An interactive 5E learning cycle-based augmented reality system to improve students' learning achievement in a microcosmic Chemistry molecule course

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***Abstract*—In this study, an interactive 5E learning cycle-based augmented reality system is proposed for conducting microcosmic Chemistry molecule learning activities. Augmented reality has been widely used for enhancing students' learning motivation. However, numerous studies have indicated that without effective learning strategies for helping students construct solid knowledge, their learning performance might be disappointing. To cope with this problem, an interactive 5E learning cycle approach has been adopted to develop an augmented reality mobile learning system which reinforces students' understanding of the concepts of the microcosmic structure of Chemistry molecule learning unit. In order to evaluate students' learning achievement, self-efficacy and learning behavior patterns when using this approach, an experiment was conducted to examine the effectiveness of the proposed approach. The students' learning behaviors when using the interactive AR tools to learn about microcosmic Chemistry molecule structures and the ways in which they perform the interactive 5E learning cycle-based learning tasks will be recorded. Accordingly, the learning behavioral patterns will be analyzed via lag-sequential analysis and quantitative content analysis.**

Keywords—augmented reality, high school education, interactive 5E learning cycle, microcosmic Chemistry molecule course

I. BACKGROUND AND OBJECTIVES

With the advancement and popularity of handheld devices and simulation technologies, teaching materials of microcosmic phenomena in science education could easily be observed or even be interacted with using visualization techniques [1][2]. In recent years, many researchers have applied Augmented Reality (AR) to emphasize learning through observation, interacting with the learning objects, and knowledge sharing [3]. Augmented Reality (AR) has been recognized as an effective tool for combining objects in the real world and virtual learning materials in the digital world that allow users to interact with virtual material in real learning contexts [4].

With the features of the Augmented Reality learning system, such as continuously interacting with the learning targets and digital contents, students can easily absorb the learning materials and interact with the AR learning systems [5][6][7]. Serio [8]found that conducting AR technology could effectively enhance the students' learning motivation. In the same year, Lin [9] utilized AR technology to present 3D images of elastic collisions that allowed students to understand the basic concepts of kinetic energy and momentum in physics. They aimed to compare the differences in students' learning performance and behavior patterns in Augmented Reality and 2D simulation learning environments. The results showed that the students who learned with the AR system showed significantly better learning achievements than those who learned with the traditional 2D simulation system. Zhang [10] then adopted the AR technology in an astronomy course. They successfully overcame the limitations of teaching astronomy by allowing students to observe constellations directly, effectively improving the students' learning interest. Furthermore, Chiang [11] designed an AR-based inquiry learning activity to compare the effects of using the conventional inquiry-based mobile learning activity. The results showed that the AR-based inquiry learning activity is able to engage the students in more interactions for knowledge construction. However, researchers have also indicated that instruction with only the emerging technology may not be able to effectively enhance the students' learning achievement. Therefore, it should be appropriately supported with pedagogies [12].

The 5E learning cycle model is an intact structure of learning activities which was developed for science education by the Biological Sciences Curriculum Study (BSCS). Via the following five phases, students' abilities of inference and comprehension are enhanced [13]:

- Engagement phase (E1): Accessing the students' prior knowledge, encouraging them to learn new concepts, and making connections between past and present knowledge.

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- Exploration phase (E2): Enabling students to reflect on the current concepts through exploration experiences.
- Explanation phase (E3): This phase provides two teaching methods for instructors to directly or indirectly introduce a concept, process, or skill.
- Elaboration phase (E4): Extending the subject to develop it more deeply, and broadening students' conceptual understanding.
- Evaluation phase (E5): Teachers evaluate students' achievements in the learning activity, and provide opportunities for students to assess their understanding.

In recent years, the 5E learning cycle has been widely applied in the field of the natural sciences. For example, Liu [14] proposed a five E-learning cycle-based learning activity combined with mobile devices and web site resources to observe students' learning situations and to analyze their behavior pattern knowledge construction. Yadigaroglu and Demircioglu [15] applied the 5E learning cycle model to gas-learning courses. The results showed that the students who learned with the 5E learning activities performed significantly better than those who learned with traditional learning activities. Moreover, Piyayodilokchai [16] utilized the five phases of the 5E model to develop a system that allowed the students to learn the Structured Query Language (SQL). The results showed that the students' learning performance made significant progress with the 5E learning instruction.

In summary, the aim of this study is to design a microcosmic Chemistry molecule learning activity based on the interactive 5E learning cycle, and to develop an Augmented Reality mobile learning system accordingly. An experiment will be conducted to investigate the following research questions:

- Does the interactive 5E learning cycle-based augmented reality system effectively improve the students' learning performance?
- Is the interactive 5E learning cycle-based augmented reality system helpful to the students for increasing their learning motivation?
- Does the chemistry self-efficacy of students who learn with the interactive 5E learning cycle-based augmented reality system differ from that of those students who learn with the conventional AR system.
- As a result of the different learning strategies in the 5E learning cycle, are there any differences in the students' learning behavior patterns?

