experiment (87), understand (42), computer (41), teacher (37), and we (21).

The most frequently mentioned phrase is 'experiment'. 'Experiment' appears in the top five most frequently used words in every grade level with the exception of grade 10 (experiment was mentioned five times in grade 10). 'Understand' appears in the top five ranking in grades 4, 10, and 12. Although 'computer' ranks second in the overall top five wordlist, it enters the top five ranking only in elementary school children's textual descriptions. This

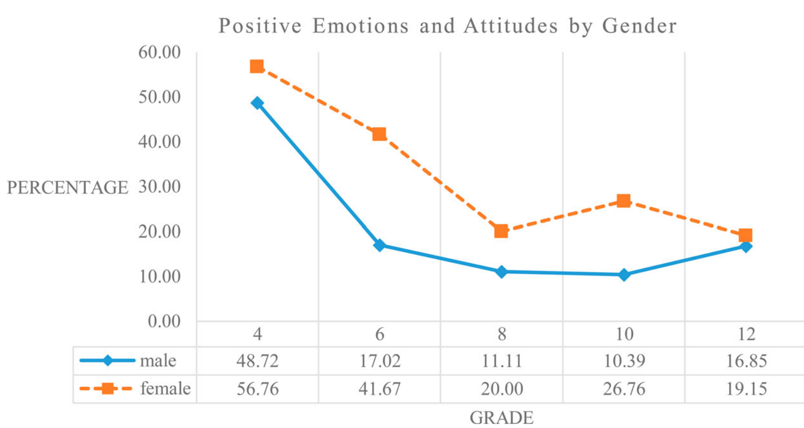


Figure 6. Students' positive emotions and attitudes by gender.

Table 5. Frequency counts of textual descriptions in the drawings by grade level.

Grade level	Drawings with descriptions	Word counts	Top five phrases in the drawings (frequency)
4	106	1824	Experiment (21) Teacher (17) Computer (14) Classroom (9) Understand (9)
6	97	3513	Experiment (36) Computer (25) (Something) can (14) Mathematics (14) We (13)
8	61	1100	Experiment (12) Teacher (6) Element (4) Be used for … (4)
10	85	1240	Understand (14) Attending class (8) Apply (6) Test (6) Discuss (6)
12	78	1306	Experiment (16) Understand (13) Concept (5) Equation (4) Chemistry (4) (Homework) problem (4)
Total	427	8983	Experiment (87) Understand (42) Computer (41) Teacher (37) We (21)

might suggest that elementary school students have more exposure or opportunities to use computer technologies for science learning. Finally, 'teacher' could only be found in grades 4 and 8's top five word lists, a pattern that is consistent with the results for the 'People involved' category obtained from the coding check list.

Discussion

Using the draw-a-picture technique, the purposes of this study were to (1) explore Taiwanese students' conceptions of science learning across different grade levels with regards to the people, locations, activities, and objectives portrayed in their drawings, and (2) examine their expressed emotions and attitudes toward science learning. The analysis showed that the majority of the students conceptualise science learning as school-based (in a laboratory or classroom) involving either certain types of experiment or teacher lecturing. Perhaps, the more notable cross-sectional difference that we observed lies in the 'Activity' and 'Emotions and attitudes' category. In the 'Activity' category, lower grade level students' drawings seem to present a didactic image of science learning (i.e. teacher lecturing), while the images produced by higher grade level students (i.e. reading/studying) potentially signal quantitative views (i.e. how much is learned) of learning science that focus more on memorising, testing, calculating, and increasing knowledge. With regard to the 'Emotions and attitudes' category, the younger the students are, the more positive emotions and attitudes could be found in their drawings. Moreover, contrary to the common belief that male students hold more positive attitudes toward science than female students, female students in this study expressed significantly more positive emotions and attitudes in their drawings than did the males. The following discussion centres on these three aspects found in this study.

