

Article

Conceptions of Learning Science among Elementary School Students in AR Learning Environment: A Case Study of “The Magic Sound”

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Abstract: Augmented reality (AR) demonstrates great promise in science education. However, students’ conceptions of learning when they learn science using AR are currently unclear. This study aimed to analyze learners’ views and scientific epistemic beliefs on learning science. Eighty-two elementary school students in grades 4–6 participated in a two-week course on the introduction to sound. The intervention adopted inquiry-based learning utilizing three AR software programs that integrated multisensory channels. The data were collected through Cheng’s Conceptions of Learning Science by AR (CLSAR) questionnaire and Learners’ Scientific Epistemic Beliefs (SEB) questionnaire. The results show that students in this study generally had positive conceptions of learning science and a high level of scientific epistemic beliefs. Moreover, gender differences existed in the relationship between CLASR and SEB. This study contributed to the currently unresolved discussion of the impact of demographic differences on students’ learning, indicating that AR can be used to enhance senior students’ learning of science in elementary schools.

Keywords: augmented reality; elementary science education; conceptions of learning science; scientific epistemic beliefs



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1. Introduction

Augmented reality (AR) adds virtual objects to the real world [1], providing users with a sensory experience that combines the physical world and virtual information, with three features: the combination of virtual and real, real-time interaction, and three-dimensional registration [2]. AR applications for smartphones and tablets have been widely promoted in education as a result of the advancement of mobile devices [3–5]. Some researchers conducted a systematic review of the literature on the use of AR technology to support science learning, analyzing the discussions and content of 42 papers published between 2012 and 2018, and found that AR technology is widely promoted in education, particularly STEM education [6]. Other researchers analyzed and evaluated the advantages of AR-STEM research from four perspectives: contribution to learners, educational outcomes, interaction, and other advantages. Some challenges, such as teacher resistance and technical problems, were also found [7].

Although there have been numerous studies on AR-based science education, most scholars generally focus on whether AR technology has a positive impact on learning outcomes. However, there is a scarcity of research on the intrinsic factors that promote learning through technology [8,9]. One area that has received little attention, for example,

is how learners perceive learning science with the help of emerging technologies such as AR, particularly from the conceptions of learning science. In 2017, some researchers investigated the conceptions of learning by observing 906 middle school students create paintings. The researchers discovered that students formed their conceptions of learning at their age, implying that the conceptions of learning are formed at a younger age [10]. Therefore, this study extrapolated the research above regarding elementary school students in higher grades and investigated elementary school students' conceptions of learning science and scientific epistemic beliefs in the AR learning environment. We believe that studying the conceptions of learning science and scientific epistemic beliefs of elementary school students can help us gain a better understanding of how they learn science.

2. Literature Review

2.1. Conceptions of Learning Science

Conceptions of learning refer to the individual's natural explanation or understanding of learning phenomena [11]. Learners' perceptions of the learning process reflect how they guide their learning in the brain. It is of vital significance as it is related to learners' approaches to learning (deep vs. surface) [12,13]. Therefore, their learning experiences and preference for learning methods contribute to the formation of their learning concepts, and different learners often show different conceptions of learning science. Many researchers have looked into different definitions and types of conceptions of learning science, and their hierarchical characteristics have been recorded in the early research [14]. According to Marton [11], conceptions of learning science are divided into six categories: (1) increasing one's knowledge, (2) memorizing, (3) applying, (4) understanding, (5) seeing differently, and (6) changing as a person. These categories are leveled in some sense, for example, the category of "increasing knowledge" reflects a relatively low-level conception of learning; "changing as a person", on the other hand, represents a higher-level and more complex conception of learning [11]. In addition, when individuals face different educational fields, such as concepts of learning mathematics [15], concepts of learning science [16], and concepts of learning engineering [17], the categories of conceptions of learning may be different. Therefore, conceptions of learning produced by learners in learning science are called conceptions of learning science [16].

Learners' conceptions of learning may be different because of their age and gender. For example, Chiou et al. [18] investigated 582 undergraduate biology majors (275 females and 307 males) and found that female students tended to express more sophisticated conceptions of learning biology (COLB) than male students. Similarly, Sadi and Lee [19] found that more female students conceptualized learning science at higher conception levels. However, according to an investigation of 1691 high school students' COLB based on gender, grade level, and school type, there was no interaction between students' gender and COLB factors. Regarding age or grade levels, Hsieh and Tsai [10] explored the learning conceptions held by students across grade levels (1067 Taiwanese students in grades 2, 4, 6, 8, 10, and 12). They found that younger students held episodic images of learning as opposed to more mature students, and negative emotions and attitudes peaked in grades 6, 8, and 10. According to the findings of the aforementioned studies, gender and grade may influence learners' conceptions of learning. Therefore, it is necessary to take gender and grade into consideration.

Many studies have also shown that conceptions of learning have an impact on learning achievement [8]. As AR-based education applications have been increasing in recent years, recent literature on understanding learners' conceptions of learning in the context of AR learning environments may provide important guidance for their independent investigations on using AR and the reasons underlying AR's promotional effects on learning.

Additionally, Hofer defined scientific epistemic beliefs as an individual's perception of the nature of science and knowledge [20]. There are four dimensions in scientific epistemic beliefs: (1) source, (2) certainty, (3) development, and (4) justification [21]. Learners' concept of learning science may be influenced by their level of scientific epistemic beliefs [22,23].

Learners' scientific epistemic beliefs are crucial, and it has been found that those with a complex level of scientific epistemic beliefs are more likely to have a higher level of learning scientific concepts [24]. In addition to discussing the impact of AR technology on the concept of learning science, we also intended to investigate the relationship between scientific epistemic beliefs and the concept of learning science.

