An AR-Based Case Study of Using Textual and Collaborative Scaffolding for Students with Different Self-Efficacy to Learn Lever Principles

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***Abstract*—With the deepening application of augmented reality (AR) in education, researches pay more attention to the evaluation of learning results rather than consider how to use teaching strategies to support personalized teaching. This study developed an AR science curriculum incorporating textual and collaborative scaffolding, and taught it in elementary school science classes to help students learn about scientific knowledge of lever principle. To explore the effects of different self-efficacy and scaffolding teaching strategies on students' learning conceptions and cognitive load, a two times two experiment was conducted on an elementary school. The results show that the use of textual and collaborative scaffolding in AR teaching can help students with low self-efficacy to pay attention to the conceptions of deep learning and effectively reduce the cognitive load of students.**

***Index Terms*—augmented reality, scaffolding, learning conceptions, cognitive load, self-efficacy**

I. Introduction

Augmented Reality (AR) is a new interactive method for learning that utilize mobile, context-aware technologies (e.g., smartphones, tablets), which enable participants to interact with digital information embedded within the physical environment [1]. It can seamlessly integrate the information of the real world and the virtual scene, emphasizing the combination of virtual reality and human-machine interaction. It has the characteristics of real-time interaction and brings good learning experience to learners, and builds a space for learners to explore by themselves in the most natural interactive way. It is very enlightening for abstract content teaching, and has great development potential and application space in education.

At present, many researches have taken AR as a learning tool to prove the application effect of AR technology in teaching practice. For example, AR can enhance students' learning motivation and improve students' academic performance and satisfaction [2]. AR can reduce the cognitive load in students' learning process and improve students' learning experience [3]–[5]. However, previous studies have shown that there is a lack of teaching methods in AR in teaching [6]. Therefore, more and more researchers have combined AR with teaching methods or teaching strategies [7]–[10]. Meanwhile, with the extensive application of AR in education and the increase of teaching content, complex AR programs may also increase students' cognitive load. So, it is necessary to combine AR with appropriate teaching strategies to promote students' learning effect.

Previous studies have confirmed that AR has a better effect on students with higher self-efficacy [11], but whether it is also related to the teaching strategies has not been confirmed. In order to explore whether the use of different teaching strategies in AR has an impact on students with different sense of self-efficacy, the study will implement different teaching strategies for students with different sense of self-efficacy. This study will also provide theoretical basis for personalized AR teaching.

Among various learning strategies, scaffolding teaching strategy is considered as an effective way to improve students' learning effect in technology-enhanced learning environments [12]. The purpose of this study is to explore whether the combination of AR and scaffolding teaching strategy can better promote students' learning of science. We developed an AR teaching software based on tablet, and conducted science teaching in a primary school for two weeks. The teaching content was lever principle, which is an important knowledge in science education in primary school. The experimental instrument has some conditions in the ordinary experimental environment, such as the wear of weight, the arm of force cannot be displayed in real time, and the instrument is not accurate, etc. Using AR technology can avoid these conditions well. Moreover, its hardware is cheaper and more interactive than Virtual Reality (VR). In this study, scaffolding teaching strategy was used to help fifth-grade students understand the knowledge of lever principle, and questionnaires were conducted on their self-efficacy, learning conceptions and cognitive load.

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II. Background

A. The Integration of Scaffolding Teaching Strategy and AR Technology

Although many studies have shown that learning based on AR technology is effective [6], some researchers have pointed out that it is necessary to use an appropriate teaching scaffold when using AR teaching. Because the current AR is often designed by developers, which is difficult to fully meet the teaching needs of teachers. This is likely to reduce students' motivation to learn and increase learning confusion [13], [14]. Some studies have pointed out that it is more effective to provide some help to students when they use AR for learning than traditional AR learning [15].

Teaching support refers to the temporary support provided to learners by teachers or parents, which can promote learners' meaningful participation in problem solving and acquisition of skills. The theory of scaffolding teaching originates from L. S. Vygotsky's Zone of Proximal Development theory, which refers to a collaborative of learning tasks that students cannot complete independently but can complete with some support and help [16].