Potentially quantitative view of science learning among higher graders

In the current study, grades 4, 6, and 8 students' drawings appear to exhibit similar patterns for the major activities drawn ('Experiment' and 'Teacher lecturing'), whereas grades 10 and 12 form another group ('Experiment' and 'Readying/Studying'). It is perhaps no surprise that students drew pictures of themselves doing experiments when asked about the two questions 'What is science learning?' and 'What is it like when you are learning science?' as experiment is the most salient component that distinguishes science from other academic subject domains. In science education, laboratory work is considered to play a central and distinctive role (Hofstein & Lunetta, 1982, 2004). Although the majority of students conceptualised science learning as doing experiments, they might perceive the purpose of laboratory work very differently. Tsai (1999) explored the interplay between eighth graders' scientific epistemological views (SEVs) and their learning in school laboratory activities, and divided the students into two SEV groups: constructivist and positivist students. While constructivist students tended to deeply explore the involved concepts of laboratory activities, the positivist students used a more surface approach (i.e. following the codified procedures of science textbooks), and viewed laboratory exercises as a 'memory aid' that helped make the scientific concepts more impressive. More recently, Chiu, Lin, and Tsai (2016) conducted a qualitative and quantitative analysis on university science-major students' conceptions of learning science by laboratory (CLSL). Their study revealed six categories of CLSL including memorising, examining prior knowledge, acquiring manipulative skills, obtaining authentic experience, reviewing prior learning profiles, and achieving in depth understanding. Even though the students in the current study pictured themselves doing experiments, their views on laboratory work might be at opposite ends of the hierarchy. In addition, from the analysis, we observed that the percentage of 'Experiment' dropped to less than half among higher grade level students (grade 10: 29.73% and grade 12: 36.07%). There seems to be a trend that as students gain more experience in schooling, the less they associate science learning with 'Experiment'. This could either be because the opportunities for students to do laboratory work decreases, or because other activities gain more importance in students' conceptions of science learning. More work is needed to explore the CLSL held by students of younger age.

The other primary images expressed through students' drawings such as 'Teacher lecturing' (grades 4, 6, 8) and 'Reading/Studying' (grades 10, 12) suggest that (1) lower grade level students conceptualise science learning with a didactic approach, and that (2) students in higher grade levels could have a more quantitative view of science learning (i.e. how much is learned, not how well it is learned) that has an external motivational orientation, and their forms of knowledge acquisition mostly focus on reproducing and knowing (see Tsai's (2004) framework for a complete mapping of students' conceptions of science learning). The international community has long been interested in 'the paradox of the Chinese learner' (e.g. Chan & Rao, 2009; Marton et al., 1997; Watkins & Biggs, 1996, 2001): the seeming paradox that while being conceived as rote learners in large didactic classrooms, students from the Confucian heritage culture continue to dominant in international comparison of academic performance reports. The major activities portrayed in this study to a certain extent reaffirm this paradox on the surface level. In Taiwan, where the cultural atmosphere values good performance in academic activities, and test scores largely dictate what college students can attend, it is plausible that this cultural context exert an influence on students' conceptions of science learning. Students study to memorise information they need in order to pass tests. The transition from 'Teacher lecturing' to 'Reading/Studying' perhaps exemplifies this point, as the majority of higher level students (i.e. grades 10 and 12) need to take the college entrance exam upon graduation, and their fates depend on their exam scores. The emergence of 'test' (in grade 10), and 'equation' and '(homework) problem' (in grade 12) among the most frequently used phrases in students' drawings further adds support to this trend. Furthermore, this might also account for the similar percentage of male and female students' positive emotions and attitudes at 12th grade. In the current study, although female students drew significantly more expressions of positive emotions and attitudes than males, the smallest difference (2.3%) exist in grade 12 (male: 16.85%, female: 19.15%). In a context where good academic performance is crucial and is valued by the society, under this kind of pressure, one can only imagine that positive emotions and attitudes toward science learning would wear out rather fast and thus levelling off the percentage difference.

However, it has been suggested that Chinese learners possess different views on the role of and the relationship between memorisation and understanding (Dahlin & Watkins, 2000; Kember, 1996, 2000; Marton et al., 1997; Marton, Wen, & Wong, 2005). For instance, Marton et al. (2005) reported that Chinese learners differentiate between memorisation before understanding (rote memorisation), understanding before memorisation (meaningful memorisation$_1$), and memorisation and understanding happen simultaneously (meaningful memorisation$_2$). Although higher grade level students in the current study pictured themselves reading/studying, the kind of memorisation process they engage in is not clear. Therefore, further research is needed to gain deeper understanding of the relationship between memorising and understanding among different age groups of students.

