Inquiry-based Learning with Augmented Reality Mobile Application to Enhance Scientific Conceptual Understanding: TheFruitAR

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Abstract: Scientific inquiry has been considered to be a process to constructing scientific knowledge. With students' misconception of Types of Fruits and Their Flowers, we developed an augmented reality mobile application and its accompanying booklet, TheFruitAR. The purpose of this development was to enhance scientific conceptual understanding on such topic guided by inquiry learning approach. This could help facilitate their learning in a more meaningful way by interacting with interactive multimedia materials and learning activities on mobile. In order to evaluate the effectiveness of TheFruitAR, a comparative experiment was conducted with upper elementary school graders in Thailand. The findings showed that students who learned with our proposed development could outperform than those who learned with the conventional approach, indicating that TheFruitAR could enhance students' conceptual understanding. Moreover, students also revealed positive attitudes towards learning on TheFruitAR, indicating that it motivates students to inquire knowledge.

Keywords: Mobile learning, Augmented Reality, Scientific Inquiry

1. Rationale and Motivation

Science has been playing a vital role in the world. The process of learning science makes learners themselves solve the problems, which is known as scientific literacy (Abd-El-Khalick, 1997). One way to develop scientific literacy is to teach science as inquiry. Inquiry-based learning provides students with opportunities to reflect on, question, and analyze the enormous amount of digital, print, and media information that characterize the complex technological society (National Research Council, 2000).

Types of fruits is one important concept in science subject describing how different kinds of fruits related to different kinds of flowers. Most students hold great amount of misconception on this learning topic because they usually learned this topic passively in the classroom only supplemented by conventional e-learning materials, in which students cannot actively inquire the conceptual understanding by interacting with the materials; such that they could not make a relationship between fruits and their flowers.

According to the advantages of Augmented Reality (AR) that can combine virtual object and physical object in real time, using AR technology could help students to solve this problem because they can interact and see the relationship of flowers and fruits simultaneously (Dunleavy, Dede and Mitchell, 2009).

Therefore, we developed an AR application on mobile to enhance students' conceptual understanding on the relationship of flowers and fruits (hereinafter called TheFruitAR), accompanying with the learning booklet designed to support their scientific inquiry learning. Moreover, this study attempted to evaluate the effectiveness of the proposed development by investigating following research questions:

1) Do students who learned with the proposed development have better scientific conceptual understanding than those who learned with the conventional approach?

2) How are the learning attitudes of students towards the proposed development?

2. Related Studies

2.1 Augmented Reality in Science Learning

Augmented Reality (AR) is a technology combining real world and virtual world together which exactly overlays physical objects in real time (Yuen, S., 2011). There are many fields beneficial for using AR technology such as entertainment, medicine, and education (Klopfer & Squire, 2008).

In science education, AR was adopted to enhance learning activities and motivation in various applications (Kerawalla, Luckin, Selijefot and Woolard, 2006). For example, Institute for the Promotion of Science and Technology (IPST) in Thailand developed a 3D AR geology textbook which enhance students to see the relationships, differences and functions between the earth and geological characteristic. Moreover, AR games have been developed in order to assist players inquiring science concepts with fun (Yuen, S., 2011); while AR technology have also been used as tools in discovery based science learning.

Although AR applications on science learning have been developed and studied in different aspects, there are a limited number of studies concerning on using AR to promote scientific inquiry (Zhou, Duh and Billinghurst, 2008).

2.2 Scientific Inquiry

Science inquiry has been defined as the process of constructing science concepts and patterns, and creating meaning about an idea to explain them (Bybee, 2000). This approach has been highly advocated to be implemented in many levels of teaching science; it allows students to inquire about the phenomenon of the nature of science through five essential features of science inquiry which are 1) engaged by instructors or posing their scientifically-oriented questions, 2) determining what constitutes evidence and gather it to provided evidence, 3) formulating explanations after summarizing evidence, 4) linking the explanations to scientific knowledge, and 5) forming reasonable and logical arguments to communicate (National Research Council, 2000).