Common scaffolds include flow charts, models, work samples, concept maps, tips, etc. Early researchers combined AR with concept map and developed a CMAR learning tool for the food chain teaching of primary school biology, and found that students' learning motivation and learning attitude were improved compared with general AR education [10]. Some researchers have combined textual, collaborative and AR scaffolds in museum learning. They found that AR itself is conducive to students' acquisition of hidden information, textual scaffolding is conducive to students' understanding of interaction with exhibits, and collaboration is conducive to understanding information and receiving feedback. The combination of the three supports is conducive to improving students' learning ability [17]. In addition, some researchers combined a grid learning tool scaffold with AR technology and found that compared with traditional AR teaching, students' academic performance was improved [18]. The above researches show that the type of scaffolding to be selected depends on the actual teaching content. Our research content is different from the knowledge of food chain. It belongs to the scientific knowledge of experimental inquiry, so it is intended to use appropriate text and collaboration as the scaffolding of this study.

B. Learn Scientific Self-Efficacy and Learning Conceptions

Self-efficacy refers to students' self-judgment of their ability to carry out learning activities and complete learning tasks, which refers to individuals' self-confidence or sense of competence in study. Bandura believes that self-efficacy affects students' learning behavior, which can lead to changes in learning ability[19]. Studies have shown that students with a high sense of self-efficacy can adjust their learning strategies and stick to their learning tasks [20]. Students with low self-efficacy are more likely to suffer from learning anxiety, and numerous studies have shown that self-efficacy is usually positively correlated with academic performance [21]. As an important factor to measure students' learning process, self-efficacy is often used as an important indicator to measure the application of a new technology in learning in recent years. For example, some studies have shown that using computer simulation experiments as teaching AIDS can effectively promote the improvement of students' self-efficacy [22]. More studies have identified self-efficacy as an important factor in technology acceptance degree [23], [24]. In most cases, self-efficacy exists as an intermediary variable, such as exploring the influence of a certain technology on students' academic performance. Therefore, students with different self-efficacy may also show different learning characteristics in AR teaching.

Learning conceptions refers to learners' understanding and explanation of their own learning. Different learners may have different learning conceptions. Researchers divides the conceptions of student learning science into the following seven categories: memory, test preparation, calculation and tutorial exercises, knowledge growth, practical application, understanding of things and vision expansion [21]. The first three are low-level learning conceptions, the last four are high-level learning conceptions. This classification will be also used in this study. Studies have proved that students' learning conceptions are influenced by students' cognitive strategies or learning methods [25], which is closely related to students' learning process. Therefore, this study takes learning conceptions as a way to measure learners' learning process.

C. AR and Cognitive Load

Cognitive load has always been a controversial topic in AR learning environment. Some researchers believe that AR causes heavy load of learning materials and heavy learning burden on students [26]. AR distracts students and increases cognitive load when they have difficulty in understanding its contents, so they are confused about using the application [27].

However, some studies have proved that the interaction with virtual objects during the use of AR can effectively reduce cognitive overload. For example, researchers designed an AR-based science class reading system, which significantly improved the academic performance and learning motivation of primary school students, and their cognitive load level significantly decreased [28].

III. Research questions

The purpose of this study is to explore the influence of scaffolding teaching strategies on students with different sense of self-efficacy on scientific learning conceptions and cognitive load when using AR. The textual and collaboration scaffolding AR teaching and the traditional AR teaching were implemented for the two classes, and the students of the two classes were further divided into different groups according to the level of self-efficacy. This study mainly focuses on the following questions:

After applying AR and scaffolding teaching strategies to the teaching of lever principle.

- What is the effect on students' learning scientific conceptions and cognitive load?
- Are there any differences among students with different sense of self-efficacy?

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IV. RESEARCH METHODS

A. Participants

There were 64 participants in this experiment, including students from two classes of grade 6 in an elementary school (aged 10-11). Before the experiment, none of these students had learned about the lever principle, and few of them had used AR for learning. Both classes are taught on tablets and the teachers are consistent. The difference is that one class (n=29 in the experimental group) was taught by AR with textual and collaborative scaffolding, while the other class (n=35 in the control group) was taught by AR in a traditional way. Before the course began, all participants were told that their participation was voluntary and that all answers would be kept completely confidential and would not affect their grades at school.

B. Equipment and App

Research has proved that the most suitable device for AR teaching is the handheld tablet [29]. This study designed and developed an AR application for android tablets. When the students open the APP on the tablet, a 3D experiment device will appear when the camera of the tablet scans the specific identification diagrams (Fig. 1). The students can have an interaction by clicking and dragging objects in the screen.

