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Surveying Students' Conceptions of Learning Science by Augmented Reality and their Scientific Epistemic Beliefs

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ABSTRACT
Previous studies have addressed the positive influences of augmented reality (AR) on science learning. However, few studies have explored how learners consider learning science by such an emerging technology, particularly from the perspectives of conceptions of learning. This study therefore aimed to develop a survey to understand students' conceptions of learning science by AR (CLSAR) considering their demographic characteristics and scientific epistemic beliefs. The CLSAR survey was validated by the responses of 267 junior high school students. The results indicate that the students generally exhibited positive conceptions, with stronger perceptions of learning science by AR as increasing motivation and interaction. Although they expressed less negative conceptions, their considerations of learning science by AR as diminishing learners' imagination about the scientific information were stronger than those as interrupting learning. The students' grade level played a role in their conceptions, but their gender did not. However, when considering the relationships between the students' scientific epistemic beliefs and their conceptions, the gender factor may interfere with the relations. Based on the findings, some suggestions for the development of AR-related science learning systems are discussed.

Keywords: augmented reality, conceptions of learning, scientific epistemic beliefs, learning phenomena, learning experience

INTRODUCTION

Recent educational studies have explored the influences of augmented reality (AR) on science learning for K-12 students. AR is a technique which can blend virtual information with physical world in real time for users to see through displays such as the screen of mobile devices. With its layering of information over real space, it is believed that AR creates new user experience and learning possibility. The features of AR could generally be classified into image-based and location-based AR based on the recognition technology. While the image-based AR provides augmented information through artificial markers or natural graphics recognition, the location-based AR offered virtual information through locational identification by global positioning system (GPS). With the development of AR technology, object-based visualization has been gradually mature with its capability of detecting and tracking intricate 3D objects or physical space (e.g., toys, products, complex geometries, or interior space). Therefore, users' AR experiences would not be limited to a 2D image-based nor a location-based trigger. It was also found that, for students' science learning, the image-based AR could support spatial ability, practical skills, and conceptual understanding of science knowledge and the location-based AR could afford inquiry-based scientific activities (Cheng & Tsai, 2013). Recently, empirical studies have addressed the positive effectiveness of learning science by AR on learning motivation or academic achievement (Liou et al., 2017; Hsiao et al., 2016; Hwang et al., 2016). Some studies with regard to AR learning in the field of science have also focused on the evaluation of learners' attitudes or perceived usability (Gopalan et al., 2016; Lin et al., 2015; Tarng et al., 2015). However, few studies have attempted to explore how learners consider learning science with the aid of emerging technologies (e.g., AR), particularly from the perspectives of conceptions of learning, which are defined as the consideration of the learning process and objectives (Benson & Lor, 1999).

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Contribution of this paper to the literature

- Developing a survey to understand learners' conceptions of learning science by AR (CLSAR).
- Identifying the relationships between learners' CLSAR and their scientific epistemic beliefs.
- Implying the mediation role of gender in the relationships between learners' scientific epistemic beliefs and their conceptions in the context of AR-based learning.

Conceptions of Learning

Conceptions of learning refer to an individual's natural interpretation or understanding of the learning phenomena (Marton, 1981). Students' views about their learning process reflect how they principle learning in their mind. Accordingly, their learning experience and preference of learning methods contribute to the formation of their conceptions of learning. A variety of conceptions of learning are usually exhibited by different learners. The various conceptions of learning have been explored, and their hierarchical features have been documented in earlier studies (Marton et al., 1993; Säljö, 1979). For example, in Marton et al.'s study (1993), individuals' conceptions of learning were categorized, from lower to higher levels, as (1) increasing one's knowledge, (2) memorizing, (3) applying, (4) understanding, (5) seeing in a different way, and (6) changing as a person. That is, while the category of "increasing one's knowledge" reflects less advanced conceptions, the category of "changing as a person" represents more sophisticated conceptions. Moreover, the categories of individuals' conceptions of learning may be different when they confront various educational domains such as engineering learning (Marshall et al., 1999), science learning (Tsai, 2004), mathematics learning (Chiu, 2012), or language learning (Drewelow & Mitchell, 2015). Researchers have also been interested in exploring individuals' conceptions of learning with the aid of technology, for example learning in blended contexts (Ellis, 2014) and learning via ubiquitous channels (Tsai et al., 2011). Since the educational applications of AR have increased recently, understanding learners' conceptions in the context of AR learning might provide crucial insights into their learning by AR.