There are many educational researches studying the effectiveness of science inquiry used for science teaching strategies. Inquiry-based laboratory work is an effective mode of learning to improve and enhance students' understanding (Lord & Orkwiszewski, 2006), reading ability and learning environment and promoting higher order thinking skills (Madhuri, 2012).

According to the implications of scientific inquiry, it has been considered and agreed to be an effective strategy to teach and learn science (Cuevas, Lee, Hart and Deaktor, 2005). It could help learner to inquire and construct knowledge by themselves and support learner to understand the scientific relationship between fruit and flower that help them to avoid the misconception (Crawford, 2007).

3. Development of AR Learning Package on Types of Fruits and Their Flowers

Fruit is one part of flowering plant which mostly derives from ovary of flower. Fruit contains one or more seeds with some accessory tissues. There are three kinds of fruits which can be distinguished by their types of flowers as follows. (1) Simple fruit is developed from both single flower and compound flower that one flower has only one ovary. (2) Aggregate fruit is developed from single flower that has multiple independent ovaries, and (3) Multiple fruits are developed from a cluster of flowers; each flower produces its fruits which later joining together.

However, most students hold great amount of misconception since they could not figure out the types of fruits and relate them with their flowers. Therefore, we developed an AR learning package to enhance scientific conceptual understanding based on guided inquiry approach. This package bundled with the designed booklet and developed mobile application, which was designed to be used in the science classroom with the content of ‘Types of Fruits and Their Flowers.’

3.1 Guided-Inquiry Learning Booklet for TheFruitAR

The main purpose of the booklet was to provide necessary information with guided-inquiry learning approach, as shown in Figure 1. The information provided in this booklet was structured as follows: 1) Providing open-ended question: to ask student if he/she already understood the topic, 2) Providing necessary theory/concept: to present key information in order to construct the conceptual understanding in the learning activity, and 3) Providing learning procedure: to show AR trigger images for learning activities on mobile application.

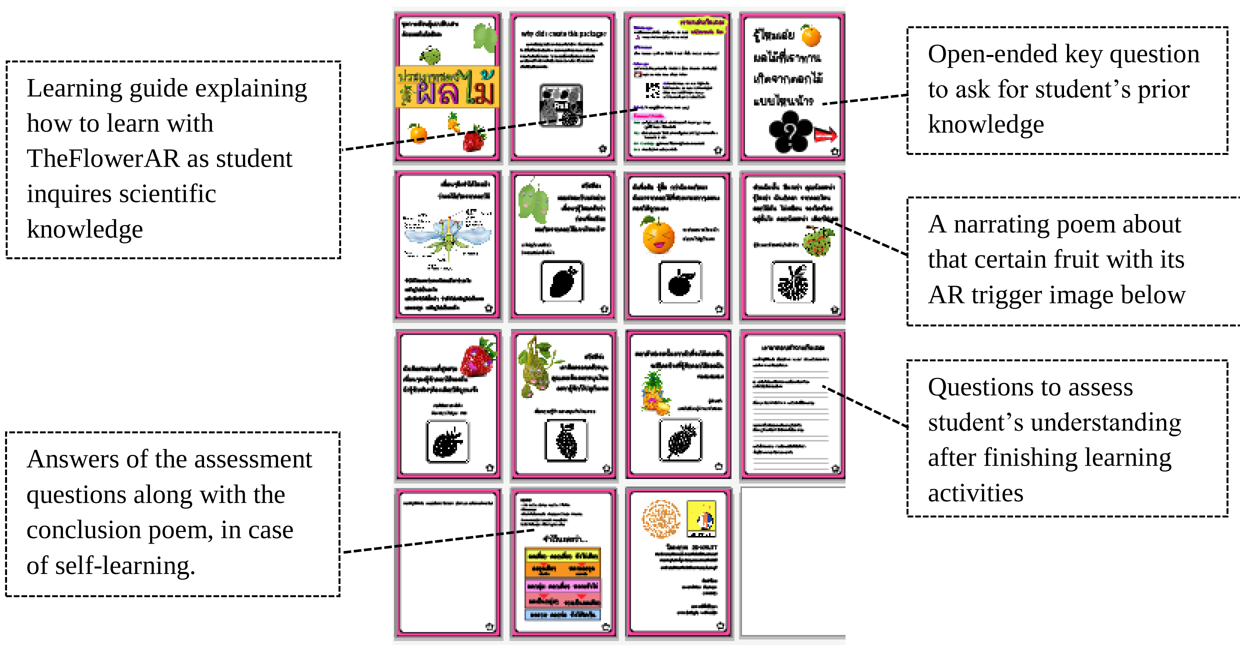

Figure 1. Page Layout of Guided-Inquiry Learning Booklet for TheFruitAR

In the later steps of analysis and discussion, these are not provided; instead, we guided students to work in group to analyze what they have learned with the questions, followed by urging them to make a conclusion statement of the learning content.