II. THE INTERACTIVE 5E LEARNING CYCLE-BASED AUGMENTED REALITY SYSTEM

In this study, the interactive 5E learning cycle-based augmented reality system was designed to assist students in improving their learning achievement and enhancing their self-efficacy in learning chemistry. To accomplish the target, the researchers carefully planned a series of learning projects with the school teachers. Figure 1 shows the framework of the proposed system, which was developed with the mechanism of the 5E learning cycle model, the interactive mechanism, and three databases of molecular materials, Q&A, and learning patterns. It is worth mentioning that the "interactive mechanism" is the only difference between the experimental and control groups; all other aspects of the system are the same for the two groups.

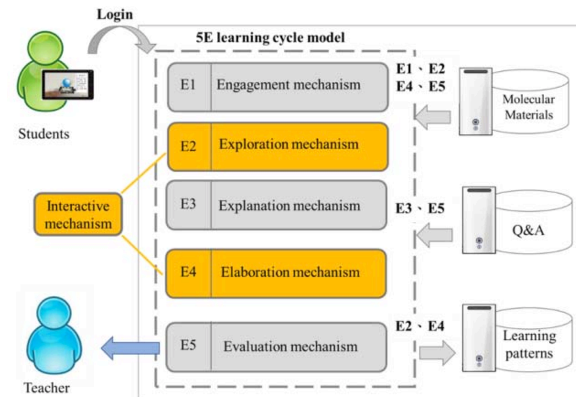

Fig. 1. The structure of the interactive 5E learning cycle-based AR system.

In phase E1, (Engagement mechanism), when the students sign into the system, they start to practice with the AR tools and learn the concepts of the octet rule, covalence, organic compounds, and the classification of hydrocarbon. Phase E2 (Exploration mechanism) is the core of the learning activity (as shown in Figure 2). In this stage, the students in the experimental group learn the molecular structure of hydrocarbon (e.g., Alkyl, alkenyl, alkynyl, cycloalkyl) by ordering the cards. To achieve the learning objectives, the learners are required to arrange the cards into their corresponding places. After the cards are correctly arranged, the emerging molecular model with additional information will be demonstrated to the students. Furthermore, if the students have trouble working with the learning targets, there are two methods to help them complete the learning tasks (as shown in Figure 3). The "light" button helps them to get the answer directly, while the "book" button gives them indirect pointers to help them correctly order the cards. On the other hand, students in the control group use the cards to observe the molecular model (but do not order them). In phase E3 (Explanation mechanism), the instructor will directly guide the students to learn the concepts and applications of the above two phases. In phase E4 (Elaboration mechanism), students in the experimental group will use the complex cards to access more difficult isomer structures, while those in the control group will use them to observe the isomer model. Finally, in phase E5 (Evaluation mechanism), the interactive 5E learning cycle-based AR system will upload the students' learning results to the teacher.

III. EXPERIMENT DESIGN

A. Participants

The participants of this experiment are 80 senior high school students from a school in northern Taiwan. During the learning activity, they will be randomly assigned to the experimental group (40 students) and the control group (40 students). The average age of the students is 16-17. The students in the experimental group will learn with the interactive 5E learning cycle-based AR system, while those in the control group will learn with the conventional AR system using the original 5E learning cycle activity.

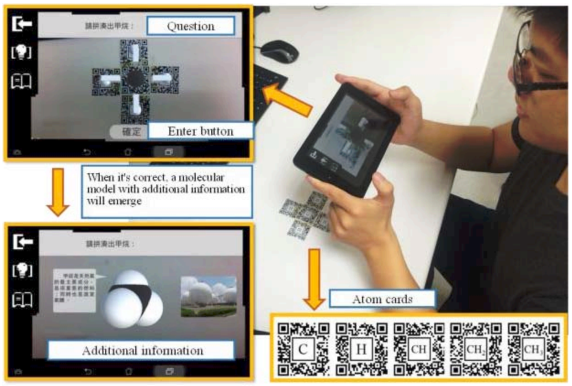

Fig. 2. Phase E2 of the interactive 5E learning cycle-based AR system.

