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The Effect of Role Assignment on Students' Collaborative Inquiry-based Learning in Augmented Reality Environment

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***Abstract*—Augmented Reality (AR) has great potential in science education, and Collaborative Inquiry-based Learning (CIBL) in the AR environment is of great significance. However, there is a problem of low collaborative performance in technology-based CIBL. This study applied the strategy of role assignment to AR-based CIBL, aiming to explore the effect of role assignment on students' collaboration. Forty-seven sixth-grade students in elementary school were randomly divided into Group A (without role assignment) and Group B (with role assignment) to participate in AR-based collaborative scientific inquiry activities. Data on students' scientific knowledge achievement, attitudes toward science learning, cognitive load, and flow experience were collected. In addition, interviews were conducted to investigate students' opinions on role assignments. It is found that the strategy of role assignment could significantly improve students' science knowledge achievement. The interview results revealed how role assignments facilitate students' collaboration from three aspects.**

Keywords—augmented reality, role assignment, collaborative inquiry-based learning, science education

I. INTRODUCTION

A. Augmented Reality and Collaborative Inquiry-based Learning (CIBL)

Augmented Reality (AR) is a technology that integrates virtual objects and the real world and displays them in a real environment. AR has been widely used in inquiry learning and collaborative learning, demonstrating better learning effects [1]. Especially in science education, AR helps learners enhance their learning experience and improves academic achievement, learning attitude, and self-efficacy[2].

In science education, collaborative inquiry-based learning (CIBL) is the main learning activity. However, due to the characteristics of science, science is difficult to learn and understand for elementary students. AR has injected new vitality into scientific inquiry activities. Carrying out CIBL with Some studies have also verified the important role of AR in collaborative inquiry, for example, AR-based scientific inquiry activities could effectively improve students' scientific argumentation skills and scientific awareness[3]. Therefore, it is of great significance to conduct CIBL in the AR environment.

Collaborative inquiry-based learning is a complex process, which involves shared activities and tasks, social interaction, and knowledge co-construction [4]. In the process of inquiry activity, the behavior of students is uncontrollable. Specifically, there are some common problems such as role solidification, low quality of discussions, etc. [4]. AR-supported collaborative inquiry-based learning also has such problems. To solve these problems, several researchers suggested that when applying AR to conduct collaborative scientific exploration activities, it is necessary to find an effective scaffold to help students to coordinate the process of collaboration and promote their knowledge co-construction [5], for example, collaborative scripts, reflection tools, and role assignments.

B. Role Assignment and Collaboration in the AR environment

Role assignment specifies the established responsibilities for directing individual behavior and regulating group interactions. Several researchers generally confirmed that role assignments could not only increase group coordination and organization but also promote more effective collaboration [4]. However, whether the strategy of providing role assignment is suitable for AR-based collaborative inquiry activities is still not clear. Furthermore, there remains a need for figuring out how role assignment affects students' collaborative inquiry in an AR learning environment. Therefore, in the present study, our purpose is to explore the effect of role assignments on students' collaborative inquiry. The research questions are as follows:

RQ1: Could the strategy of role assignment improve students' scientific knowledge achievement in AR-supported CIBL?

RQ2: Could the strategy of role assignment reduce students' cognitive load and improve their attitude towards science learning and flow experience?

RQ3: How do students collaborate in the AR learning environment? How does the role assignment facilitate students' collaboration in the AR learning environment?

