Enhancing AR-based Science Exploration through Learning Cycle

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***Abstract*—The purpose of this study was to explore whether employing a learning cycle model helps students' science exploration within an AR-based environment. Two types of guiding strategies were implemented within the learning cycle, including the procedural guidance and the question guidance. A pilot test was conducted to examine the design of AR-based science exploration using a learning cycle framework and the effect of type of guidance on participants' learning performance and attitudes. The results revealed that when learning from the augmented-reality environment, the question-guidance group achieved better knowledge application performance than the procedural-guidance group and learners of both groups showed positive attitudes toward the employed learning activity.**

Keywords—learning cycle; learning guidance; digital learning environment; augmented-reality

I. INTRODUCTION

The advantage of applying virtual reality in the education was to present those invisible situations and abstract concepts with static or dynamic methods, transferring the abstract concepts into concrete knowledge and allowing the learners to feel and experience [1], [2]. Due to the fact that the leaners could not be perceptive about the changes in the surroundings when entering the virtual reality, a technology combining the real world was extended—Augmented Reality. Shelton and Hedley suggested that the technology of augmented reality could present the three-dimensional concepts, not only allowing the learners to observe abstract phenomena of science with their visibility but also letting them operate the tools and interface; such learning method could improve learners' perception along with their understanding in the learning. Moreover, in order to make the learners be immersive in the learning activity and achieve better learning performance, adding gaming interface and tasks in the AR-based learning activity could initiate the positive learning motivation for the learners [3]. Accordingly, the teachers should appropriately integrate learning guidance to guide the learners to think and discover the reasons to the knowledge, which would further lead to the construction of individual viewpoints and knowledge.

Therefore, this study aimed to employ a learning cycle framework to enhance learners' AR-based science exploration and examine the effect of guiding strategies on participants' learning performance and attitudes. The learners were expected to construct their own knowledge and be immersive in the AR-based science exploration learning through the use of 5E learning cycle and, therefore, bring about better understanding of learning.

II. LITERATURE REVIEW

A. 5E Learning Cycle and Inquery Learning

The 5E learning cycle was developed by the US Biological Science Curriculum Study (BSCS) and involved the learning with constructivist features, including 5 stages—Engagement, Exploration, Explanation, Elaboration, and Evaluation [4]. The 5E learning cycle aims to help the learners construct their knowledge and cultivate their abilities of inquiry and problem-solving of science. Thus, using 5E-learning for the design of AR-based exploratory learning could let the learners activate pre-existed knowledge by inquiry, which would connect the received knowledge to the prior knowledge; lastly, explanation could be expected according to the inquiry experiences with further effective application of the received knowledge.

The inquiry-based learning was commonly applied to the related fields in science education, which had been acknowledged for a positive feedback on learners' perception and problem-solving ability of science [5]. However, learners' self-involvement in science activity and the process of exploration did not correspond to the learning from experiences nor did they further obtain accurate concepts on science or the ability to ponder like a scientist. As a result, teachers should give procedural instruction or questioning guidance to lead the learners more effectively in the inquiry-based learning [6].

B. Guiding Strategies

For achieving better learning effects, in the learning activities, the teachers were not expected to directly deliver the knowledge to the learners but with preliminarily planned situations to guide the learners and inspire their desire for knowledge, at the same time using systematic methods to encode the knowledge into the long-term memory for the enforcement of problem-solving ability [7]. However, the learners actively identifying concepts or problems took more time than the conventional teaching so that the progress of

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learning was chronically influenced by time. In particular, when the learners faced the units that were more complicated, inquiry-needed, and confusing, they often led themselves to incorrect thinking due to the time limitation of class; also, the leaners often lost their motivation and confidence in learning during the learning difficulty which blocked the expected outcome of learning. Thus, if the teachers employed the method of guidance and led the learners with correct path of thinking to control the entire learning process and lower the mistakes, they could possibly lower leaners' frustration caused by the failure in learning.

III. METHODS

A. The Study

The purpose of this study was to explore whether employing a learning cycle model helps students' science exploration within an AR-based environment. Two types of guiding strategies were implemented within the learning cycle, including the procedural guidance and the question guidance. A pilot test was conducted to examine the effect of AR-based science exploration with a learning cycle framework on participants' learning performance and attitudes. The procedural-guidance group received hints about the procedure of concept clarification, and the learners were asked to record their inferred conclusion onto the learning sheet. On the other hand, the question-guidance group were prompted about the emphasis, construction, attributes, and features of the concepts related to their life experiences and were asked to find the answers through the inquiry. Moreover, participants' learning performance in four seasons concepts and learning attitudes toward received learning were assessed. This pilot test was conducted in the computer classes and lasted 3 weeks with 40 minutes in each class. Students used tablet PCs to receive the experimental learning activity individually.