2.2. AR-Based Conceptions of Learning Science

In terms of learning science, researchers have explored the influencing factors of the conception of learning science and have confirmed that grade, school type, and teacher's teaching methods all have an impact on learners' conception of learning science [25]. Some researchers have confirmed the important role of conceptions of learning science in strategies for learning science and have expressed that learners' sense of self-efficacy and motivation in learning science [23] has a great connection with conceptions of learning science. According to previous studies, conceptions of learning science play an important role when learners are learning science. In addition, some studies also emphasize the importance of applying AR to science education. For example, some scholars have found no significant difference in knowledge of science and attitude toward science learning between a group learning science with AR and a group learning science with interactive simulation technology. However, such differences are significant if the learners' perception of technology are assessed [26]. Specifically, the more positive conceptions of learning that learners have, the more their attitudes toward social science issues (such as nuclear power) will change positively [26]. The results also suggest that learners' perception of AR technology may play a role in learning science. In addition, previous studies have shown that conceptions of learning can be regarded as unique features for each learner, and more research on science education is needed to investigate AR-based features [27]. Therefore, this study believes that there is substantial teaching potential in AR-based K-12 science education [28]. In addition to simply understanding the learner's perception of technical characteristics, further research is needed to analyze conceptions of learning science regarding AR. In this research, we call it AR-based conceptions of learning science.

Concerning the measurement of conceptions of learning science, the common method is the COLS scale developed by Tsai [16] to survey students' conceptions of learning science [29–31], which reveals seven categories of conceptions of learning science, including memorizing, testing, calculating, increase, applying, understanding, and seeing in a new way. In AR-based environments, Cheng [8] developed a tool called CLSAR for measuring students' conceptions of learning science in AR-based learning environments, which consist of eight dimensions: presence, attention, motivation, extending, understanding, interaction, obstructing learning, and diminishing imagination. Therefore, this research investigated students' conceptions of learning science in the AR environment through Cheng's science learning conceptions scale.

2.3. Applications of AR Technology in Acoustics Education

In terms of the application of AR in education, AR software and image target are used in school education to carry out science teaching activities such as exploration and experimentation. Therefore, lots of AR books and integrated AR learning software have been developed [6]. In the informal learning environment, such as museums, the structure, historical story, and restoration process of the exhibit can be presented by scanning the QR code of the exhibits [32].

In the field of education, acoustics is a subject with wide application, involving many aspects of human life [33]. As a subject with strong coverage and wide application fields, acoustics is inextricably linked to educational development [34]. However, acoustics education in China mainly relies on discrete lessons in elementary science and music courses without systematic scaffolding. Moreover, acoustics is deeply related to the nature of science, and the acoustic phenomena can be therefore visualized and audible through

AR applications to resolve a series of problems (such as abstraction, micro-cosmology, and modeling).

By reviewing the existing literature, we discovered few studies that discuss the combination of AR and acoustics, especially concerning education. Moreover, most of the existing work is still at the preliminary level of theoretical development. Some researchers have introduced the AR software “Music AR”, which is used to teach sound characteristics such as pitch and volume [35]. Some researchers have also helped visually impaired children by proposing an AR system allowing novices to augment real objects with audio feedback producing better interactive effects [36]. Finally, several scholars have used AR combined with audio and video to develop electronic textbooks to improve learning achievement [37]. None of the above studies has fully utilized AR technology’s advantages based on the aspect of sound being invisible and untouchable. Therefore, if the visual and auditory channels can be integrated into AR applications to help students understand the phenomenon and nature of sound—such as the Doppler effect—it will be meaningful, as this study examined student learning and effectiveness from the perspectives of conception of learning science and scientific epistemic beliefs.

2.4. Inquiry-Based Learning Strategy in AR Environments

There are many learning strategies based on constructivism that are equally applicable to AR learning environments, such as inquiry-based learning, collaborative learning, situated learning, project-based learning, and multimedia learning [38,39]. Among them, the inquiry-based learning strategy has been exclusively used in AR environments that involve the broad field of natural sciences [40]. Many studies have shown that AR environments and inquiry-based learning could support each other. The AR environment could help students better organize their learning content in inquiry-based learning activities [41], while the AR environment could be more thematic and exploratory under the guidance of inquiry-based learning [42].

Cai et al. [43] analyzed AR-based physics class videos by lag sequence analysis and found that AR-supported inquiry-based learning had more positive responses from students and higher response rates from the teacher. Similarly, Chiang et al. [44] found that in comparison with the conventional inquiry-based learning activity, the AR-based inquiry learning activity was able to engage the students in more interactions for knowledge construction. At the same time, the inquiry-based learning strategy in AR environments has higher requirements for teachers, such as the skills of asking, feedback, and guiding [43]. Therefore, AR-based inquiry activities can enhance the interaction between students, students and teachers, and students and learning materials and promote the cultivation of students’ thinking literacy and practical ability. This research adopted the inquiry-based learning strategy to carry out science teaching to encourage students to explore, observe, and discover the scientific phenomenon.

2.5. Research Questions

In summary, conceptions of learning science and scientific epistemic beliefs will impact the learning effect in science learning; however, research on conceptions of learning science in elementary school has not yet begun. This study aimed to explore how elementary school students view learning science with AR’s help in acoustics education. The research questions were as follows, given an AR-based learning environment:

- RQ1: What are the conceptions of learning science of elementary school students in acoustics education after experiencing multiple AR learning environments?
- RQ2: Are there any gender or grade differences in students’ conceptions of learning science after experiencing multiple AR learning environments?
- RQ3: What are the scientific epistemic beliefs of elementary school students in acoustics education after experiencing multiple AR learning environments?