Conceptions of Learning by AR

A recent study explored parents' conceptions of AR learning (e.g., Cheng, 2017) and identified eight hierarchical categories of their conceptions. That is, the parents considered learning by AR as (1) increasing presence, (2) drawing attention, (3) fostering motivation, (4) extending content, (5) attaining in-depth understanding, (6) enhancing interaction, (7) obstructing reading, and (8) diminishing imagination. Notably, the categories represented the parents' conceptions from positive (1 to 6) to negative (7 to 8). It was also found that parents who held higher-level conceptions (e.g., learning by AR as increasing the interaction between learners and learning materials) may have used more advanced strategies to learn with their children (e.g., discussing the learning content with their children in order to help their children's reflection on the content learned previously), and vice versa. Interestingly, in that study (Cheng, 2017), for those parents with negative conceptions, they may have thought more critically rather than superficially about the disadvantages of AR learning, and therefore tended to utilize more advanced strategies. To some extent, the findings imply the relationships between individuals' conceptions of learning and the way they learn.

With regard to science learning, several studies have explored students' conceptions of learning science (Park & Jeon, 2015; Sadi & Lee, 2015; Zhao & Thomas, 2016). Some studies have also identified the important role of conceptions of learning science in the strategies they use to learn science (Shen et al., 2016), their science learning self-efficacy (Tsai et al., 2011), and their motivation to learn science (Ho & Liang, 2015). According to these studies, it can be contended that students' conceptions of learning science play a significant role in their science learning. Moreover, the importance of AR technology applied for science education has been highlighted by the literature (Chang et al., 2016; Cheng & Tsai, 2013). For example, in Chang et al.'s study (2016), it was found that there were no significant differences in knowledge and attitude, but a significant difference in the students' perceptions of technology features between the group of learning science by AR and the group of learning science by interactive simulation technology. Specifically, the more positive perceptions the students possessed, the more the student's attitude changed to oppose socio-scientific issue such as nuclear power. The results imply that learners' views on AR technology may play a role in their science learning. In addition, the previous review has suggested more research for science education is required to explore learner characteristics involved in AR (Cheng & Tsai, 2013). Students' conceptions of learning could be deemed as a type of learner characteristics. This study hence considered that, since learning science by AR is suggested as a potential instruction for K-12 education (e.g., Liou et al., 2017; Hsiao et al., 2016; Hwang et al., 2016), there is a need to explore students' conceptions of learning science by such a state-of-the-art technology beyond simply understanding their perceptions of technology features (Chang et al., 2016).

Demographic Variables and Conceptions of Learning Science

The exploration of students' conceptions of learning has been carried out considering demographic variables such as gender and grade level. For example, in Chiou et al.'s study (2012), they investigated the gender differences of undergraduate students' conceptions of learning biology. It was found that females were likely to exhibit more sophisticated conceptions than males. Similar results were found in Sadi and Lee's study (2015), which reported that female students considered learning science with higher levels of conception than male students. However, some other studies with large sample sizes (e.g., Sadi & Cevik, 2016 with 1,691 high school students) did not find any interaction between students' gender and their conceptions of learning science. Grade level is another demographic variable included in the studies of students' conceptions of learning science. Some studies have addressed that students with higher-level grades tended to express more sophisticated conceptions of learning science (e.g., learning science as a process of active construction of meaning) than those students in lower grades (Li et al., 2013; Sadi & Cevik, 2016). Nevertheless, a few studies have addressed that higher graders may possess more unfruitful conceptions than lower graders such as considering science learning from the aspects of how much is learned, not how well it is learned (Hsieh & Tsai, 2017). The aforementioned studies presented inconsistent results regarding the role of students' demographic characteristics including gender and grade level in their conceptions of learning science. Considering that students' conceptions of learning science with the aid of AR have been initially explored, research on demographic issues in conceptions should now be taken into account.

Scientific Epistemic Beliefs and Conceptions of Learning Science

Individuals' views on the nature of scientific knowing and knowledge are described as scientific epistemic beliefs (Hofer & Pintrich, 1997). Scientific epistemic beliefs consist of four dimensions: (1) source (e.g., scientific knowledge is transmitted by authority), (2) certainty (e.g., scientific knowledge is fixed), (3) development (e.g., scientific knowledge is continuously developing), and (4) justification (e.g., scientific knowledge can be evaluated from multiple sources) (Conley et al., 2004). Since the epistemic views are continuum scale, the beliefs of certainty or uncertainty of knowledge and simplicity or development of knowledge represent the nature of knowledge, whereas the beliefs of source of knowing and justification of knowing represent the nature of knowing. An individual with sophisticated scientific epistemic beliefs usually considers science knowledge as tentative and constructive. On the other hand, an individual with sophisticated scientific epistemic usually views science knowledge as authoritative and certain. Several studies have addressed that students' conceptions of learning science may be guided by their scientific epistemic beliefs (Chiou et al., 2013; Ho & Liang, 2015; Sadi & Dagyar, 2015; Tsai et al., 2011). To be more specific, students with sophisticated scientific epistemic beliefs tend to have constructive conceptions of learning science (e.g., considering learning science as understanding and seeing in a new way), while students with absolutist scientific epistemic beliefs are inclined to possess reproduced conceptions of learning science (e.g., viewing learning science as memorizing, preparing for tests, or calculating). It could be believed that scientific epistemic beliefs play a role in individuals' science learning processes. Accordingly, to explore the issues of conceptions of learning science by AR in more depth, students' scientific epistemic beliefs were also examined along with their conceptions in this study.