B. The AR-based Science Exploration

The 5E learning cycle was employed as the learning framework for learners to explore the formation of day and night and the four seasons due to the relative position of the Sun and the Earth through the AR-based science exploration. With the virtual simulation of the features, the AR-based exploration allow the learners to experience the formation of day and night and four seasons, so they could further understand how to apply related concepts and skills in daily lives. Unity3D game engine and Vuforia SDK were employed to develop the AR-based exploration tasks running on Android system tablet PCs. The domain knowledge, science concepts of day and night and four seasons, was adopted from the junior high school curriculum of "Science and Technology". A storyline of Rescue the Earth was implemented for the AR-based exploration, and the tasks were given following the 5E-learning cycle phases. As shown in Table 1, participants follow the 5E phases to Engage, Explore, Explain, and Elaborate the content knowledge, and finally learning gains were assessed at the end of the activity. As shown in Figure 1 and Figure 2, by touching the virtual image of the Earth on the tablet's screen, a learner can activate the AR interactions, explore the content knowledge, and solve the encountered problems. Responsive interactions and feedbacks are provided accordingly upon given learners' exploration behaviors.

TABLE I. THE PHASES OF THE AR-BASED 5E INQUIRY LEARNING—"RESCUE THE EARTH"

5E learning cycle	Learning objective	Learning theme	Learning activity
Engagement	Initiate the leaners' curiosity and their interest.	**Understanding activity:** Introduction to the Day-Night alternation and the changes in Four Seasons.	The instruction of the operation on the tablet game, using the features of the Earth as the example.
Exploration	Challenging tasks were designed for the learners to solve problems.	**Knowledge construction:** 1. Understand the cause of Day-Night and the application of related concepts. 2. Understand the cause of Four Seasons and the application of related concepts.	Tasks of the tablet game: "Earth rotation and Day-Night alternation" and "Earth revolution and Four Seasons."
Explanation	Further explain the confusing concepts for the learners to have better understanding.	**Concepts clarification and understanding reinforcement:** Concepts about the Earth Day-Night alternation Sunshine in Four Seasons	Learners will be given learning sheets before the class ends for the learners to reconstruct the knowledge and explain the concept from previous task in order to clarify and build the concepts.
Elaboration	The learners use the knowledge previously proposed and defined for the opportunity of extension and application.	**Concepts proficiency and application:** Concepts about the Earth The length of day and night The difference of the seasons	To rescue the dying Earth, learners are expected to take the Archenemy challenge with the received concepts. The learners have to apply the received concepts in the Archenemy challenge at the end of each class.
Evaluation	Evaluate learners' understanding of the concepts and their abilities of the skill application.	**Assessment of overall concepts**	Posttest and questionnaire will be conducted as the reference for the improvement of the learning.

Fig. 1. By touching the virtual image of Earth on the tablet's screen, learners can activate the AR interactions.

Fig. 2. Interactions and feedbacks are provided accordingly upon learners' actions.

IV. PRELIMINARILY RESULTS

A. Analysis on Learning Performance

ANCOVA analysis was conducted to examine participants' learning performance in knowledge application of day and night and four seasons with prior knowledge as covariant. Prior knowledge was significant on knowledge application and its impact on learning performance was eliminated from the analysis for better examination of the effect of the treatment on the dependent measure. Both groups achieved satisfied learning performance (the question-guidance group: 85.3%; the procedural-guidance group: 78.6%), indicating that the AR-based 5E-learning-cycle exploration helped participants comprehend the content knowledge effectively. Furthermore, the type of learning guidance was significant on participants' knowledge application performance ($F_{(1,52)}$=3.96, p=.05), which indicates that the question-guidance is more superior in facilitating the AR-based exploration learning than the procedural-guidance. That is to say, in a hands-on exploratory learning environment, giving the guiding questions in advance is better than providing procedural information during the exploration.

B. Analysis on Attitudes

MANOVA analysis was conducted to examine participants' attitudes, including value, helpfulness and satisfaction, toward learning from the AR-based 5E-learning-cycle exploration on a 5-point Likert-type scale. The non-significant main effects and positive attitudes (value: 3.82, helpfulness: 3.74, satisfaction: 3.95) indicated that the learners valued the learning process of the AR-based 5E-learning-cycle exploration and perceived the learning activity as helpful to them by being satisfied with the learning outcomes.

V. CONCLUSIONS

In sum, this pilot test examined the appropriateness of employing the 5E learning cycle as a learning framework for AR-based secince exploration and analyzed the effect of type of guidane on learning performance in and attitudes toward AR-based secince exploration. The revealed positive attitudes and satisfied learning gains did support the hypothesis of enhancing AR-based science exploration learning through learning cycle. In fact, the 5E learning cycle was origionally developed to help learning of science through exploration. With the exploration learning nature and step-by-step phases, the 5E learning cycle provided a solid learning framework for the design and development of the AR-based exploration. Therefore, the target content knowledge can be acquired smoothly by the learners via the AR-based exploration learning. However, the step-by-step exploratary learning activities (phases of the 5E learning cycle) need to be further integrated as a whole to bring about efficient learning effect. In the present study, a storyline was employed to provide a logical and motivating context to facilitate the connection among the parts (the 5Es). Hence, it is suggested that whether there is any other effective way in achieving the integration of the 5E phases can be further investigated.

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