- RQ4: What is the relationship between elementary school students' conceptions of learning science and scientific epistemic beliefs in acoustics education after experiencing multiple AR learning environments?

Based on the literature review, the research hypotheses were as follows:

Hypothesis 1 (H1). *Students have positive conceptions of learning science in acoustics education after experiencing multiple AR learning environments.*

Hypothesis 2 (H2). *There is a gender difference in students' conceptions of learning science.*

Hypothesis 3 (H3). *Students' scientific epistemic beliefs are at a high level.*

Hypothesis 4 (H4). *There is a positive correlation between students' conceptions of learning science and scientific epistemic beliefs in acoustics education after experiencing multiple AR learning environments.*

3. Materials and Methods

3.1. Participants

In this study, 82 elementary school students from Grades 4 through 6 in Anhui Province, China, were selected as participants. Among the participants, 54.9% ($N = 45$) were male and 45.1% ($N = 37$) were female. Their ages ranged from 9 to 11; 25.6% ($N = 21$) were in Grade 4 and Grade 5, while 74.4% ($N = 61$) were in Grade 6, which were considered to be the upper grades of elementary school students. Students were given a two-week extension course on acoustics through AR applications. The selected school is located in an under-resourced area of central China, which might serve to bring technological equity to education. The participants were familiar with operating mobile devices and had experience with tablets and personal computers (PCs), but they had not used AR-related applications before. The students all had similar backgrounds in science learning.

3.2. Procedure

This study used a mixed-method. The research procedure is presented in Figure 1. Before the course began, there was a brief introduction concerning the basic information about AR software that let the students become familiar with the operation of AR software. After that, a two-week AR course "magical sound" was carried out. The AR-themed course of "magical sound" mainly adopts an inquiry-based learning strategy and integrates the teaching method of observational learning. The themed course expands on learners' previous knowledge regarding sounds. The teaching activities were divided into two themes, which were (a) Ears and Sound and (b) Sound and Our Lives. Each theme comprised two lessons, and each lesson lasted for 40 min. Detailed course topics and content are shown in Table 1. The teaching contents of the two themes are designed and developed in the progressive order of "understanding sound—hearing sound by ear vibration—connecting with life", the standard approach practiced by most teachers. All participants learned with tablets in pairs under the instruction of the teacher. Each group was equipped with a tablet and corresponding marker cards and worksheets. During the learning activities, students collaborated on a single iteration of the learning tasks, with one holding the tablet and the other one holding the marker cards. The learning activities included situational introduction, inquiry, summary, and practice. At the end of the fourth lesson, learners filled out the questionnaires Conceptions of Learning Science by AR (CLSAR) and Learners' Scientific Epistemic Beliefs (SEB). Finally, this study randomly selected 10 learners for semi-structured interviews.

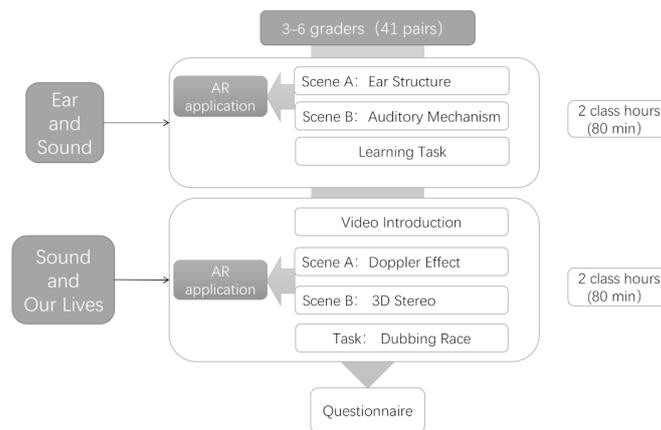


Figure 1. The procedure of the study.

Table 1. The course themes and contents in this study.

| Lesson | Time | Theme | Contents |
|--------|--------|---------------------|---|
| 1st | 40 min | Introduction | <ul style="list-style-type: none"> • Survey of students' basic information • Becoming familiar with the operation of AR software |
| 2nd | 40 min | Ears and Sound | <ul style="list-style-type: none"> • Question import • Learning ear structure with AR software 1 • Summarizing |
| 3rd | 40 min | Ears and Sound | <ul style="list-style-type: none"> • Exploring auditory mechanism with AR software 1 • Hearing protection • Learning task • Summarizing |
| 4rd | 40 min | Sound and Our Lives | <ul style="list-style-type: none"> • Video introduction • History of acoustics • Exploring the Doppler effect with AR software 2 • Summarizing |
| 5th | 40 min | Sound and Our Lives | <ul style="list-style-type: none"> • Exploring surround sound with AR software 3 • Game: Dubbing Race • Summarizing • Completing the CLSAR and SEB questionnaires |

3.3. AR-Based Application Design

According to the science curriculum standard of Chinese elementary schools [45] and the relevant requirements of elementary school science content knowledge in Anhui Province, “magical sound” AR teaching software was developed, which consisted of three applications—“Ear and Sound”, “Doppler Effect”, and “3D Stereo”—as shown in Figure 2a–c. The software utilized integrated visual-audio dual sensory channels in the tablet to help learners better grasp the essence of sound, with full consideration given to the characteristics of sound being invisible and intangible. In addition, in order to allow students to better carry out inquiry learning, the design of the software was fully based on the inquiry-based learning strategy. The development of all AR software in this study was based on Unity3D, VR Audio Kit, and Vuforia, and it is suitable for the Android system.