Research Questions

In summary, the aim of this study was to explore how students considered learning science with the aid of AR. Firstly, an instrument for examining students' conceptions of learning science by AR was developed based on the findings of Cheng's study (2017). The students' conceptions of learning science by AR were then analyzed. The understandings of students' conceptions could be helpful for the pedagogical development of AR science learning systems. Finally, following the aforementioned argument, the students' demographic characteristics (i.e., gender and grade level) and their scientific epistemic beliefs were also examined along with their conceptions. Therefore, the research questions of this study are listed as follows:

1. What are the reliability and validity of the questionnaire developed for exploring students' conceptions of learning science by AR in this study?
2. How do the students conceptualize learning science by AR?
3. Are there any interactions between the students' demographic characteristics (i.e., gender and grade level) and their conceptions of learning science by AR?
4. What are the relationships between the students' scientific epistemic beliefs and their conceptions of learning science by AR?

METHOD

Respondents

The respondents of this study included 267 junior high school students in Taiwan, of which 131 were female (49%) and 136 were male (51%), making a balanced gender distribution. These students were in seventh (165 students, 62%) or eighth (102 students, 38%) grade, and ranged from 12 to 15 years old (mean=13.28, SD=0.63). About 71% of the students reported a high frequency of using smart phones or tablet PCs. Despite being familiar with the operation of mobile devices, the respondents had relatively less experience of using AR applications. To be more specific, while 35% of the students had seen AR-related demonstrations, only 30% had actually used AR applications themselves.

AR Book for Science Learning

To investigate how effective the students considered learning science by AR to be, this study adopted an AR book, namely "iStorm: Wild Weather and Other Forces of Nature," for each student to read. As a result, the students could acquire experience of learning science by AR. The AR book was originally published by Carlton Books, a publisher in London, United Kingdom. We used the Chinese version of the book, which was published in Taiwan. The AR book introduces several natural phenomena such as tornadoes, volcanic eruptions, earthquakes, floods, and avalanches, and briefly shows why the natural events occur and their influences on the earth. The augmented elements in the book can be observed through focusing on specific pages using a mobile device with a camera. Subsequently, displayed via the screen of the mobile device, the virtual information related to the book content would be overlapped on the paper book (see **Figure 1**). Learners can inspect and interact with the augmented elements on the screen of the mobile device. These typical features of book reading by AR technology are the reason why the AR book was adopted in this study.

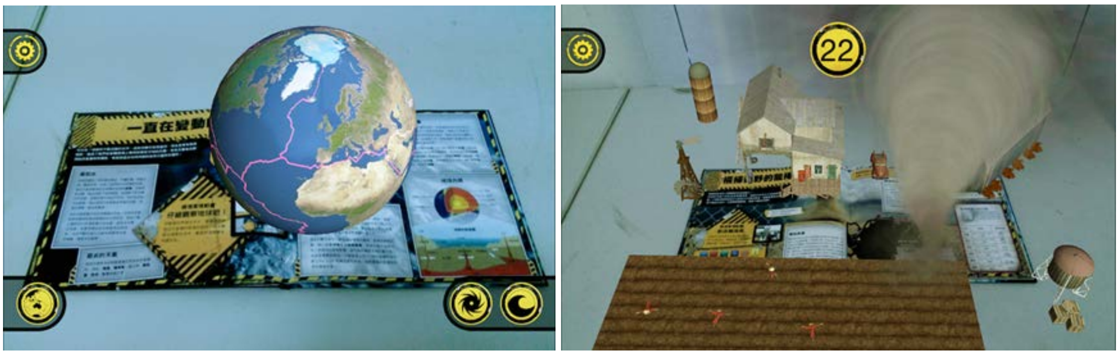

Figure 1. Demonstration of the AR book used in this study

Instruments

Based on the categories of parents' conceptions of AR learning developed by Cheng (2017), in this study, we developed an instrument, namely the Conceptions of Learning Science by AR (CLSAR) survey, to investigate the students' beliefs about learning science by AR. Firstly, the eight categories of parents' conceptions of AR learning in Cheng's study (2017), namely (1) increasing presence (called presence), (2) drawing attention (called attention), (3) fostering motivation (called motivation), (4) extending content (called extending), (5) attaining in-depth understanding (called understanding), (6) enhancing interaction (called interaction), (7) obstructing reading, and (8) diminishing imagination, were adopted as the scales of the CLSAR survey. We subsequently developed four items for each scale (using a 5-point Likert scale: from 1, *strongly disagree* to 5, *strongly agree*), making a total of 32 items. The description of the items was aligned with science learning context. Secondly, to confirm the content validity of the CLSAR survey, all the items were examined by two experts in this research field. Pretest of the instrument were conducted with five target samples (junior high school students) to make sure that the students can understand the statement of the items of the CLSAR survey. The evaluation of the instrument was finally implemented through a series of factor analysis and internal consistency test (described later). The descriptions of the eight scales are as follows:

1. Presence: assessing the extent to which students consider learning science by AR as being for the purpose of increasing presence of scientific phenomena.