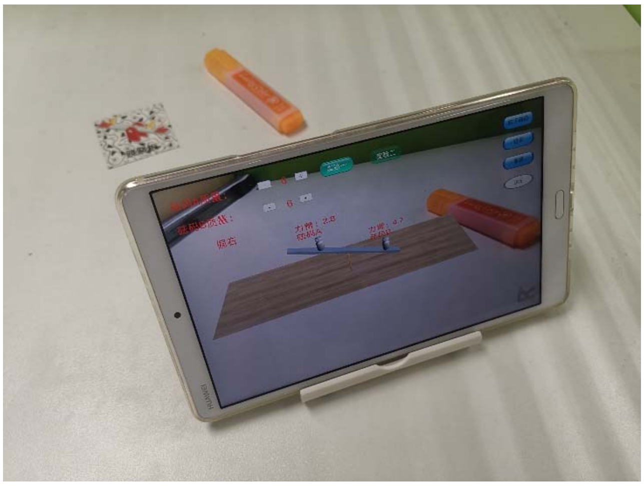

Fig. 1. The AR app of lever principle.

Traditional lever experimental instruments have some problems, such as the surface of the instrument wear and tear, the arm of force cannot be displayed in real time, instrument imprecision, etc. When students use the AR application program for learning, they can see the arm of force and its value in time, which is intuitive and accurate. The application program serves as a teaching assisting media to help students understand the knowledge of lever principle in science.

C. Research Design

AR teaching was carried out for two classes respectively in this study. One class integrated a textual and collaborative support scaffolding in the use of AR teaching, while the other class followed the traditional AR teaching without intervention. Textual scaffolding refers to giving each student a paper study task list in the teaching process. On the study task list, there is a semi-structured form to be filled in for experimental exploration. In the process of using AR for learning, students need to operate the software and fill in the form according to the requirements of the form. The collaborative scaffolding requires two students to work together to complete the learning task list. The implementation process is shown in the Fig. 2.

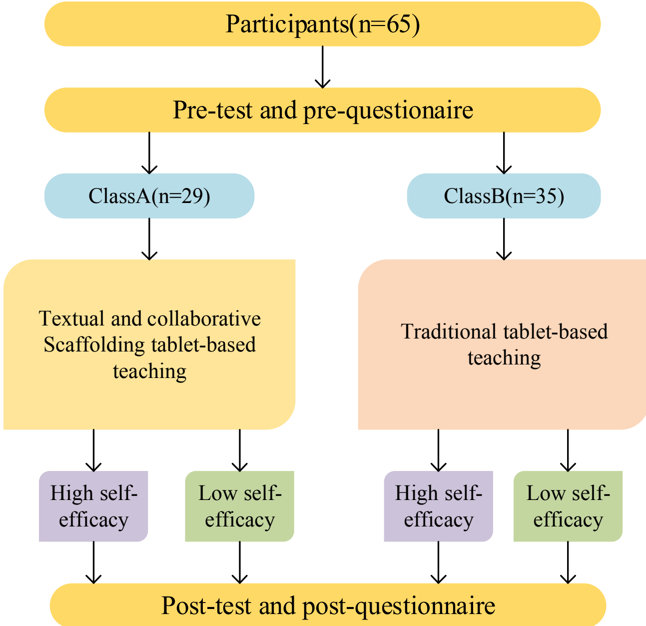

Fig. 2. The experiment procedure.

Students in each class were divided into two categories according to the level of self-efficacy: high self-efficacy and low self-efficacy. After implementing the whole teaching process, students were asked to fill in a post-test questionnaire about learning attitude and cognitive load.

Fig. 3. Students are studying with AR app.

D. Measuring Tools

All the participants took the pre-test before class and the post-test at the end of the class. The pretest included the self-efficacy questionnaire [30] and the learning of scientific conceptions questionnaire [31], while the posttest included the learning of scientific conceptions questionnaire and the cognitive load questionnaire [32].

Questionnaire about learning scientific conceptions describe the students pay more attention to what in learning science, and why they think it is very important to study science, or what is the purpose of science study. It describes seven common conceptions in students' learning process

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[21]. Students need to choose their degree of identification. The seven factors considered in this study are as follows:

1) Memorizing: Learning science stands for simply memorizing definitions, formulas, important conceptions and proper nouns.