When using the camera to scan the specific image marker on paper, a 3D model will be present on the card.

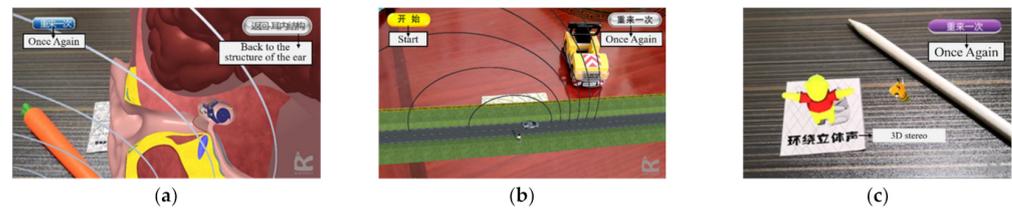


Figure 2. AR teaching applications: (a) Ears and Sounds; (b) Doppler Effect; (c) 3D stereo.

The first application, “Ears and Sounds”, is divided into two scenes. Scene A tells the story of the ear elves taking learners to visit the ear factory. It presents the local structure model of the inner ear. Students can observe not only the auricle and the ear canal, which are easy to observe in daily life, but also the tympanic membrane, the cochlea, the auditory ossicle, and the auditory nerve, all of which are hard to observe in daily life. Scene B introduces the internal operation process of the ear factory. Building on Scene A, the model is expanded to show the structure related to hearing above the neck, further helping learners understand the relationship between the hearing organ and the body while carefully observing the model through finger rotation scaling, which is the first step of inquiry-based learning.

The second application is the “Doppler Effect”. This application introduces the basic principles of the Doppler effect. That is, the sound waves in front of the source moving direction are “squeezed”, making the wavelength shorter and the frequency higher; in contrast, the sound waves behind the source are “stretched”, moving forward, making the wavelength longer and the frequency lower. By learning with this application, students could click the buttons or move the marker cards collaboratively to observe and explore the laws of objects’ motion and sound wavelengths.

The third application, “3D stereo”, introduces stereo sound as a sound with spatial distribution characteristics, such as a certain degree of azimuth level sense, demonstrated in Figure 3. This application constructs a situation in which a bee chases a Pooh bear. The bee is relatively small. It is difficult for the Pooh bear to find the bee with his eyes, but the bear can judge the bee’s location by listening to the sound of the bee. The application provides two modes: (a) the user can observe the bee flying around the Pooh bear from an overlook and visually verify the bee’s orientation according to the stereo source of the auditory channel; and (b) the user can hold the tablet from the Pooh bear’s view by rotating the tablet according to the sound source, changing the view angle, and chasing the flying bee. In this activity, learners should compare the orientation of the bee with the stereo source of the auditory channel to make a conclusion, which encourages them to inquire and find the scientific law collaboratively.



Figure 3. AR teaching experiment.

3.4. Instruments

In this study, two questionnaires were given to the participants after the AR lessons.

3.4.1. Cheng's Science Learning Conceptions (CLSAR) Questionnaire

To investigate learners' conception of learning science in the AR environment, Cheng's science learning conceptions (CLSAR) questionnaire in AR learning environments was used in this study [8,24]. The CLSAR questionnaire is divided into 8 dimensions, including 27 subitems (5-point Likert scale). In order to verify Cheng's science learning conceptions (CLSAR) questionnaire, exploratory factor analysis was carried out. The results are consistent with the results of Cheng [24]. The explanation and reliability of eight dimensions are as follows: presence (learners considered that the purpose of learning with AR was to increase presence; $\alpha = 0.659$), attention (learners considered learning by AR because it attracted their attention; $\alpha = 0.686$), motivation (learners considered learning by AR because it fostered their willingness to learn; $\alpha = 0.765$), extending (learners considered AR because it offered relevant knowledge while they engaged in learning; $\alpha = 0.785$), understanding (learners who consider learning by AR could attain a thorough understanding of the learning materials; $\alpha = 0.862$), interaction (learners considered AR technology because it created interactive environments for learning; $\alpha = 0.821$), obstructing learning (learners who consider learning by AR may even interrupt their learning, resulting in a further negative effect on their learning; $\alpha = 0.906$), and diminishing imagination (learners who consider learning by AR may diminish their imagination originating from traditional texts; $\alpha = 0.912$). The overall Cronbach's alpha of the CLSAR is 0.808, suggesting that the questionnaire has a high inner consistency and reliability.

3.4.2. Learners' Scientific Epistemic Beliefs (SEB) Questionnaire

The second questionnaire adopted a previous SEB questionnaire to investigate learners' scientific epistemic beliefs [21]. This questionnaire mainly measures learners' understanding of the nature of science knowledge. Each item in the questionnaire was developed according to a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree). The SEB questionnaire is divided into four dimensions: source (beliefs about knowledge residing in external authorities; $\alpha = 0.879$), certainty (belief in a right answer; $\alpha = 0.754$), development (beliefs about science as an evolving and changing subject; $\alpha = 0.616$), and justification (the role of experiments and how individuals justify knowledge; $\alpha = 0.716$). The source and certainty dimensions reveal learners' absolute scientific epistemic beliefs, while the development and justification dimensions reflect learners' complex scientific epistemic beliefs. The reliability of the measured items ranged from 0.61 to 0.87 in terms of the four dimensions of SEB, and the convergent validity of the survey had a good model fit (CFI = 0.90, RMSEA = 0.038), suggesting that the SEB questionnaire has high reliability and validity.