2. Attention: assessing the extent to which students consider learning science by AR as being for the purpose of attracting learners' attention to learning materials regarding scientific information.
3. Motivation: assessing the extent to which students consider learning science by AR as being for the purpose of fostering learners' willingness to learn science.
4. Extending: assessing the extent to which students consider learning science by AR as being for the purpose of extending learning content with relevant scientific knowledge.
5. Understanding: assessing the extent to which students consider learning science by AR as being for the purpose of attaining more in-depth scientific understandings of the learning materials.
6. Interaction: assessing the extent to which students consider learning science by AR as being for the purpose of creating interaction between learners and learning materials and providing the opportunity for learners to explore scientific knowledge.
7. Obstructing reading: assessing the extent to which students consider learning science by AR as probably interrupting learners' reading when engaging in science learning.
8. Diminishing imagination: assessing the extent to which students consider learning science by AR as probably restraining learners' imagination about the scientific information they have read in paper books.

Moreover, to examine the students' scientific epistemic beliefs, this study adopted the scientific epistemic belief (SEB) survey which was developed by Conley et al. (2004) and has been utilized in various recent studies (e.g., Cheng & Wan, 2016; Kampa et al., 2016; Lee et al., 2016). The SEB survey consists of four scales, namely source, certainty, development, and justification, and mainly measures learners' beliefs about the nature of scientific knowledge and knowing. Each item in the survey was rated on a 7-point Likert scale (from 1, *strongly disagree* to 7, *strongly agree*). While the source and certainty scales reveal learners' absolutist scientific epistemic beliefs, the development and justification scales reflect their sophisticated scientific epistemic beliefs. Following are descriptions of the four scales.

1. Source: measuring the extent to which students believe that scientific knowledge is from external authority.
2. Certainty: measuring the extent to which students believe that scientific knowledge is absolute and has certain answers.
3. Development: measuring the extent to which students consider that scientific knowledge is continuously evolving and changing.
4. Justification: measuring the extent to which students consider that scientific knowledge is inquired, evaluated, and justified through multiple sources.

Data Collection Procedures

To ensure that all the students had had previous experience of learning science by AR, they were required to read the AR book adopted in this study. Before the reading activity began, the research assistant introduced how to read the AR book with a mobile device. It should be noted that she did not interfere with the students' reading once the activity began. On average, they read the book for approximately 20 minutes. When the students finished the AR book reading, they subsequently responded to the CLSAR and SEB surveys along with some demographic items (e.g., gender, age, grade level, mobile usage experience, and AR experience).

RESULTS

Factor Analysis of the CLSAR Survey

To verify the CLSAR survey developed in this study, an exploratory factor analysis (EFA) of the instrument with the principle component method was firstly implemented. The results of the EFA show that, in line with Cheng's study (2017), there were eight scales generated with a total of 27 items. The factor loading values for each item of the CLSAR survey are presented in **Table 1**, as well as the details of these items. A total of 77.96% of the variance is explained by the eight scales. The reliability coefficients (α) for these scales were 0.93 (presence), 0.84 (attention), 0.85 (motivation), 0.87 (extending), 0.85 (understanding), 0.86 (interaction), 0.85 (obstructing reading), and 0.92 (diminishing imagination). The overall α value for the scales was 0.92. Accordingly, these scales were considered to be sufficiently reliable to assess the students' conceptions of learning science by AR.

