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Using Inquiry-based Augmented Reality Tool to Explore Chemistry Micro Worlds

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Abstract: In this paper, an inquiry-based Augmented Reality learning tool was implemented. Students could control, combine and interact with the 3D model of micro particles using markers, and conduct a series of inquiry-based experiments. The AR tool developed was tested in practice at a junior high school. Experiment result shows that the AR tool has significant supplemental learning effect as a computer-assisted learning tool and students generally have a positive attitude towards this software.

Keywords: Augmented Reality Environment, chemistry course, inquiry-based learning

1. Introduction

It is the first time that students came into the world of chemistry in junior high school. Abstract concepts such as molecule, atom, amount-of-substance, etc., are all formidable tasks for them, and they are often required to envision across micro and macro worlds, which can be really challenging. "The composition of substances" is a critical concept in chemistry learning, as it is the foundation of further learning of chemicals and organic chemistry. However, young students' ability of imagination is limited, and it is difficult for them to imagine how particles such as atoms could compose substances. The situation calls for an urge to improve the present learning methods and tools in chemistry teaching.

Augmented Reality (AR) provides a seamless interface for users that combines both the real world and the virtual world. Nowadays, the integration of AR with disciplinary teaching has greatly emerged. For example, Cai et al. (2013) used AR technology to simulate the convex imaging experiment in the physical course. As a computer assisted tool, we think AR is also the most suitable and appropriate solution for the present problems in the instruction of chemistry micro worlds.

In this paper, we first review related works in section 2, and then introduce the inquiry-based AR tool we developed in section 3; we further present the empirical study and results in section 4 and 5, and finally propose the conclusions in the last section.

2. Related Work

There are considerable computer-assisted learning tools in chemistry teaching, and a great number of researchers have designed specific scenarios with these tools and tested their learning effect with students. Among them, the most applauded ones in recent years for microstructure learning is Virtual Reality and Augmented Reality based learning tools.

According to Merchant et al. (2012), they examined the impact of 3D desktop virtual reality environments on learner characteristics with 3 simulations set up in Second Life. The interactive features of these applications include the ability to interact with the object by zooming in and out, rotating the object and programming the objects to behave in a certain manner. They found that the 3D virtual reality environment would promote students' chemistry learning achievement. Dalgarno et al. (2009) used a Virtual Laboratory to prepare new university chemistry students studying at a distance for their on-campus schools. Most students who used it found it a valuable preparatory tool and would recommend it for future use. These VR applications are tested to be effective, whereas their interactive methods are considered to be unnatural and limited.

Iordaches, Pribeanu, & Balog (2012) implemented a chemistry scenario under the Augmented Reality Teaching Platform (ARTP). Students could fulfill tasks with colored balls on the periodic table. “Assigning semantics to a ball by placing it onto a Chemical element on the periodic table creates a feeling of freedom and control for the student who can master the learning process” (Pribeanu & Iordache, 2010). The results of the study show that by using ARTP, the students could better understand the lesson and learn Chemistry with less effort. In another study, researchers constructed an AR environment under ARIES, which allows students to conduct chemistry experiments such as the reaction of hydrochloric acid (HCl) and sodium hydroxide (NaOH) produces a table salt (NaCl) and water. “Image-based AR environments seamlessly combine interactive 3D learning content with real environments containing physical objects. The learners can interact with the content in a direct and intuitive way by manipulation of physical objects. The active participation of learners in hands-on activities has a particularly positive effect on the perceived enjoyment, resulting in their increased motivation for learning” (Wojciechowski, Cellary, 2013).

Despite the integration of AR with science disciplines, such as chemistry and physics, AR environment also works well with art disciplines. Several recent applications of AR in art courses have proved its motivation value to students in addition to its interactive feature. Chen, & Tsai (2012) developed an augmented reality system for library instruction. The application results in significant learning performance improvement and is indeed helpful in promoting learner motivation and willingness to learn. “obviously, learners were very satisfied with the proposed ARLIS for library instruction.” Di Serio, Ibanez, & Kloos (2012) discussed the impact of an AR system on students’ motivation for a visual art course. In the paper, the authors show that augmented reality has a positive impact on the motivation of middle school students.