3.4.3. Interview Questions

Interview questions were designed to investigate students' attitudes toward science knowledge and the AR software. They were modified from the questions developed by Hwang, Yang, Tsai, and Yang [46]. The interview data were recorded with an audio recorder. The questions included but were not limited to the following:

1. How is this class different from the science class you have taken before? Why?
2. What are the advantages of AR application? What are the disadvantages?
3. Do you like to use AR software to learn science knowledge? Why?
4. Which part of the course do you like best? Or what activities do you think are particularly interesting in this class? Why?
5. Are there any suggestions about the AR software?

4. Results

4.1. Analysis of CLSAR

To answer research question 1, which is the characteristics of students' conceptions of learning science, descriptive statistics of the results were generated, and the results are shown in Table 2.

Table 2. Comparison of the scales of the CLSAR survey.

| Scale | Mean | SD | F | η^2 | Post Hoc |
|----------------------------|------|------|----------|------------------|----------|
| Positive factors: | | | | | |
| 1. Presence | 4.26 | 0.62 | | | |
| 2. Attention | 4.05 | 0.80 | | | |
| 3. Motivation | 4.41 | 0.65 | 2.38 * | 0.024 | 3 > 2 ** |
| 4. Extending | 4.26 | 0.69 | | | 6 > 2 * |
| 5. Understanding | 4.25 | 0.77 | | | |
| 6. Interaction | 4.32 | 0.68 | | | |
| Negative factors: | | | | | |
| 7. Obstructing learning | 1.62 | 1.02 | <i>t</i> | <i>Cohen's d</i> | <i>p</i> |
| 8. Diminishing imagination | 1.65 | 1.11 | −0.512 | −0.028 | 0.610 |

Note: * $p < 0.05$, ** $p < 0.01$.

It could be seen from the table that the mean values of participants in six factors were all greater than 4 points, which indicated that participants showed a positive attitude toward using AR software to learn science; thus, these six factors were also listed as *positive factors*. To analyze the differences among the six positive factors, ANOVA was conducted. It could be seen from Table 2 that the scores of motivation ($M = 4.412$, $SD = 0.650$) and interaction ($M = 4.326$, $SD = 0.682$) were slightly higher than those of attention ($M = 4.052$, $SD = 0.806$), which showed that participants who used AR software to learn science had stronger learning motivation and interaction than attention.

The participants' average scores in obstructing learning and diminishing imagination were both less than 2 points; hence these two items could be considered negative factors. From the average value of these two negative factors, participants did not think that AR software would affect their science learning status. To compare the difference between the two negative factors, a paired-samples *t* test was conducted. Results show that there was no significant difference between students' conceptions of these two negative factors ($t = -0.51$, $p > 0.05$).

4.2. Gender and Age Differences in CLSAR

To understand the role of demographic factors in CLSAR, which is research question 2, this study analyzed gender and grade differences by independent sample *t*-tests. The results, as shown in Table 3, demonstrated that there was no significant difference between males and females in the scores of all the eight dimensions. In addition, there were no significant differences between concepts of learning science of fifth- and sixth-graders for all eight dimensions.

Table 3. Gender and age differences in CLSAR.

| | Gender | | | | Grade | | | |
|-------------------------|------------------|--------------------|----------|----------|-------------------|-------------------|----------|----------|
| | Male (N = 45) | Female (N = 37) | <i>t</i> | <i>p</i> | Fifth (N = 21) | Sixth (N = 61) | <i>t</i> | <i>p</i> |
| Presence | 4.34/0.61 | 4.15/0.62 | 1.41 | 0.161 | 4.17/0.63 | 4.29/0.62 | −0.72 | 0.470 |
| Attention | 4.08/0.78 | 4.01/0.83 | 0.38 | 0.699 | 4.11/0.74 | 4.02/0.82 | 0.44 | 0.660 |
| Motivation | 4.43/0.63 | 4.39/0.66 | 0.28 | 0.779 | 4.28/0.70 | 4.46/0.62 | −1.09 | 0.278 |
| Extending | 4.34/0.66 | 4.16/0.72 | 1.19 | 0.237 | 4.17/0.69 | 4.29/0.69 | −0.64 | 0.524 |
| Understanding | 4.28/0.86 | 4.21/0.66 | 0.42 | 0.676 | 4.23/0.58 | 4.26/0.83 | −0.12 | 0.903 |
| Interaction | 4.32/0.68 | 4.32/0.69 | 0.02 | 0.982 | 4.23/0.61 | 4.35/0.70 | −0.68 | 0.496 |
| Obstructing learning | 1.55/0.89 | 1.71/1.15 | −0.68 | 0.494 | 1.93/1.23 | 1.52/0.92 | −1.63 | 0.106 |
| Diminishing imagination | 1.60/1.07 | 1.71/1.16 | −0.42 | 0.675 | 1.95/1.12 | 1.55/1.09 | −1.43 | 0.156 |

4.3. Learners' Scientific Epistemic Beliefs (SEB)

To answer research question 3, which is the characteristics of learners' scientific epistemic beliefs, descriptive statistics were generated, and the results are shown in Table 4.

Table 4. Comparison of the scales of the SEB survey.

| Scale | Mean | SD | F | η^2 | Post Hoc |
|------------------|------|------|-----------|----------|---------------------|
| 1. Source | 4.30 | 1.52 | 68.02 *** | 0.386 | 1 > 2 *** |
| 2. Certainty | 3.43 | 1.42 | | | 3 > 1 *** 4 > 1 *** |
| 3. Development | 5.36 | 1.15 | | | 3 > 2 *** 4 > 2 *** |
| 4. Justification | 6.05 | 0.86 | | | 4 > 3 *** |

Note: *** $p < 0.001$.