2) Testing: Learning science for passing examinations or getting high scores in the standardized test.

3) Calculation and practice: Learning science is to pay more attention to calculation, solveing the problem with scientific thinking and sustained practice of exercises.

4) Increase one's knowledge: Learning science is seen as getting more unrevealed scientific knowledge.

5) Application: Scientific learning is to apply scientific knowledge to improve our life quality.

6) Understanding: The goal of learning science is to achieve a correct understanding of scientific knowledge.

7) Seeing in a new way: Learning science is for changing one's perspective on the surrounding environment.

The Cronbach Alpha coefficient of the learning conceptions scale is 0.948, indicating that the reliability of the questionnaire is good. Since the Alpha value of each dimension is greater than 0.70, each dimension is considered to have high internal consistency and reliability.

The designer of the scale thinks that there are different levels of learning conceptions. In this study, the first three dimensions are considered as the lower-level conceptions of learning science, and the last four dimensions are considered as the higher-level conceptions of learning science.

The Cronbach Alpha coefficient of the cognitive load scale is 0.741, indicating that the questionnaire also have high internal consistency and is reliable.

V. Data analysis and findings

The data before and after scientific learning are analyzed with two-way ANCOVA, and a total of 64 questionnaires were issued, all of which were considered effective. The pre-test part included self-efficacy and learning conceptions, while the post-test part included learning conceptions and cognitive load. Students were divided into two groups according to the difference of students' sense of self-efficacy in learning science: high self-efficacy group and low self-efficacy group. The single-sample t-test was conducted to check the response of each group of students' self-efficacy, so as to determine the high and low grouping.

TABLE I. The clustered students' self-efficacy of learning physics

	Overall group	***Group (1)***	***Group (2)***
	(N=64)	Lower self-efficacy group (N=32)	Higher self-efficacy group (N=32)
	Mean (SD)	***Mean (SD), t-value***	***Mean (SD), t-value***
Self-efficacy of learning physics	82.80 (15.869)	70.16 (10.411), -6.870***	95.44 (8.572), 8.340***
One sample t-test		(1) < Overall	(2) > Overall

***p<0.001.

As shown in Table I the results show that the mean response of students in group (1) to self-efficacy was lower than that of the overall group(t-value=-6.87, p<0.001), and the response of students in group (2) to self-efficacy was significantly higher than that of the overall group(t-value= 8.34,p<0.001). Therefore, group(1) was identified as low self-efficacy group (N=32) and group(2) as high self-efficacy group (N=32).

A. Analysis of Learning Conceptions

Two-way ANCOVA was used to analyze each dimension under the learning conceptions. The pre-test score of each dimension was used as the covariable, while whether the scaffold and self-efficacy were used as independent variables, and the post-test score of each dimension was used as the dependent variable. The results showed that there were only significant differences in the two dimensions of understanding and seeing in a new way.

TABLE II. Results of two-way ANCOVA on students' understanding

Source	***SS***	***Df***	***MS***	***F***	η^2
Pretest (covariate)	7.647	1	7.647	1.452	.024
Scaffolding	21.095	1	21.095	4.007	.064
Self-efficiency	37.806	1	37.806	7.181*	.109
Scaffolding* Self-efficiency	34.888	1	34.888	6.627*	.101
Error	310.630	59	5.265		

*Interaction between scaffolding and self-efficiency; *p<0.05.

TABLE III. The descriptive data of students' understanding divided by scaffolding

Scaffolding	***Self-efficacy***	***Adjusted mean***	***Standard error***
Scaffolding	Low Self-efficiency	17.028	.692
	High Self-efficiency	17.170	.548
Non-Scaffolding	Low Self-efficiency	14.297	.528
	High Self-efficiency	17.529	.632

TABLE IV. Results of the simple main effect analysis of students' understanding

Variables	***SS***	***Df***	***MS***	***F***	η^2
Scaffolding					
Scaffolding	.136	1	.136	.026	.000
Non-Scaffolding	75.389	1	75.389	14.319**	.195
Self-efficacy					
Low Self-efficiency	52.359	1	52.359	9.945**	.144
High Self-efficiency	1.010	1	1.010	.192	.003