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II. METHODS

A. Participants and Procedure

A total of 47 sixth-grade primary school students from China participated in the experiment. They were randomly divided into two groups. the experimental procedure is shown in Fig. 1. A quasi-experimental method was used in this study. At first, before the class began, the teacher gave a brief introduction. And tablets, image markers, and worksheets required for the class were distributed. After that, AR-based collaborative inquiry activities were carried out in the classroom. Students studied in pairs and were equipped with a tablet. In group B (N = 24), students were prompted to play a specific role when using the tablet to collaborate with their partner, with one operator and one recorder. The operator's responsibility is to operate the tablet, and the recorder needed to record and write the experimental results down on the worksheet. The students in group A (N = 23) were not prompted to have role assignments when conducting collaborative inquiry-based learning. The class lasted for 45 minutes approximately, and the teaching activities of the two groups were the same except for the intervention of the role assignment. After the class, students completed the scientific knowledge achievement test and questionnaires. Finally, six students in group B were randomly invited to conduct semi-structured interviews to investigate their views on the role assignment.

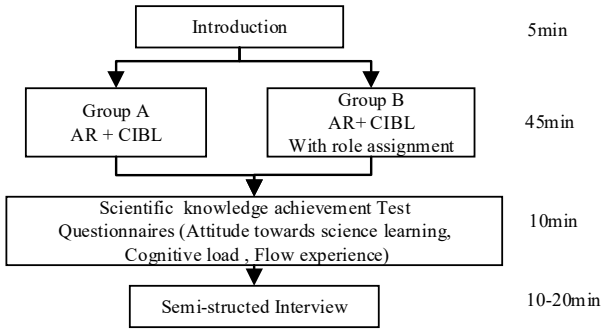

Fig. 1. The experiment procedure of the present study

B. Experiment materials: AR application

The main content of AR application is the scientific knowledge of "the three primary colors of light" in elementary school. The AR application was developed by Unity3D and Vuforia. There were 3 parts included in this application (Fig. 2).

Fig. 2. The screenshot of the AR application

The first part is situational import. When scanning the tracker card called “image marker”, the scene of a little girl dancing will appear. Students can observe the color of the stage lights and the color of the girl's skirt. The second part is the inquiry activity. Students must drag the light by hand and control the intensity of the light (click "+" or "-") to explore the mixing law of the three primary colors of light. The third part is the practice activity. Students need to work together to answer the questions in the AR application.

C. Instruments

The scientific Knowledge Achievement Test was prepared by a science teacher to evaluate students’ understanding of scientific knowledge. There were 3 questions, with 30 points in total. Attitudes Toward Science Learning Questionnaire was adapted from Hwang’s learning attitude questionnaire[6]. It contained three questions, a 5-point Likert scale, with high reliability (Cronbach’s α = 0.84). The cognitive Load Questionnaire was designed by Hwang [6]. It included two dimensions: mental load and mental effort. It was a 5-point Likert scale. Its’ Cronbach's α was 0.74. The flow Experience Questionnaire was adapted from the flow experience questionnaire developed by J. M. Pearce, M. Ainley, and S. Howard [7]. There were 4 items and it was a 5-point Likert scale (Cronbach's α = 0.90). Besides, the interview questions were designed to investigate students’ opinions on AR and role assignment when using AR for CIBL.

D. Data analysis

For the scientific knowledge achievement test, attitude towards science learning, cognitive load, and flow experience, the differences between groups were determined by independent samples *t*-test. In addition, the collected interview data were analyzed and encoded. To further investigate how role assignments support student collaboration, we conducted a thematic analysis of the interview data and identified the core variables of role assignments that facilitate student collaboration.

III. RESULTS

A. Scientific Knowledge Achievement

An independent sample *t*-test was performed to compare the differences in scientific knowledge achievement scores between the two groups (as shown in Table I). There was a significant difference between the two groups in scientific knowledge achievement ($t = 3.547$, $p < .001$). The scientific achievement scores of students in Group B were significantly higher than those in Group A.