Our research targets at the chapter “The composition of substances” in junior high school chemistry course. Traditional 2D pictures and textbooks cause great cognitive loads on students. Using AR to learn, students can observe the molecule or crystal model from each angle. Furthermore, Piaget said that “knowledge origins from activities and recognition starts from practice”. In prevalent chemistry learning software, students can only observe structures rather than interact with them. In the proposed AR environment, students could control particles in micro worlds with markers, combine molecules and substances with these particles, and further comprehend and conclude the process of substance composition.

3. Inquiry-based AR Tool Description

3.1 Instructional Design

The software contains 4 specific applications of substance composition 1) hydrogen atom and oxygen atom compose water molecule, and water molecules compose water; 2) carbon atoms compose diamond crystals; 3) carbon atoms compose graphite crystals; 4) chloridion and sodion compose NaCl.

Students are required to complete the inquiry-based activity with the AR tool and fulfill the exploration form in groups of three. We’ll introduce the first learning activity (the water application) in details.

Table 10 Learning activity design of application 1.

Time	Activity form content	Knowledge point
8-10 min	Learning activity 1： Operation procedure 1.Double click application 1. 2.Place marker “4” under the camera. The atom you observe is______. Explain the reasoning________. 3.Lift marker “2” slowly. What happens? _______. 4.Place maker “3”under the camera. The atom you observe is______. Explain the reasoning ________. 5.Lift marker “3” slowly. What happens?_______. 6.Place markers “2” “3” and “4” on the table in	Know the structure of the hydrogen atom. Know the structure of the oxygen atom Know the composition of the atom and that electrons revolve around the nucleus. Know the composition of the water molecule

	order and move “2” and “4” toward “3”. What happens?________. 7.Turn to the back sides of markers “2” “4” and lift “3” slowly. What happens?________ 8.Form a conclusion regarding your observation and record_______________________	Know the composition of water. Be able to conclude that a molecule is one of the particles that can compose substances.

As shown in Table 1, after using the AR tool to complete the inquiry-based activity, researchers expect students to (1) know there are 3 particles that could compose substances, could explain the formulation of water, graphite, diamond and NaCl, know the structure of atoms of different elements, and connect the features of substances with micro structures; (2) able to generalize abstract concepts, and master basic research methods of chemistry; (3) form the habit of respecting objective facts and serious attitude towards science, inspire inner interest in learning chemistry.

3.2 Application Design

The software is programmed in Java, and the extra packages used include, NyArToolkit, Java3D and JMF (Java Media Framework). Besides accurate modeling, the essence of Human-Computer Interaction in this software is to detect and record the position of each marker in the camera’s view, as the application will trigger different animation when the marker is at different position. In a word, the interaction between users and computer is position-based interaction. The following shows some operation screens of two applications, the water and the diamond case.

When students move marker “2” within the camera’s view, they’ll see the model of hydrogen atom, when lifting the marker, they’ll see the electron is revolving about the nucleus irregularly.

When putting all 3 markers within the view, students could see the oxygen atom and hydrogen atom. If both hydrogen atoms are moved close to the oxygen atom, we could see a water molecule formed. Afterwards, we can turn the marker of hydrogen atoms over, and lift the water molecule to observe its structure. When lifting the water molecule, we could see water molecules form a real water drop.

In the second application, the inquiry-based activity requires students to construct the diamond crystal using carbon atoms. First, we construct a basic tetrahedron unit of diamond crystal using carbon atom and chemical bond, as shown in Figure 1. Further we will use this unit to construct a more complete structure of diamond crystal, as shown in Figure 2. Students can get hints from another marker to deduct the structure they have built is the structure of diamond, which combines chemistry with daily social life.

Figure 16 Basic unit of diamond crystal

Figure 17 Part of diamond crystal

The interaction tool of this software is marker. A set contains 6 markers, with numbers printed from 1 to 6, which are selectively applicable for different applications. After the software is installed, students could use different markers to control micro particles and complete the inquiry-based learning activity as instructed in the exploration form, and further generalize concepts and conclusions.

4. Experiment Methods

The software's validity was tested in Meishan Junior High School, Shenzhen. The subjects of the empirical study are the 29 students of Class 9, Grade 2. Before the experiment, researchers installed the AR software on each computer of the classroom. The experiment design contains 4 sections as shown in Table 2.

