Peer Learning in an AR-based Learning Environment

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Abstract: The purpose of this study is to explore the effectiveness of peer learning in an AR-based learning environment to learn science concepts. Augmented reality (AR) is an advanced technology with which users can interact with 3-D objects and the real world at the same time. Ninety sixty subjects participated in this study. They were randomly assigned to three groups: individual learning with AR, peer learning with AR, and individual learning without AR to learn the concept of protein structure. The results show that students thought learning with peer would help them understand more about the content but might spend more efforts on it. Students learning with AR alone performed better than other two groups.

Keywords: Augmented reality, Peer learning, CSCL, Science education

1. Purpose of the study

The purpose of this study is to explore how a new instructional technology, augmented reality (AR) may use a new kind of visualization to facilitate students to learn chemistry. Unlike virtual reality (VR), which separates users from the real world, AR is an interactive interface with which people can work in the real world and manipulate three-dimensional (3-D) objects at the same time. That is, virtual objects and real objects coexist in the same place at the same time [1][3][7]. An AR system is able to carry multimedia representations including static images, animations, and 3-D objects. More importantly, AR allows users to interact with visual representations with their hands, rather than mouse clicking, which most computer-based simulations do. AR shows great potential to convey visual-spatial concepts and to provide a kinesthetic experience which together may facilitate memory encoding [4]. Therefore, using AR may enhance chemistry learning.

When exposed to a rich visualization-based and collaborative learning environment, will students put more effort into processing what they encounter or not? In the past, cognitive load theory [6] generally deals with designing external representations to reduce learners' external cognitive load. When "the two (visualization and constructive learning environment) meet in the use of external representation" [8], what is the extent of the cognitive load on the learners? Studying cognitive load in a computer supported collaborative learning (CSCL) environment is still new and needs to be explored. The research questions addressed in this study are:

1. In what setting students can learn chemistry more effectively using AR, individual learning or peer learning?
2. How much cognitive load and efforts do students encounter when working alone or with another student learning with AR?

To examine these research questions, an AR application, the Protein Magic Book (PMB), developed at the Human Interface Technology Laboratory (HIT Lab) at the University of Washington and the SCRIPPS Research Institute at La Jolla, will be used as the learning material. The PMB is an interactive book which introduces basic concepts about protein structures. The AR technology of the PMB requires a webcam to track a specific pattern that uses the computer to render 3-D objects, which are shown on the computer screen. Therefore, in this AR system, users do not have to wear any head-mounted display. This feature allows users to interact with 3-D objects with their hands and manipulate 3-D objects more freely and authentically.

3. Theoretical Framework

3.1 Collaborative learning

In a computer-supported collaborative learning (CSCL) environment, students share external representations of content. van Bruggen, Kirschner, and Jochems [8] indicated that in a CSCL environment, external representations are a catalyst to "augment" cognitive activities. With compelling visual representation, it is predicted that AR is able to serve the role of a catalyst in a CSCL environment.

However, sharing the external representations might cause high cognitive load because it takes more effort to explain what students see to their peers or to understand their peers [8]. The PMB only offers text and AR representations without any auditory explanation. In terms of the modality effect, it would be better to have auditory information in the intervention to support visual displays. However, verbally explaining your thoughts to a peer will help you clarify your ideas, especially if the other person has a problem understanding your explanation. This removes the need provide auditory information about content. Therefore, it is assumed that collaborative learning enables students to reduce cognitive load through the process of peer discussion instead of causing high cognitive load. Moreover, students may develop some learning strategies together which leads to the enhancement of germane load, such as asking each other to explain what the content or pictures mean.

The next question is how many students will be in the collaborative learning setting in this project. Roth [5] found when more than two students work in a group, the physical arrangement and computer interaction will "curtail the mutual orientation of the students." In a group interaction, gestures help students express their opinion in addition to verbalization. Also, access to the visual representations is an important factor in collaborative learning. Having more than two students may decrease their ability to see and interact with the visualized objects and the power of collaborative learning might be lessened. Therefore, in this project, two students will be assigned to be a team to study the material together.

3.2 Augmented reality (AR)

Augmented reality (AR) is an interactive system which integrates virtual objects (computer-generated three-dimensional objects) into the real world. In this system, users can work in the real world and handle 3-D virtual objects at the same time. Virtual objects and real objects coexist in the same place and at the same time [1][3][7].

Being a member of the VR family, AR shares some characteristics of VR that can facilitate learning. Examples include drawing attention, creating an interactive environment, and providing a sense of presence. Also, as a new technology, AR has its particular features that contribute to learning, which are retaining users' view of the world and body learning. Winn [9] argued that in an artificial learning environment, cognition is embodied in our physical action. Body movement helps people remember what they perceive and provides a cue for future recall. In addition, Chen [2] indicated that AR is able to facilitate learning in the following ways: (1) drawing attention, (2) creating an interactive learning environment, (3) providing a sense of presence, (4) facilitating conceptual learning, (5) retaining the user's view of the world and proprioception, (6) offering an opportunity for body learning, and (7) providing a tool which requires users to think carefully. The powerful visualization and intuitive interface lends AR itself to enhance chemistry learning.