The results are shown in Table II. There is no violation of homogeneity test hypotheses (F = 1.766, p > 0.05). The study found that the self-efficacy significantly influences the students attention in the process of understanding(F=7.181,p<0.05,η2=0.109), high self-efficacy of the students (M=17.47,SD=2.369) in understanding was significantly higher than low self-efficacy of the students (M=15.09,SD=2.582). The interaction between self-efficacy and scaffolding was significant (F=6.627,p<0.05,η2=0.101), so it is necessary to conduct a simple main effect analysis of their interactions. The results are shown in Table III combined with the results

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in Table IV it can be seen that without the scaffolding, the group with low self-efficacy (Adjusted mean=14.297,SD=2.211) was significantly lower than the group with high self-efficacy (Adjusted mean=17.529,SD=2.894), while the students with different self-efficacy showed no significant difference in their understanding when using the scaffolding.

Fig. 1 shows the interaction between scaffolding and students' self-efficacy. The study shows that students with high self-efficacy pay more attention to understanding than students with low self-efficacy in AR teaching without scaffolding. Students with low self-efficacy paid more attention to understanding when learning AR with scaffolding than students without scaffolding. This indicates that the use of scaffolding in AR teaching can be more helpful to students with low self-efficacy.

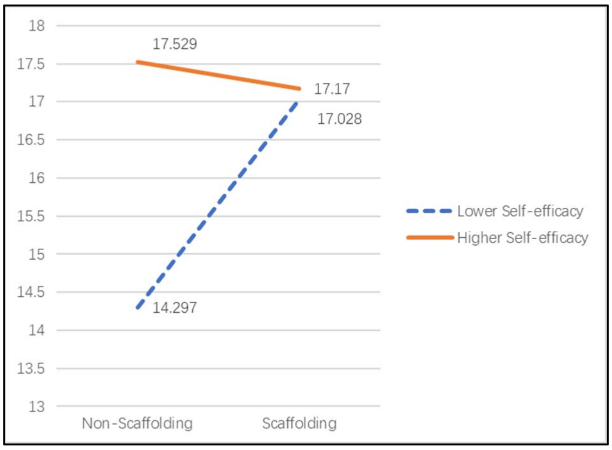

Fig. 1. Interaction between the scaffolding and self-efficiency on understanding.

Similarly, two-way ANCOVA was used to analyze the dimension of horizon expansion, and the results are shown in Table V. To seeing in a new way dimensions, students in the process of learning AR had a great effect on whether to use scaffolding ($F = 226.062$, $p < 0.05$, $\eta^2 = 0.793$). The teaching method of AR with scaffolding (Adjusted mean=15.463,SD=0.574) was significantly higher than that without the scaffolding (Adjusted mean=13.582,SD=0.612), which indicate that it is necessary to incorporate the scaffolding in AR teaching. Students with different self-efficacy also have significant differences in the learning process($F=25.226,p<0.05,\eta2=0.300$). Students with high self-efficacy(Adjusted mean=14.830,SD=0.999) were significantly more likely to pay more attention to seeing in a new way dimensions than students with low self-efficacy (Adjusted mean=14.189,SD=1.081). However, the interaction between scaffolding and self-efficacy was not significant in this dimension ($F=1.484$, $p> 0.05$).

TABLE V. RESULTS OF TWO-WAY ANCOVA ON STUDENTS' SEEING IN A NEW WAY

Source	*SS*	*Df*	*MS*	*F*	*η²*
Pretest (covariate)	.559	1	.559	2.486	.040
Scaffolding	50.808	1	50.808	226.062**	.793
Self-efficiency	5.670	1	5.670	25.226**	.300
Scaffolding* Self-efficiency	.334	1	.334	1.484	.025
Error	13.260	59	.225		

TABLE VI. THE DESCRIPTIVE DATA OF STUDENTS' SEEING IN A NEW WAY DIVIDED BY SCAFFOLDING

Variables	*Adjusted mean*	*Standard error*
Scaffolding	15.436	.091
Non-Scaffolding	13.582	.082
Low Self-efficiency	14.189	.090
High Self-efficiency	14.830	.087

B. *Analysis of Cognitive Load*

Two-factor ANOVA was used to analyze whether there were significant differences in students' cognitive load. Scaffolding and self-efficacy were used as independent variables, and the post-test score of cognitive load was used as the dependent variable. The analysis results are shown in Table VII.