The participants' performance in development ($M = 5.366$, $SD = 1.154$) and justification ($M = 6.055$, $SD = 0.864$) was significantly higher than that in source ($M = 4.302$, $SD = 1.523$) and certainty ($M = 3.436$, $SD = 1.427$). As for the high level of the SEB, learners' performance in justification ($M = 6.055$, $SD = 0.864$) was significantly higher than that in development ($M = 5.366$, $SD = 1.154$). In addition, the average score of justification was high and the standard deviation was low, indicating that scientific knowledge needs continuous verification and experimentation, which has been widely recognized by students. Views on source and development were scattered, and most students disagreed with the view that scientific knowledge is definitive and certain. This also reflected that in the process of learning science, participants' scientific epistemic beliefs based on AR software are often complicated. They tended to think that scientific knowledge is constantly changing and developing and is the result of continuous verification. In addition, participants did not believe that science comes from authority, nor did they think that science is equivalent to being unique and definite.

4.4. Relationship between Learners' CLSAR and SEB

To investigate the relationship between learners' CLSAR and SEB, which is research question 4, Pearson's correlation analysis was conducted in this study. The results are shown in Table 5. In general, development of SEB, complex level of scientific epistemic beliefs, was positively correlated with all the positive factors of CLSAR: presence ($r = 0.363$, $p < 0.01$), attention ($r = 0.401$, $p < 0.01$), motivation ($r = 0.407$, $p < 0.01$), extending ($r = 0.534$, $p < 0.01$), understanding ($r = 0.390$, $p < 0.01$), and interaction ($r = 0.526$, $p < 0.01$). In addition, another complex level of scientific epistemic beliefs, justification, was positively associated with all the positive factors of CLSAR except for motivation: presence ($r = 0.296$, $p < 0.01$), attention ($r = 0.250$, $p < 0.05$), extending ($r = 0.296$, $p < 0.01$), understanding ($r = 0.437$, $p < 0.01$), and interaction ($r = 0.453$, $p < 0.01$). It is worth mentioning that source and certainty of the SEB (less complex scientific epistemic beliefs) were positively associated with all the negative factors of CLSAR: source and obstructing learning ($r = 0.223$, $p < 0.05$), source and diminishing imagination ($r = 0.281$, $p < 0.05$), certainty and obstructing learning ($r = 0.275$, $p < 0.05$), certainty and diminishing imagination ($r = 0.307$, $p < 0.05$). This result indicates that the learner's complex scientific epistemic beliefs (that is, development and justification) were strongly related to the six positive factors of CLSAR, while less complex scientific epistemic beliefs were related to the negative factors of CLSAR in this study.

In addition, to understand gender differences, the gender of the participating learners was classified under Cheng's eight CLSAR dimensions to conduct a correlation analysis further. As can be seen in Table 6, among the six positive factors of the CLSAR, only the relationships between presence, attention, and motivation of CLSAR and development of SEB had a gender difference. To be specific, only female students' presence ($r = 0.423$, $p < 0.01$), attention ($r = 0.546$, $p < 0.01$), and motivation ($r = 0.603$, $p < 0.01$) were correlated with their development of SEB, while male participants had no significant correlation. This implied that when learning science with AR software in this research, female participants' development of SEB was the main factor affecting their presence, attention, and motivation of CLSAR; however, this is not the case for male participants. Moreover, the relationship between presence, extending, and justification was statistically significant only among female participants: presence ($r = 0.466$, $p < 0.01$), extending ($r = 0.676$, $p < 0.01$).

Table 5. The relationships between the learners' CLSAR and SEB.

| | Scale | N | SEB | | | |
|--------------------------------|----------------------------|----|---------|-----------|-------------|---------------|
| | | | Source | Certainty | Development | Justification |
| CLSAR (Positive factors) | Presence | 82 | −0.018 | 0.197 | 0.363 ** | 0.296 ** |
| | Attention | 82 | 0.169 | 0.233 * | 0.401 ** | 0.250 * |
| | Motivation | 82 | −0.154 | −0.129 | 0.407 ** | 0.188 |
| | Extending | 82 | −0.099 | −0.030 | 0.534 ** | 0.296 ** |
| | Understanding | 82 | −0.088 | −0.002 | 0.390 ** | 0.437 ** |
| | Interaction | 82 | 0.006 | 0.108 | 0.526 ** | 0.453 ** |
| CLSAR (Negative factors) | Obstructing learning | 82 | 0.223 * | 0.275 * | −0.151 | −0.106 |
| | Diminishing imagination | 82 | 0.281 * | 0.307 * | −0.205 | −0.055 |

Note: * $p < 0.05$, ** $p < 0.01$.