TABLE I. *THE COMPARISON OF STUDENTS’ SCIENTIFIC KNOWLEDGE ACHIEVEMENT*

Group	*N*	*M*（*SD*）	*SE*	*t*	*Df*	*p*
Group A	24	19.58 (9.88)	2.017	3.547	45	0.001***
Group B	23	27.39 (4.22)	.882			

Note: ** $p < .01$, *** $p < .001$

B. Attitudes Toward Science Learning, Cognitive Load, and Flow Experience

The *t*-test was also conducted (as shown in Table II). For attitudes toward science learning, there is no significant difference in students' learning attitudes ($t = 1.750$, $p > .05$), cognitive load ($t = -0.105$, $p > .05$) and flow experience ($t = -0.586$, $p > 0.05$) between the two groups.

TABLE II. *THE* COMPARISON *OF STUDENTS' LEARNING ATTITUDE, COGNITIVE LOAD, AND FLOW EXPERIENCE*

Group	Group A		Group B		*Df*	*t*	*p*
Variable	***M(SD)***	***SE***	***M(SD)***	***SE***			
Scientific attitudes	4.63 (.44)	.09	4.82 (.27)	.05	45	1.750	0.088
Cognitive load	1.78 (1.31)	.27	1.82 (1.46)	.29	45	-.105	0.917
Flow Experience	4.68 (.39)	.08	4.74 (.33)	.06	45	-.586	0.561

C. *Interview Results*

Interview data were coded in this study. First, regarding how students valued the role assignment in the process of AR-based collaboration, the students reflected different attitudes towards the role assignment. Some students believed that role assignments could help them improve their collaborative ability (students1, 3, 4, 5); on the other hand, some students revealed that they could complete learning tasks well without role assignments (students 2, 6).

The interview data gave us further insight into how the role assignment helped students' collaboration in AR. The results of the thematic analysis are shown in Table III. Overall, the role assignment facilitates students' collaboration in three aspects: 1) Coordinated assignment of learning tasks (students 3, 4); 2) Facilitated dialogue within the group (students 1, 2, 5); 3) Enhance the sense of collective responsibility (students 1, 3).

TABLE III. *INTERVIEW RESULTS ON HOW ROLE ASSIGNMENTS FACILITATE STUDENTS' COLLABORATION*

Themes	Number	Examples
Coordinate assignment of learning tasks	S04	I help him (partner) when he can't do it well, and he helps me too.
	S03	He always instructed me how to do it.
Facilitate dialogue within the group	S05	It encouraged me to communicate with my partner. We didn't talk with each other before.
	S02	It improved my ability to express myself.
	S01	It improved our communication skills.
Enhance the sense of collective responsibility	S01	My partner didn't understand how to do it. I helped him and he solved it.
	S03	Increased cohesion within our group.

IV. DISCUSSION AND CONCLUSION

Both quantitative and qualitative data in this study showed a positive effect of providing role assignments in collaborative inquiry. This is consistent with the findings of Van der Meij [8], that role scripts can significantly improve learners' discourse cognitive depth and academic performance. Several studies generally proved that role assignment could increase group coordination, and organization and could facilitate more effective collaboration[4].

The results showed that there was no significant difference in learning attitude, learning experience, and cognitive load between the two groups. This is inconsistent with research by Hara [9] and Strijbos [10], who verified the positive effects of role scripts on student engagement, interaction patterns, and group effectiveness. Combined with the analysis of qualitative data, the possible reasons for this result may be: First, the strict role assignment may limit the freedom of students. Second, the role design in this study was not optimal. The role design of collaboration should be carried out according to the specific inquiry content and instructional theory. Future research could explore how to design role scripts for collaborative inquiry to facilitate students' collaborative experience.

The interview results revealed that role assignments facilitated students' collaborative inquiry in three ways. Many studies have shown that collaborative groups with clear role assignments make members more aware of their responsibilities and effectively improve the quality of group interactions [8], this study further verified the conclusion.

This research revealed the effect of role assignment when using AR for collaborative inquiry through qualitative and quantitative perspectives, which has guiding significance for AR-supported collaborative inquiry-based learning. Future research could delve into the design of role scripts and the impact of different collaboration patterns on students' collaboration results in the AR learning environment.

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