4. Research methods

4.1 Participants

Ninety six subjects who took "Organic Chemistry" class and "General Chemistry" in the spring quarter took part in this study. Forty four students were randomly assigned to study the PMB in pairs. Twenty six students were in individual group studying with the PMB, while twenty six students were in the control group, in which students learned the same content but without AR (text-based material).

4.2 Procedure

This study went through five steps. First, before students started the learning activity, they were asked about personal background by questionnaire and prior knowledge by a test of general chemistry knowledge. They also filled in the self-efficacy scale before starting the learning activity. Next, students studied the PMB individually or in pairs for twenty minutes. During the learning activity, they were asked to think aloud to vocalize what they are doing and what they are thinking. After the learning activity, they were asked to take the tests to assess their learning performance, cognitive load, and mental rotation test. The control group went through the same process, except that they read the material without AR.

5. Results

5.1 Collaboration

Students in the AR-peer Treatment were asked about their collaboration on a seven-point scale with the other member. Table 1 shows the means and standard deviations of the values on their efforts to collaborate with peers. Students considered that peer collaboration was helpful and also thought the collaboration made it easier to understand the content.

Table 1 Collaboration in the AR-Peer Treatment

Question	N	Mean	SD
How much did you collaborate? possible rating: 0: not at all, 7: a lot	44	4.70	1.21
Was the peer collaboration helpful? possible rating: 0: not at all, 7: very helpful	44	5.34	1.36
Did the collaboration make it easier to understand the content? possible rating: 0: not at all, 7: much easier	44	5.30	1.32

In order to assess student perceptions about collaborative learning across treatment conditions, students were asked two hypothetical questions. One was "Did you work harder to understand the material by working with your partner than if you had studied this material on your own for students in the AR-single treatment" (shown in Table 2). Compared to the control treatment, students in the AR-single treatment reported that they would work harder in a collaborative learning setting. The result of ANOVA indicates that group differences exist among these three treatment conditions (F(2, 93)=43.23, *p*<.01, MSE=111.90). The post hoc comparison with Tukey HSD method (AR-peer>AR-single, mean difference=2.79; AR-peer>Control, mean difference=3.29) shows students in the AR-peer condition would work harder with a peer than in the other treatments.

Table 2 Comparison among the three groups regarding how hard to study alone or work with peers (1=not at all, 7=very hard)

Question	N	Mean	SD
AR-single Treatment			
Did you work harder to understand the material by working with your partner than if you had studied this material on your own?	26	2.73	1.73
AR-peer Treatment*			
Did you work harder to understand the material on your own than if you had studied this material by working with a partner?	44	5.52*	1.68
Control Treatment			
Did you work harder to understand the material by working with your partner than if you had studied this material on your own?	26	2.23	1.33

*the score was reversed to represent students' efforts on working with a partner

5.2 Analysis of outcome measures

The post-test score and the measure of cognitive load were two outcome measures after students participated in the treatments. Table 3 shows the means and standard deviations for each outcome measure. The result of ANOVA indicates that students performed differently in their post-test (F(2,114)=4.15, *p*<.05, MSE=77.70), but not in their cognitive load. To gain deeper understanding about student cognitive load, the cognitive load was measured from three parts: text load, picture load, and AR load. Although no group differences were found for these three loads, students in the AR-peer treatment seemed to have higher ratings in these three loads.

Table 3 Mean and standard deviation of outcome measures for three treatments

	AR-single N=26		AR-peer N=44		Control N=26		F value
	Mean	SD	Mean	SD	Mean	SD	
Post-test	30.75	2.3	26.89	5.37	28.46	3.79	6.56*
Cognitive load	2.06	0.91	2.27	0.89	2.02	0.73	0.86
Text load	2.26	1.08	2.39	1.11	2.00	0.70	1.25
Picture load	1.94	0.91	2.23	0.97	2.03	0.81	0.92
AR load	1.99	0.93	2.18	1.08	-	-	0.53

**p*<.05

6. Discussion and Conclusion

The results shown above indicate that learning with peers in an AR-based learning environment may facilitate learning. Students in the peer learning group reported that collaboration was quite helpful and made it easier to understand the content. However, learning with peers also spent more efforts to understand the material. This finding corresponded with the cognitive load measures. The cognitive load measures revealed that students in the peer-learning group gained higher cognitive load in the texts, pictures, and AR as well. This result did not support the research hypothesis. One possible explanation is that when students in the peer learning situation have to pay more attention to what they read and what questions that their peer asks in order to interact with each other. Therefore, their cognitive load is much higher with extraneous load. In addition, it is assumed that students in the peer learning group would perform better. However, they did not in this study. All students had to finish learning the material within certain amount of time. Students in the peer learning group had to spend their time with the material and their peer as well; therefore, they might not have much time on the material compared to students who studied the material alone. It is suggested that in an AR-based learning environment, students who learn with peers are allowed to have enough time to study the material and interact with their peer.

In spite of the fact that students in the peer learning group did not performed better than other two groups, students learning with AR alone did perform better than those who only read the traditional material. It implies that AR did have the potential to help students understand and learn the concepts.

This preliminary study indicates that AR facilitates the concept learning about protein structure when students learn alone, not with peer. Since peer learning is a more complex situation. It is hoped that future studies can discover effective peer learning strategies in an AR-based learning environment.

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