Table 6. The gender difference in the relationships between CLSAR and SEB.

| | Scale | Gender | N | SEB | | | | |
|--------------------------------|--------------------------------|-------------------------|--------|---------|-----------|-------------|---------------|--------|
| | | | | Source | Certainty | Development | Justification | |
| CLSAR (Positive factors) | Presence | Male | 45 | 0.171 | 0.132 | 0.285 | 0.241 | |
| | | Female | 37 | −0.213 | 0.241 | 0.423 ** | 0.466 ** | |
| | Attention | Male | 45 | 0.206 | 0.240 | 0.289 | 0.257 | |
| | | Female | 37 | 0.137 | 0.218 | 0.546 ** | 0.268 | |
| | Motivation | Male | 45 | −0.259 | −0.220 | 0.262 | 0.066 | |
| | | Female | 37 | −0.022 | −0.029 | 0.603 ** | 0.271 | |
| | Extending | Male | 45 | −0.101 | −0.211 | 0.419 ** | 0.113 | |
| | | Female | 37 | −0.069 | 0.140 | 0.657 ** | 0.676 ** | |
| | Understanding | Male | 45 | −0.049 | −0.116 | 0.353 ** | 0.393 ** | |
| | | Female | 37 | −0.142 | 0.171 | 0.454 ** | 0.569 ** | |
| | Interaction | Male | 45 | 0.013 | 0.009 | 0.485 ** | 0.438 ** | |
| | | Female | 37 | −0.029 | 0.234 | 0.606 ** | 0.516 ** | |
| | CLSAR (Negative factors) | Obstructing learning | Male | 45 | 0.225 | 0.230 | −0.253 | −0.165 |
| | | | Female | 37 | 0.212 * | 0.351 * | −0.024 | −0.051 |
| Diminishing imagination | | Male | 45 | 0.331 * | 0.311 * | −0.204 | −0.031 | |
| | | Female | 37 | 0.216 | 0.323 | −0.197 | −0.112 | |

Note: * $p < 0.05$, ** $p < 0.01$.

As for the negative factors of CLSAR, only female participants' obstructing learning was correlated with their source ($r = 0.212$, $p < 0.05$) and certainty ($r = 0.351$, $p < 0.05$) of SEB, while male participants had no significant correlation. Interestingly, the gender difference in diminishing imagination was contrary to the obstructing learning, which means that only male participants' diminishing imagination was correlated with their source ($r = 0.331$, $p < 0.05$) and certainty ($r = 0.311$, $p < 0.05$) of SEB. This showed that female participants' source and certainty of SEB would obstruct their learning process, while male participants' source and certainty of SEB would reduce their imagination.

4.5. Interview Results

To analyze the qualitative data, the students' interviews were fully transcribed as verbatim text. The open-ended coding method was used to analyze the interview data by two researchers based on Cheng's coding framework [24]. Some of the students' responses are extracted below. As can be seen in Table 7, most students expressed that they liked using AR software to learn scientific knowledge and believed that using AR software would make the learning content more attractive and can also enhance the communication between peers or teachers, which can explain why the AR learning environment can help students improve learning motivation and interactivity. One of the students also said that he did not

like using AR software to learn scientific knowledge because learning with AR software needed to follow a certain sequence of operations, which could weaken his imagination.

Table 7. Interview results of the students' views on learning with AR.

| Examples of Students' Opinions | Coding | Frequency |
|--|-------------------------|-----------|
| AR can help me observe the ear structure and the sound waves from various perspectives, which were very realistic. | Presence | 9 |
| These 3D models are very realistic and three-dimensional, they can help me understand the internal structure of the ear and the shape of sound waves from various angles, and combine the effects of sound with the vision, which I have never experienced before. | Attention | 6 |
| I like it because using AR software makes me want to learn boring scientific knowledge more and makes me feel that learning is interesting! | Motivation | 7 |
| I was deeply impressed by the history of acoustic science. It helped me understand that scientists reveal scientific laws through conjecture and experiment, and this process is not smooth and needs constant improvement. | Extending | 3 |
| It helped me understand the internal structure of the ear and the shape of sound waves. | Understanding | 8 |
| Kind of. Using AR software allows me to have more communication with my classmates and teachers in class, which is very helpful to my study. | Interaction | 2 |
| But I am not proficient in tablet operation, so it takes me a long time to catch up with the teacher's explanation. | Obstructing learning | 1 |
| Not really. Because using this AR software need us to learn according to the rules of operation. We can't play it freely, so I feel that many of my ideas can't be put into practice. | Diminishing imagination | 1 |

4.6. Summary of Data Analysis

In summary, the research questions raised in this study could be answered:

1. What are the conceptions of learning science of elementary school students in acoustics education after experiencing multiple AR learning environments? Are there any gender or grade differences?

Students in this study showed a positive attitude toward using AR software to learn science, which is consistent with Hypothesis 1, and they had stronger learning motivation and interaction than attention. As for the negative factors, participants did not think that AR software would affect their science learning status, and there was no difference between students' conceptions of these two negative factors.

2. Are there any gender or grade differences in students' conceptions of learning science after experiencing multiple AR learning environments?

Against Hypothesis 2, there were no gender or grade differences in CLSAR.

3. What are the scientific epistemic beliefs of elementary school students in acoustics education after experiencing multiple AR learning environments?

The participants in this study tended to think that scientific knowledge is developing and is the result of continuous verification, which shows a high level of scientific epistemic beliefs, which allows us to accept the original Hypothesis 3.

4. What is the relationship between elementary school students' conceptions of learning science and scientific epistemic beliefs in acoustics education after experiencing multiple AR learning environments?

The learner's complex scientific epistemic beliefs were strongly related to the six positive factors of CLSAR, while less complex scientific epistemic beliefs were related to the negative factors of CLSAR in this study. There were gender differences in the relationship between CLSAR and SEB. When learning science with AR software, female students' development of SEB was the main factor affecting their presence, attention, and motivation of CLSAR. Female students' source and certainty of SEB would obstruct their learning process, while male students' source and certainty of SEB would reduce their imagination.

5. Discussion

This study developed educational applications by integrating auditory and visual channels into AR technology to assist elementary school students in learning acoustics, which combined inquiry-based teaching strategies and observational learning to achieve better teaching outcomes.