Table 1. Exploratory factor analysis of the CLSAR survey

Scale items		Factor loading	Cronbach's α
Presence			
I think learning science by AR is to...			
1.	engage learners in experiencing the reality of scientific phenomena	0.89	0.93
2.	help learners to observe scientific phenomena from 3D perspectives.	0.93	
3.	increase the feeling of visiting natural phenomena in person	0.84	
Attention			
I think learning science by AR is to...			
4.	draw learners' attention	0.77	0.84
5.	increase the attractiveness of the learning content	0.82	
6.	strengthen the learners' focus on the learning materials	0.63	
7.	stop learners from being distracted from the learning materials	0.62	
Motivation			
I think learning science by AR is to...			
8.	encourage learners to learn science	0.66	0.85
9.	foster learners' interest in learning science.	0.74	
10.	arouse learners' curiosity when learning science	0.70	
Extending			
I think learning science by AR is to...			
11.	extend learning content	0.65	0.87
12.	replenish scientific knowledge	0.63	
13.	enhance the scientific information in the paper book	0.75	
14.	provide more scientific knowledge beyond the paper book	0.79	
Understanding			
I think learning science by AR is to...			
15.	understand scientific knowledge in more depth	0.50	0.85
16.	increase the comprehension of the background of scientific knowledge	0.74	
17.	understand the source of knowledge in the paper book	0.68	
Interaction			
I think learning science by AR is to...			
18.	increase the interactivity of reading	0.66	0.86
19.	create the opportunity to explore scientific knowledge	0.69	
20.	provide opportunities to learn actively	0.66	
21.	encourage learners to interact with the learning content	0.62	
Obstructing reading			
I think learning science by AR would...			
22.	interrupt learners' reading of the paper book	0.84	0.85
23.	lessen learners' concentration when reading	0.82	
Diminishing imagination			
I think learning science by AR would...			
24.	result in negative influences on learners' imagination about the learning content	0.87	0.92
25.	diminish learners' imagination generated by reading	0.89	
26.	restrain learners' thinking about the scientific knowledge	0.91	
27.	restrict learners' imagination about the scientific information they have read in the paper book.	0.82	

Overall α = 0.92, total variance explained = 77.96%

Comparisons of the Students' Responses to the Scales of the CLSAR Survey

To briefly understand the students' conceptions of learning science by AR in this study, their responses to the scales of the CLSAR survey were examined through a series of within-subject comparison tests. Notably, the scales of the CLSAR survey were firstly classified into the two categories of positive and negative conceptions to make a reasonable comparison. As shown in **Table 1**, the students' rating scores on the scales of positive conceptions were higher than 4 points, indicating that they generally exhibited positive attitudes toward the AR book. Taking this a step further, it was found that, to a significant level (F=2.74, p<0.05), the students' rating scores on the scales of "motivation" (mean=4.18, SD=0.74) and "interaction" (mean=4.18, SD=0.72) were slightly higher than the scores on other scales including "presence" (mean=4.04, SD=1.03), "attention" (mean=4.09, SD=0.75), and "extending" (mean=4.11, SD=0.73). That is, among their perceived positive conceptions, they showed stronger AR conceptions regarding motivating learners to learn science, as well as increasing the interaction between learners and learning content.

Regarding the negative conceptions, the results in **Table 2** show that the students' rating scores on the negative scales were all lower than 4 points. That is, the students in this study may not strongly possess negative conceptions of learning science by AR. Further examining the difference between the two negative conceptions, it was found that the students significantly considered that (t=-3.19, p<0.01) learning science by AR may result in negative influences on their imagination about the scientific content of the paper book (mean=3.43, SD=1.17) rather than interrupting their reading of the paper book (mean=3.22, SD=1.20).

Table 2. Comparison of the scales of the CLSAR survey

Scale	*Mean*	*SD*	*F*	*Post-hoc*
Positive conceptions				
(1) Presence	4.04	1.03	2.74*	3>1*
(2) Attention	4.09	0.75		3>2*
(3) Motivation	4.18	0.74		3>4*
(4) Extending	4.11	0.73		6>1*
(5) Understanding	4.12	0.75		6>2*
(6) Interaction	4.18	0.72		6>4*
Scale	***Mean***	***SD***	***t***	***p value***
Negative conceptions				
(7) Obstructing reading	3.22	1.20	-3.19**	0.002
(8) Diminishing imagination	3.43	1.17		

* p<.05, ** p<.01

Demographic Differences in Conceptions of Learning Science by AR

To understand the role of demographics in the students' conceptions of learning science by AR, we firstly examined the gender differences in their conceptions. The results of the t test in **Table 3** show that there was no significant difference between the male and female students' scores for any of the CLSAR scales. That is, the variable of gender may not play a role in the students' conceptions of learning science by AR. Furthermore, we examined the grade level differences in the students' conceptions. As shown in **Table 4**, compared with the seventh-grade students, the eighth graders had higher scores on the scales of "extending" (t=-2.11, p<.05) and "interaction" (t=-2.53, p<.05). Interestingly, in addition to possessing stronger positive conceptions, the eighth-grade students held more negative conceptions than the seventh graders did. That is, the eighth-grade students were inclined to consider learning science by AR as probably interrupting learners' reading (t=-3.37, p<.01) and restraining learners' imagination about the scientific information they have read in paper books (t=-4.87, p<.001). In short, the findings implied that, compared with the students in the lower grade level, those in the higher grade level may have mixed conceptions of learning science by AR (i.e., higher-level conceptions and negative conceptions).

In addition, someone may have concerns about the impacts of the respondents' previous AR experiences (35% of the students had seen AR-related demonstrations and 30% had used AR applications) on how they consider learning science by AR is. This study therefore conducted a series of t-test to examine whether the students' previous AR experiences may influence their conceptions or not. The results show that no significant differences of AR experiences in the students' conceptions were found. As a result, the students' previous AR experiences may not interfere their responses to the CLSAR survey.