TABLE VII. THE DESCRIPTIVE DATA OF THE COGNITIVE LOAD DIVIDED BY SCAFFOLDING MECHANISM

Source	*SS*	*Df*	*MS*	*F*	*η²*
Scaffolding	137.452	1	137.452	5.990*	.017
Self-efficacy	179.899	1	179.899	7.840**	.007
Scaffolding* Self-efficacy	30.606	1	30.606	1.334	.253
Error	1376.712	60	22.945		

TABLE VIII. THE DESCRIPTIVE DATA OF THE COGNITIVE LOAD DIVIDED BY SCAFFOLDING MECHANISM.

Scaffolding	*Self-efficacy*	*M*	*SD*
Scaffolding	Low Self-efficacy	13.36	3.355
	High Self-efficacy	11.33	3.378
Non-Scaffolding	Low Self-efficacy	17.81	6.361
	High Self-efficacy	12.93	4.480

The results showed that both scaffolding and self-efficacy had significant effects on students' cognitive load, but the effect of their interaction was not significant ($F=1.334,p>0.05$). Scaffolding has significant effect to the students' cognitive load ($F = 5.990$, $p < 0.05$, $\eta^2 = 0.017$). As shown in Table VIII. the cognitive load of students using scaffolding (M=12.01,SD=3.457) was significantly lower than that of students without scaffolding (M=15.86,SD=6.112). The cognitive load of students with high self-efficacy was lower than that of students with low self-efficacy($F=7.840,p<0.01,\eta^2=0.007$).

VI. DISCUSSION AND CONCLUSION

Previous studies have focused on the impact of AR on the learning conceptions of students with different levels of self-efficacy, confirming that students with higher levels of self-efficacy are more likely to be motivated by the learning methods of high-level learning conceptions [11]. On the basis of this research, this study introduces the scaffolding teaching strategy to explore how to better stimulate students with different self-efficacy deep thinking and reduce their cognitive load.

In this study, two classes of students were respectively implemented tablet-based AR teaching supported by textual and collaborative scaffolding and traditional tablet-based teaching. Furthermore, students in these two classes were further divided into two groups of high self-efficacy and low self-efficacy to study their cognitive load and learning conceptions about learning science.

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The study found that whether or not to use teaching scaffolding has a significant impact on students' learning conceptions, especially in understanding and seeing in a new way. The classes that used textual and collaborative scaffolding were significantly higher than those that did not, which was consistent with previous studies [17]. In previous studies, some scholars combined the dimensions of understanding and seeing in a new way into one dimension, and changed the learning of scientific conceptions from seven to six dimensions [33]. In the dimension of learning scientific conceptions to understand things, the use of scaffolding teaching strategies has a significant interaction with students' sense of self-efficacy. The study found that in AR teaching without a scaffolding, students with high self-efficacy paid significantly more attention to understand things than students with low self-efficacy. Students with low self-efficacy paid significantly more attention to understand things when learning with the scaffolding than students without it. It indicates that scaffolding teaching is very important for the improvement of students' understanding with low self-efficacy. Therefore, in the future AR teaching, students with low self-efficacy can be helped to better understand things through appropriate texts and cooperation, which has a very positive significance for the design of AR teaching process.

In terms of self-efficacy, students with high self-efficacy scored significantly higher than those with low self-efficacy in terms of conceptual identity in deep learning. Students with high self-efficacy were more likely to identify with the conceptions of high-level learning when using tablet for AR learning [11]. The use of scaffolding in teaching can significantly improve the high-level learning conceptions of students with low self-efficacy. Studies have shown that the textual and collaboration scaffolding enhance students' sense of participation in learning activities, improves their learning motivation [14], and increases students' enthusiasm for new technologies [34], which is an important reason for enhancing students' sense of identity in deep learning conceptions

Interestingly, when the same teaching scaffolding is used, students with different self-efficacy have no significant difference in understanding, which indicates that the teaching scaffolding reduces the gap between students with different self-efficacy. Whether the use of scaffolding can improve the learning effect of students with low self-efficacy remains to be further studied. In addition, the textual and collaborative scaffolding in this study is one of many teaching scaffolds, and the effect of combining other types of teaching scaffolding with AR cannot be evaluated due to constraints. In order to make the conclusion of this study more convincing, it is necessary to increase the number of subjects. In future studies, we can consider expanding the scope of subjects. At the same time, we can collect some qualitative data in other ways to obtain more reliable research conclusions based on the real feedback of teachers and students.

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