One of the purposes of this study was to investigate learners' conceptions of learning science in the AR learning environment. The results of this study show that most learners tend to have a positive attitude toward using AR learning applications to learn science in acoustics education, rather than obstructing learning and diminishing imagination. The stronger this positive conception is, the higher the participants' motivation to learn science and interact with the learning content, which was consistent with Cheng's research results [8]. The interview results in this study verify this conclusion further, which is that students in this study thought that AR could help them improve their motivation to learn scientific knowledge and have the chance to interact with their classmates. Among the negative factors, learners in this study did not think that AR software would affect their learning or diminish their imagination. This was not consistent with Cheng's results [8], who found that learners tended to believe that AR software learning will weaken learners' imaginary power regarding learning content. This could be explained by the students' background. The participants in this study were from the underdeveloped region of China, who had never learned science with this new technology before and lacked the opportunity to develop their imagination. Therefore, in this study, AR could help them expand their imagination instead of diminishing it. From the interview results, we could see that most students in this study had extremely high passion and attitude toward learning science, and they pointed out that AR was very attractive and they immersed in it totally, which was consistent with our qualitative results.

As to the gender and grade differences in the learners' conceptions of learning science based on AR, which was the second purpose of this study, this study did not find that there was a gender or age difference in CLSAR, which means that the learners' differences in age or gender do not affect their conceptions of learning science in the AR-based learning environment. This is consistent with Sadi and Çevik [25] in that there are no significant correlations between gender and learners' conceptions of learning science. From the perspective of age, however, the result of this study is different from Cheng [8], who found that the higher-grade students tended to possess more complex conceptions of learning science by AR. The participants were all situated in the concrete operational stage of development, sharing a similar understanding and performance of cognition and development, which lends credence to the fact that the age difference resulted in no significant impact on the concepts of learning science.

The third purpose of this study was to further investigate the learners' scientific epistemic beliefs. The results show that the scores of development and justification were higher than those of source and certainty in SEB, which means that it was highly recognized by almost all students that scientific knowledge requires continuous experimental verification (justification), while most students disagreed with the view that scientific knowledge is unique and definite (certainty). Holding asynchronous from the findings of Cheng [8], learners in the upper grades of the elementary school in this study already have a more complex level of scientific epistemic beliefs; that is, scientific knowledge is continually evolving (development) and has been confirmed in many ways (justification).

This study also established the relationship between learners' CLSAR and SEB. It was found that the learner's complex scientific epistemic beliefs (that is, development and justification) were strongly related to the six positive learning factors but were not strongly related to the negative learning factors, which is similar to previous research conclusions on general learning scientific concepts [29]. This indicated that learners with complex SEB were more inclined to think that using AR software to learn sciences was to obtain in-depth scientific understanding and might prefer to use AR software for science learning in an inquiring and constructive way [47]. Therefore, improving learners' SEB level is conducive to improving their CLSAR and thus helping them obtain a better learning effect regarding sciences, especially through the promotion of complex SEB such as development and justification to promote positive learning factors. It is worth mentioning that female learners were more inclined to think complex scientific epistemic beliefs were the main factors affecting their presence, attention, and motivation of CLSAR than male learners, which was consistent with the finding of Chiou, Liang, and Tsai [18] and Sadi and Lee [19], who found that female students tended to express more sophisticated conceptions at higher conception levels than male students, such as applying, understanding, and seeing in a new way.

6. Conclusions

This study investigated and verified elementary school students' conceptions of learning science and scientific epistemic beliefs from the quantitative and qualitative perspectives. Moreover, it supplemented the correlation between conceptions of learning science and scientific epistemic beliefs in the AR learning environment.

In conclusion, learners in the upper grades of elementary school exhibited rather complex conceptions of learning science and a high level of scientific epistemic beliefs, which is consistent with the previous studies by Sadi and Dağyar [22] and Cheng [8]. In addition, gender differences were found in the relationship between learners' conception of learning science and scientific epistemic beliefs. The implications of this finding are as follows: First, from the theoretical perspective, these two characteristics can be used as indicators for educators to guide students to learn science in an autonomous learning environment. Second, from the practical perspective, it also determines the necessity of carrying out science education in the upper grades of elementary schools and requires some advanced educational technologies, such as AR, to help learners better explore science. Third, educators and instructional designers are encouraged to develop AR software that aims to improve learners' conceptions of learning science and scientific epistemic beliefs. For example, in addition to providing a wide range of learning content, teaching with AR technology also needs to provide learners with more opportunities for independent exploration to avoid providing too much learning information and to give them the opportunities to develop their imagination. Lastly, female learners were more inclined to think about complex scientific epistemic beliefs affecting their conceptions of AR learning than male learners. In the future, researchers are encouraged to discover the potential factors that influence these gender differences through in-depth studies such as the structural equation model.

This study also has some limitations. Due to the limitations of external conditions for the implementation, the teaching activity process was relatively short, and the two-week science learning had a limited impact on learners' conceptions of learning science and scientific epistemic beliefs, and the longer-term impact of the AR learning environment is unknown. The participants were from only one primary school, which does not represent the situation of primary school students under different teaching levels and regions. Considering that most of the participants had no experience in learning with AR, the impact of freshness on learners cannot be ruled out. In future research, it will be necessary to expand the sample size and design teaching activities to be richer and more complete to capture each learner's status better and make the research results more accurate. In addition, more

research is needed on how AR technology promotes motivation and interaction in learners' conceptions of learning science.

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