The waxing negative and the waning positive emotions and attitudes

There are three cross-sectional trends of the positive and negative emotions and attitudes students portrayed in their conceptions of science learning. Firstly, the lower the level, the more positive emotions and attitudes could be found in the students' drawings. Secondly, the negative emotions and attitudes expressed in students' drawings started out relatively low (8.55% in grade 4) and climbed to the highest point in grade 8 (22.29%) and stayed around the 20% line until grade 12. Finally, students' negative emotions and attitudes expressed in their drawings exceed the positive emotions and attitudes from grade 8 on, and reach around the same point as the positive emotions and attitudes, around 18%, in grade 12.

'Academic emotions' refers to students' emotions that are associated with academic learning, classroom instruction, and achievement (Pekrun, Goetz, Titz, & Perry, 2002). It has been shown to influence student academic engagement and performance (e.g. Lichtenfeld, Pekrun, Stupnisky, Reiss, & Murayama, 2012). Overall, the three trends found in the study are consistent with previous findings (e.g. Hsieh & Tsai, in press; Vierhaus, Lohaus, & Wild, 2016). Vierhaus et al. (2016) traced students' development of achievement emotions and coping/emotion regulation, and found that between the end of grade 5 and the end of grade 7 enjoyment decreased, while boredom increased. Hsieh and Tsai's (in press) cross-sectional analysis of students' learning conceptions also revealed a similar pattern in that students' negative emotions and attitudes have relatively low percentages in grades 2 and 4, but reach a plateau in grades 6, 8, and 10. Taken together, three trends appear to emerge from the aforementioned studies and the current one: (1) the reversed trajectories of positive and negative emotions and attitudes, (2) the peak of students' negative emotions and attitudes all register near or around middle school (grades 6, 7, and 8), and (3) the patterns observed might be independent of academic domain. However, researchers have not yet reached a consensus as to the reasons behind these trends (see discussion in Vierhaus et al., 2016). Thus, further investigation is needed to uncover the underlying reasons for these changes.

Gender difference in emotions and attitudes toward science learning

There is a recurrent lament that women are under-represented in science, technology, engineering, and mathematics (STEM) majors and careers (e.g. Blickenstaff, 2005; Harding & Parker, 1995; Sikora & Pokropek, 2012). Consequently, gender difference in science education is a topic that has been discussed extensively. For instance, studies have shown that boys and girls differ in a number of areas such as attitudes (e.g. Desy, Peterson, & Brockman, 2011; Miller, Slawinski Blessing, & Schwartz, 2006; Osborne, Simon, & Collins, 2003), science-related experiences (e.g. Jones, Howe, & Rua, 2000), college major enrolments (e.g. Chachashvili-Bolotin, Milner-Bolotin, & Lissitsa, 2016; Smith, 2011), and career choices (e.g. Blickenstaff, 2005), among others.

Take attitudes for example; previous research has shown that female students generally have lower interest in science, hold negative feelings, and demonstrate less enjoyment of science (e.g. Desy et al., 2011; Jones et al., 2000; Meece, Glienke, & Burg, 2006; Miller et al., 2006). In a study which examined 79 high-school students' gender differences in attitudes toward their science classes, perceptions of science and scientists, and views on majoring in science, Miller et al. (2006) found that females generally viewed science as uninteresting and the scientific lifestyle unattractive. In a more recent study, Desy et al. (2011) surveyed 1299 students in middle school (grades 6–8) and high school (grades 9–12) regarding their science-related attitudes and interests. They found that females reported more anxiety about science, and less motivation in and enjoyment of science. Females also tended to rank science as one of their least favourite subjects.

However, contrary to the findings in previous research, our analysis showed that female students drew significantly more expressions of positive emotions and attitudes in their drawings than did the male students. Furthermore, the percentage of positive emotions and attitudes in female students' drawings is higher than in the male students' drawings at every grade level, with the greatest gap (24.65%) in grade 6 (male: 17.02%, female: 41.67%) and the smallest difference (2.3%) in grade 12 (male: 16.85%, female: 19.15%). This contradiction might be explained in terms of the general assumption that females are more expressive of their emotions and attitudes, or the different tendencies in thinking styles (analytics vs. holistic) between the East Asian and Western students within each gender.