Table 11 Experiment Design

Experiment content and operation methods	Source of measure instrument
Pre-test: a paper and pencil quiz test with every student, required to complete independently	The quiz was devised by Ms. Shengyan Wan of Meishan Junior High School.
Divide the class into groups of 3 randomly. Each group is required to use the AR tool to learn as indicated on the exploration form and complete the form in cooperation without teacher's guidance. (the tool contains AR-based software, markers and the activity form)	The exploration form is devised by the researcher, which corresponds with the software and the learning objectives.
Post-test: the same quiz test with every student, required to complete independently	The paper quiz test was the same with pre-test
Paper and pencil questionnaire survey with every student, required to complete independently	The scale consists of 4 constructs, which respectively based on the following 3 papers with minor revisions. (Learning attitude (Hwang & Chang, 2011), Satisfaction towards the software (Chu, Hwang & Tsai, 2010), Cognitive validity and accessibility (Chu, Hwang, Tsai & Tseng, 2010)).

This empirical study mainly focuses on the supplemental learning effect of AR-based learning tool. The students in the class tested were taught the content of "The composition of substances" just in the week of this experiment. However, according to their teacher, students are not much motivated and did not comprehend the materials well, as the content is dull and abstract. Their chemistry teacher expressed the hope to review the content with AR tool. For this reason, the experiment didn't arrange a control group. The score of pre-test will represent students' learning outcome with textbooks, and the score of post-test will represent students' learning outcome with AR inquiry-based learning tool. All the tools used in the activity including the software, markers and the activity form did not literally present knowledge points in the quiz test, which means what students need to write in the quiz must be concluded by themselves in the observation and exploration during the inquiry-based learning process. And in this case, we consider the vertical change of pre-test and post-test scores will represent the AR tool's learning effect. The questionnaire mainly surveys students' attitudes towards this AR learning tool.

5. Result and interview

During the process of the whole experiment, researchers observed carefully and made records of students' performance. Most students looked excited, curious and motivated during the inquiry-based learning activity. The first 2 groups to finish the whole activity were all boys. At first, 2 girls did not participate in the learning activity, meanwhile, they were doing homework on the other side; after the teacher's encouragement, they joined the experiment later. We found that most students do not like to consult the papery activity form; on the other hand, they like to interact with the software on their own. According to the responses of the activity form, we found there are still conspicuous mistakes which can be avoided with careful observation and proper teacher guidance.

After the experiment, we picked 5 students tested randomly for interview and communication. In the interview, we asked them to talk about their feelings about the learning tool. First, they admitted the AR tool could help them remember the structure of atoms. In traditional class, it's difficult to remember all these with merely teacher's plain instruction. On the contrary, the software is more attractive which leaves a deeper impression in their mind. Second, compared with previous flash courseware and other 3D modeling software, AR tool could help them develop their operation capabilities. The natural and direct interaction is better than keyboard and mouse interaction for them to remember especially the procedural knowledge. At the same time, students also proposed some suggestions towards this tool. First, the model can be instable and twinkling at times. Second, they hope the simulation of substances can be more real. Third, they hope the software could add some cartoon or animation elements to be more fascinating. When the researcher asked the 5 students interviewed whether they would like to use AR tool in future study, they said "yes" with one accord.

6. Conclusions and discussion

We acquired the preliminary conclusions as follows: (1)The AR inquiry-based learning tool has significant supplemental learning effects. (2)Students in general possess a positive learning attitude, and present positive evaluations towards the AR tool.

The empirical study belongs to software supplemental effect tests. We represent the score of pre-test as students' learning outcome with textbooks. Although students learned the chapter in class within a week, memory decay is inevitable. As a result, the score of pre-test should be lower than students' learning outcome with textbooks. We didn't arrange control group experiments, and we have to admit if they review the same content with other tools or materials, score promotion may also be witnessed.

In both the interview and the questionnaire, we found that students think the stability of the AR tool is not satisfactory. The main reason is AR software needs to detect the real scene with the camera, which can be constricted by the lighting condition of the spot. The problem provides more space for our improvement of the software.

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