Table 3. Gender differences in the students' CLSAR

	Gender		t-value
	Male (mean/SD, n=136)	Female (mean/SD, n=131)	
Presence	3.99/1.05	4.11/1.00	-0.98
Attention	4.12/0.73	4.07/0.77	0.55
Motivation	4.15/0.75	4.22/0.73	-0.76
Extending	4.13/0.70	4.10/0.76	0.35
Understanding	4.15/0.79	4.10/0.71	0.55
Interaction	4.15/0.73	4.21/0.71	-0.75
Obstructing reading	3.22/1.20	3.21/1.20	0.12
Diminishing imagination	3.37/1.17	3.48/1.16	-0.78

Table 4. Grade level differences in the students' CLSAR

	Grade		t-value
	Seventh (mean/SD, n=165)	**Eighth (mean/SD, n=102)**	
Presence	4.10/0.95	3.96/1.15	1.05
Attention	4.02/0.74	4.21/0.75	-1.94
Motivation	4.13/0.74	4.27/0.74	-1.41
Extending	4.04/0.75	4.23/0.68	-2.11*
Understanding	4.06/0.77	4.23/0.71	-1.78
Interaction	4.09/0.72	4.31/0.71	-2.53*
Obstructing reading	3.03/1.23	3.51/1.08	-3.37**
Diminishing imagination	3.18/1.25	3.82/0.90	-4.87***

* $p<.05$, ** $p<.01$, *** $p<.001$

Factor Analysis of the SEB Survey

In addition to exploring the students' conceptions of learning science by AR, we further examined the role of their scientific epistemic beliefs in their CLSAR. Therefore, we firstly conducted an exploratory factor analysis (EFA) to examine the validity and reliability of the SEB survey used in this study. Corresponding to the previous studies (Lee et al., 2016), four scales of the survey were yielded with a total of 17 items in this study. According to **Table 5**, the factor loading values for each item of the survey range from 0.63 to 0.87. The four scales accounted for 75.17% of the variance. With regard to the internal consistency reliability test of the SEB survey in this study, the results in **Table 5** show that the overall Cronbach's α value for the scales is 0.88, and the values for each scale are 0.91 (source), 0.82 (certainty), 0.86 (development), and 0.93 (justification). These results indicate the satisfactory validity and reliability of the SEB survey.

Table 5. Exploratory factor analysis of the SEB survey

Scale items	Factor loading	Cronbach's α
Source		
1. Everybody has to believe what scientists say.	0.82	0.91
2. You have to believe what the science books say about stuff.	0.88	
3. Whatever the teacher says in science class is true.	0.85	
4. If you read something in a science book, you can be sure it's true.	0.85	
Certainty		
5. All questions in science have one right answer.	0.82	0.82
6. The most important part of doing science is coming up with the right answer.	0.76	
7. Scientists pretty much know everything about science; there is not much more to know.	0.71	
8. Once scientists have a result from an experiment that is the only answer.	0.68	
Development		
9. Some ideas in science today are different from what scientists used to think.	0.74	0.86
10. The ideas in science books sometimes change.	0.81	
11. There are some questions that even scientists cannot answer.	0.63	
Justification		
12. In science, there can be more than one way for scientists to test their ideas.	0.74	0.93
13. Ideas in science can come from your own questions and experiments.	0.78	
14. It is good to try experiments more than once to make sure of your findings.	0.81	
15. One important part of science is doing experiments to come up with new ideas about how things work.	0.87	
16. A good way to know if something is true is to do an experiment.	0.86	
17. Good answers are based on evidence from many different experiments.	0.86	

Overall α = 0.88, total variance explained = 75.17%

Comparisons of the Students' Responses to the Scales of the SEB Survey

Through a series of within-subject comparison tests, the students' scientific epistemic beliefs in this study were examined. According to **Table 6**, the students' rating scores for the scales of "development" (mean=3.81, SD=0.94) and "justification" (mean=3.89, SD=0.88) were significantly higher than (F=209.53, p<0.001) the scores for the other two scales, "source" (mean=2.60, SD=0.99) and "certainty" (mean=2.66, SD=0.97). The results indicate that, in this study, the students tended to possess stronger sophisticated scientific epistemic beliefs to consider scientific knowledge as being continuously changing (development) and justified through multiple sources (justification). Relatively, their absolutist scientific epistemic beliefs such as believing scientific knowledge as being from external authority (source) and having certain answers (certainty) may be weaker.