Wang and Tseng (2013) explored the effects of thinking styles on science achievement and attitudes toward science class among Taiwanese elementary school students in an attempt to examine the difference in modes of thinking between male and female students. In terms of thinking style and attitudes, their findings revealed that students with an analytical thinking style and an integrative thinking style showed more positive attitudes toward science class than students with a holistic thinking style. In addition, Taiwanese male students tended to be more holistic thinkers than their female counterparts, whereas Taiwanese female students tended to be more analytical thinkers. It should be highlighted that the male–female thinking style patterns found in Wang and Tseng's (2013) study showed a reverse pattern when compared to those found in the Canadian context: Canadian male secondary school students tended to be more analytical in their thinking style than their female counterparts. Wang and Tseng (2013), in discussing this reverse pattern, associated this disparity with cultural preferences for thinking styles.

Since analytical thinkers tend to show more positive attitudes towards science class according to Wang and Tseng (2013), it follows that Taiwanese female students could potentially have more positive attitudes. The more significant positive emotions and attitudes observed in this study could therefore be a manifestation of the trend Wang and Tseng (2013) found in their study. Due to the exploratory nature of the current study, more research is needed in order to explore the possible reasons for the disparate results observed in this study.

Limitations

Using the draw-a-picture technique as the primary data collection method, this study explored and compared students' conceptions of science learning across different age groups in a high-performing TIMSS nation, Taiwan. The current study unveiled dimensions that are different from those that can be derived from phenomenographic studies (i.e. the quantitative view of science learning held by higher grade level students, and the higher positive academic emotions express by females) and potentially contributed to the collective understanding of the science learning conceptions held by this particular groups of students. However, such kind of method is not without limitation. In the DAST literature, it has been noted that the drawings produced by the students oftentimes were not necessarily their own perception but instead reflected their perception of public stereotypes of scientist (Symington & Spurling, 1990), and that it is difficult to correlate stereotypical images found in the drawing to negative attitudes to science (Losh, Wilke, & Pop, 2008). The first concern originated from the drawing prompt given to the students: 'draw a picture of a scientist'. Symington and Spurling (1990) investigated the effect of a revised prompt 'Do a drawing which tells me what you know about scientists and their work' and discovered that students drew differently with the two prompts. Symington and Spurling (1990) thus came to the conclusion that children may be interpreting the request to 'draw a picture of a scientist' as needing to incorporate a known public stereotype even though their own conceptions of scientist is different from the public view. The results of Symington and Spurling (1990) suggested the importance of giving clear and specific drawing prompts that tap into student's personal experience when administering such drawing test. In the current study, this potential pitfall was avoided by the drawing prompts we gave to students in which we specifically asked them of their own experience

'What is it like when you are learning science?' This prompt also helped to avoid the second concern of the DAST (i.e. it is difficult to correlate stereotypical images found in the drawing to negative attitudes to science). By directly tapping into students' own experience of science learning, it allowed us to obtain students' most immediate attitudes toward science learning.

Concluding remarks

In concluding this research, there might be several issues that need further investigation, specifically, higher grade level students' potentially quantitative views on science learning, and the positive emotions and attitudes female students hold toward science learning. The conceptions of science learning held by the higher grade level students (grades 10, 12) in the current study might be of external motivational orientation, and the forms of knowledge acquisition mostly focus on reproducing and knowing – all of which point to the reliance on lower-level thinking skills. According to Duschl (2008), one of the science learning domains that science education should focus on is 'conceptual structures and cognitive processes used when reasoning scientifically' (p. 277). This speaks to the importance of cultivating students' higher-order thinking skills such as critical thinking in science education, a goal that will be difficult to reach if the students hold mostly quantitative views of science learning (i.e. how much is learned, not how well it is learned). How to change students' unfruitful conceptions of science learning so that we can help them to develop higher-order thinking skills has become a crucial agenda that deserves educators' as well as researchers' attention. Secondly, it has been suggested that students' attitudes toward science influence their interest in science (e.g. Farenga & Joyce, 1998). In reviewing the low engagement of females in STEM, Miller et al. (2006) contended that girls have low interest in science rather than low ability or low achievement. Contrary to the previous findings on girls' attitudes toward science or science learning, the Taiwanese female students in this study demonstrated higher positive emotions and attitudes than their male counterparts. Further investigations on this reverse pattern of attitudes toward science learning in this context might be able to shed light on the change in women's under-representation in STEM.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

The funding of this research is supported by the Ministry of Science and Technology, Taiwan, under grant contract number MOST 104-2511-S-011-002-MY2. The authors would like to thank Dr. Pin-Ju Chen for his assistance with data collection. The acknowledgement also goes to the six coders for their assistance with coding.

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