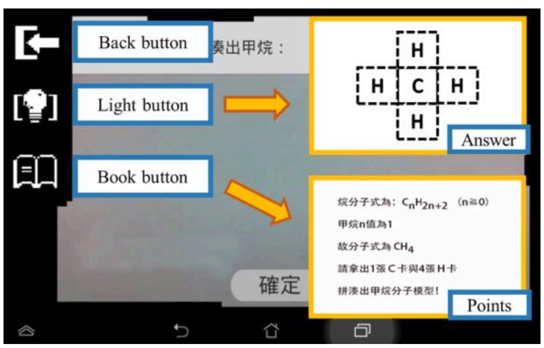

Fig. 3. The meanings of the buttons.

B. Instruments

1) Course material: Nowadays, the teaching in senior high schools in Taiwan is largely examination-oriented. In order to keep up with the chemistry course, and to help the students enhance their learning performance, in this study the researchers adopted the chemistry course of organic compounds as the learning target; this is regarded as a difficult subject as it deals with molecular structure and characteristics in organic chemistry. Moreover, the researchers rigorously designed a series of 5E instructional learning activities with the school teachers. Table 1 shows the detailed information of the learning activity.

TABLE I. THE CONTENT OF THE 5E LEARNING CYCLE ACTIVITY.

Phase	Content	Time
E1(Engagement)	1. Augmented Reality Exercise (octet rule, covalent bond concept) 2. The definition of the organic compound 3. Hydrocarbon Classification 4. Chain hydrocarbons and cyclic hydrocarbons	20 min
E2(Exploration)	1. Alkyl 2. Alkenyl 3. Alkynyl 4. Cycloalkyl	40 min
E3(Explanation)	1. Definition and clarification of hydrocarbons 2. Practicing with the questions	30 min
E4(Elaboration)	1. Isomer	30 min
E5(Evaluation)	1. Evaluating students' learning achievements in the above phases	30 min

2) Pre-test and post-test: In this study, the researchers designed the questions together with chemistry teachers who had at least five years of teaching experience. The pre-test includes 10 multiple-choice items (70%) and 5 fill-in-the-blank items (30%) with a full score of 100. To evaluate the students' learning performance of organic compound concepts to ensure that they really understand them, the post-test consists of 10 fill-in-the-blank (70%) and 5 question (30%) items with a full score of 100.

3) Questionnaires: To analyze the students' learning situation, the questionnaires of learning motivation and chemistry self-efficacy have been adopted using a five-point Likert scheme. In this study, the researchers utilized MSLQ (Motivated Strategies for Learning Questionnaire) as the learning motivation survey which was revised by Pintrich, Smith, Garcia, and McKeachie, and is divided into two parts: one part for intrinsic motivation, and the other for extrinsic motivation, each consisting of seven questions. The chemistry self-efficacy questionnaire was modified from Wang and Hwang's (2012) self-efficacy questionnaires. To evaluate the learners' confidence in the learning activity, the pre- and post-questionnaires were designed with the same content and each included eight questions.

4) Experimental Procedure: Figure 4 displays the experimental procedure of this study. Students in both the experimental group and the control group will take the pre-test and questionnaire of chemistry. Before the learning activity, they will not have learned the knowledge of organic compounds but have previously learned the concepts of matter composition. After the exercise of the Augmented Reality system, the students in the experimental group will learn about organic compounds with the interactive 5E learning cycle-based AR system, while the students in the control group will utilize the AR simulation system with the traditional 5E instructional model to learn the concepts of organic compounds. After the learning activity, the students in both the experimental group and control group will take a post-test.

Then, they will be asked to complete the same questionnaire to analyze their learning motivation and chemistry self-efficacy.

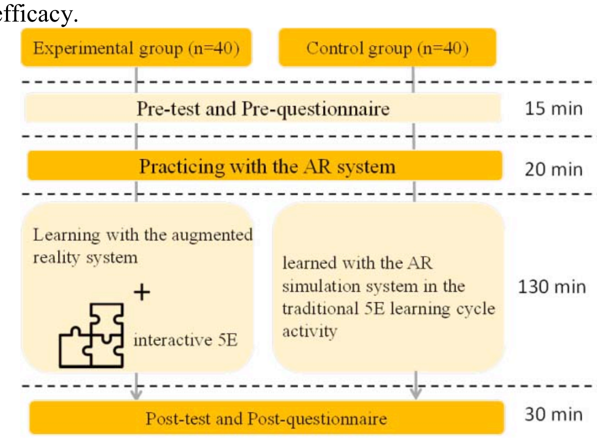

Fig. 4. Experiment procedure.

FUTURE WORK

To improve the current microcosmic Chemistry molecule course, the interactive 5E learning cycle-based augmented reality system is proposed in this study. The visualization tools play the role of intellectual partners of the students learning about molecules. The experiment will be conducted in April, 2016. It is expected that the students will benefit from using the advanced interactive 5E learning cycle and AR technology and from constructing mental images of the microcosmic molecule world.

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