Table 6. Comparison of the scales of the SEB survey

Scale	*Mean*	*SD*	*F*	*Post-hoc*
(1) Source	2.60	0.99	209.53***	3>1***
(2) Certainty	2.66	0.97		4>1***
(3) Development	3.81	0.94		3>2***
(4) Justification	3.89	0.88		4>2***

*** $p<.001$

The Relationships between the Students' CLSAR and SEB

Through Pearson correlation analysis, this study examined the relationships between the students' conceptions of learning science by AR and their scientific epistemic beliefs. Since conceptions of learning have been identified as a hierarchical system by previous studies (e.g., Tsai et al., 2011), we firstly categorized the scales of "presence," "attention," and "motivation" as lower-level CLSAR and the scales of "extending," "understanding," and "interaction" as higher-level CLSAR. Moreover, the scales of "obstructing reading" and "diminishing imagination" were categorized as negative CLSAR. The relationships between the students' CLSAR and SEB were then examined. In addition, to understand the role of gender play in the relationships, the students were classified by gender for further correlation analyses.

Table 7 shows that the students' lower-level CLSAR was significantly related to their scientific epistemic beliefs of "source" (r=0.15, p<.05) and "justification" (r=0.20, p<.01). When the students were categorized by gender, the significant relationships between lower-level CLSAR and beliefs of "source" (r=0.24, p<.01) and "justification" (r=0.25, p<.01) were only found for females but not for males. The results indicate that, for the female students, stronger beliefs about scientific knowledge as being from authority (e.g., teachers), as well as being justified through multiple sources, may be related to the consideration of learning science by AR so as to increase the sense of presence, attention, and motivation. However, for the male students, the role of scientific epistemic beliefs may not play a role in their lower-level conceptions of learning science by AR.

Moreover, the students' higher-level CLSAR was significantly related to their beliefs about "source" (r=0.13, p<.05), "development" (r=0.16, p<.01), and "justification" (r=0.26, p<.01). In consideration of the gender issue, there was no relationship between their higher-level CLSAR and absolutist scientific epistemic beliefs (i.e., source and certainty) for either males or females. According to **Table 7**, for the females, the higher-level CLSAR was related to the beliefs of "development" (r=0.22, p<.01) and "justification" (r=0.35, p<.01). For the males, there was only one slight correlation between the higher-level CLSAR and the belief of "justification" (r=0.18, p<.05). That is, the female students in this study with more sophisticated scientific epistemic beliefs tended to have higher-level conceptions of learning science by AR for extending scientific knowledge, attaining more in-depth understandings of scientific knowledge, or enhancing interaction between learners and learning materials. A similar situation was found for the male students, but with slighter effects.

In addition, the results in **Table 7** show that the students' beliefs regarding "source" (r=-0.16, p<.01) and "certainty" (r=-0.22, p<.01) were negatively related to their negative CLSAR. Similarly, the relationships between beliefs of "source" (r=-0.25, p<.01) and "certainty" (r=-0.32, p<.01) and the negative CLSAR were also found for the female students but not for the male students. The results indicate that the students with more absolutist scientific epistemic beliefs, especially for the females, may not consider learning science by AR as interrupting learners' reading when engaging in science learning and restraining learners to imagine what scientific information they have read in paper books. Moreover, it was found that there was a positive relationship between the students' beliefs regarding "development" (r=-0.13, p<.05) and their negative CLSAR. A similar correlation was found for males (r=-0.17, p<.05) but not for females. That is, the students with more sophisticated scientific epistemic beliefs may have negative attitudes toward AR learning, particularly the males.

Table 7. The relationships between the students' CLSAR and SEB

		Source	Certainty	Development	Justification
Lower-level CLSAR	All (n=267)	0.15*	0.06	0.10	0.20**
	Male (n=136)	0.09	-0.02	0.14	0.15
	Female (n=131)	0.24**	0.15	0.06	0.25**
Higher-level CLSAR	All (n=267)	0.13*	0.06	0.16**	0.26**
	Male (n=136)	0.13	0.06	0.11	0.18*
	Female (n=131)	0.12	0.06	0.22*	0.35**
Negative CLSAR	All (n=267)	-0.16**	-0.22**	0.13*	0.06
	Male (n=136)	-0.08	-0.12	0.17*	0.06
	Female (n=131)	-0.25**	-0.32**	0.09	0.05

* $p<.05$, ** $p<.01$

DISCUSSION AND CONCLUSION

In this study, we developed a CLSAR (conceptions of learning science by AR) survey to investigate students' beliefs about how they consider learning science by AR. Corresponding to Cheng's study (2017), the factor analysis of this study identified the eight constructs of CLSAR exhibited by the students, and also showed the reliability and validity of the CLSAR survey. According to the students' responses to the survey, they generally expressed positive conceptions of learning science by AR. It should be noted that they showed relatively stronger conceptions of learning science by AR as being able to increase learners' motivation to learn science (motivation) and enhance the interaction between learners and scientific materials (interaction). Compared with other positive conceptions perceived by the students in this study (e.g., increasing the presence of scientific phenomena or extending learning content with relevant scientific knowledge), the results may highlight the significance of how to arouse learners' motivation and fulfill interaction design when considering the development of AR books for science learning in the future. Moreover, regarding the negative conceptions exhibited by the students in this study, it was found that they tended to consider learning science by AR as diminishing learners' imagination about the scientific content in the paper book rather than as interrupting their reading of the AR book. The results imply that, in addition to extensively providing concrete scientific information by AR, the design of AR books could include more scientific cues or prompts to involve students in inquiry practices. Providing the opportunities of active learning by inquiry practices may reduce students' negative conceptions regarding diminishing their imagination by the concrete augmented information.

With regard to the interactions between the students' demographic characteristics and their conceptions of learning science by AR, it was found that their grade level played a role in their conceptions. Similar to the findings of previous studies in traditional science learning contexts (Li et al., 2013; Sadi & Cevik, 2016), the higher grade students in this study tended to possess more sophisticated conceptions of learning science by AR as extending learning content (extending) and creating interaction between learners and learning materials (interaction) than the lower grade students did. In addition to the positive conceptions, the higher grade students also showed an inclination to think negatively about learning science by AR (i.e., obstructing reading and diminishing imagination). On one hand, the results imply that the higher graders may have had more learning experience and hence engaged in more reflective thinking about technology-enhanced learning. On the other hand, the results provide empirical evidence for the proposals of integrating an adaptive mechanism into the design of AR books. For example, based on the suggestions in the previous paragraph, different scientific scaffoldings could be offered to students with different educational levels for them to get involved in inquiry practices when reading scientific AR books. We contend that students with more learning experience can benefit more by receiving advanced inquiry prompts to thoroughly explore the scientific knowledge, which can particularly attenuate their negative conceptions of learning science by AR.

In this study, we further surveyed the students' scientific epistemic beliefs and found that they tended to have stronger sophisticated beliefs that scientific knowledge is continuously evolving (development) and verified through multiple sources (justification) than beliefs about absolutist scientific knowing (source) and knowledge (certainty). The relationships between the students' scientific epistemic beliefs and their conceptions of learning science by AR were also established in this study. Specifically, the sophisticated scientific epistemic beliefs (i.e., development and justification) were related to both higher-level and lower-level conceptions to a significant level. However, the correlation coefficients between sophisticated beliefs and lower-level conceptions were relatively low, indicating that the students with more sophisticated scientific epistemic beliefs showed a greater tendency to consider learning science by AR as attaining in-depth scientific understandings or creating interaction between learners and scientific knowledge (higher-level conceptions). On the other hand, the relationships between the absolutist beliefs (e.g., source: considering scientific knowledge as being from external authority) and conceptions were not strong. However, when considering the effects of gender differences, the relationships between the absolutist beliefs and lower-level conceptions become apparent for the female students. Also, the correlation coefficients between the females' sophisticated beliefs and higher-level conceptions became larger. Moreover, this study found that the students with more absolutist beliefs tended not to consider learning science by AR from the negative perspectives. The same situations were found for the females but not for males. That is, when the students believed that scientific knowledge comes from authority or deemed that scientific knowledge is certain, they tended to accept the presentation of the AR book in its current form; this was particularly true for the females.

To some extent, the aforementioned findings are in line with the previous studies in the context of traditional science learning (e.g., Chiou et al., 2013; Ho & Liang, 2015; Sadi & Dagyar, 2015). In this study, we further argue that, although there were no gender differences in the students' conceptions, gender may play a role in the relationships between learners' scientific epistemic beliefs and their conceptions in the context of AR learning. The results may indicate that, compared with the male students, the female students' existing beliefs about scientific knowledge and knowing probably guided how they conceptualized learning science by AR. It is suggested that future work examine the relationships with mediation effect tests, for example with gender as a mediator. Through clearer understandings of the relationships between learners' epistemic beliefs and conceptions in the context of science learning by AR, instructional designers could give more careful consideration of the development of the learning content of scientific AR applications (e.g., integrating scientific content in terms of argumentation for adaptively stimulating learners to reflect on their scientific epistemic beliefs). In addition, the CLSAR survey developed by this study could be further validated through confirmatory factor analysis (CFA) and utilized to examine other cohorts of learners' views on learning science by AR in the future. It was considered that the understandings of students' conceptions of learning science by AR could be helpful for the development of AR-related science learning systems. We also contend that the evaluation results of students' conceptions could also be the indicators for teachers or educators to guide students to adaptively learn science in the context of AR learning. Moreover, follow-up studies could implement AR-based instruction in the long term for examining the interaction between students' conceptions and how AR facilitate and sustain their motivation in the learning process. For example, Keller's ARCS model (Keller, 1987) describing learners' motivation from the four aspects including attention, relevance, confidence, and satisfaction could be considered as a theoretical basis of motivational assessment. Understanding the relationships between students' perceptual arousal and their sustainable motivation in learning science by AR may go beyond viewing AR as a new educational technique and could get more insights into how AR-based learning occurred.

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