3.2 Augmented Reality Mobile Application (TheFruitAR)

To provide more interesting learning experience to the students, we developed the AR application to use in the third step of the guided inquiry procedure. AR application was developed with a free account of Aurasma software.

Once the student opens the AR application and capture to any trigger image on the booklet, he/she is entering to the interactive mobile learning activity. As shown in Figure 2, the student will first be prompted to select a corresponding flower to its fruit, a direct feedback is then given with the sound to let student know if he/she correctly or incorrectly understood.

Figure 2. Learning Activity in AR Application

If answered incorrectly, the meaningful feedback is given, followed by presenting the interactive multimedia video presenting its type of fruit by considering the characteristic along with its flower. In the meantime, student could actively learn the subjects by swiping force and back and by zooming in and out to any misunderstood parts. Here, the student will enjoy learning and have inquired more conceptual understanding at his/her learning pace. Once the student finished learning, he/she will be re-prompted to answer the question again. With this mechanism, it could ensure a student if he/she has reached the certain required conceptual understanding level of the subjects.

4. Experimental Design

In order to investigate the effectiveness of TheFruitAR, an experiment was conducted with 2 classes of 83 upper elementary school graders in central Thailand who were taught by the same teacher.

One class of students learned with our proposed TheFruitAR called experimental group, while another class learned with the conventional e-learning approach, mainly video learning material on computer, called control group. The group selection was done by a draw by representatives of 2 classes. Both groups started with the pretest for 10 minutes. After that each group of students participated in their selected learning approach for 30 minutes. Finally, both groups tool the parallel posttest; moreover, the experimental group took additional learning attitude questionnaire.

The pretest and posttest, each comprised of 12 multiple-choice items with a total score of 12, were collaboratively designed by 3 experienced teachers to investigate the scientific conceptual understanding; while the attitude questionnaire was adopted from Chu, Hwang, Tsai and Tseng (2010). Cronbach's alpha of pre and post tests, and of the questionnaire were 0.86 and 0.82, respectively.

5. Experimental Results

5.1 Scientific Conceptual Understanding

To test the effectiveness of the proposed TheFruitAR, all students took the same conceptual pretest. It was found that the mean ± standard deviation of the control group was 5.30 ± 1.58 and of the experimental group was 5.25 ± 1.39, showing that there was no difference between two groups before the experiment (*t* = 0.295, *p* = 0.371).

After the control group learned with the conventional e-learning approach while the experimental group learned with TheFruitAR, all students took the same posttest to investigate the scientific conceptual understanding. As shown in Table 1, an independent t-test was performed by including 2 different learning strategies as independent variable, the result showed that the posttest score of those who learned with TheFruitAR was significantly higher than those who learned with the conventional e-learning strategy (*t* = 2.135, *p* = 0.008). Therefore, it could be implied that learning with TheFruitAR helped students gain more conceptual understanding.

Table 1: Students' posttest scores between control and experimental groups.

Independent variable	N	Mean	SD	*t*	*p*
Learning with conventional e-learning (Control group)	43	8.15	2.35	2.135	0.008*
Learning with TheFruitAR (Experimental group)	40	9.92	2.64		

*$p<0.05$

5.2 Learning Attitudes towards TheFruitAR

To investigate how students in the experimental group perceived TheFruitAR, they took a learning attitude questionnaire to express their satisfaction, as shown in Table 2. The descriptive statistics were analyzed from the 5-Likert scale measures ranging from 5 for "Highest satisfaction" and 1 for "Lowest satisfaction."

It was found that students revealed high satisfaction on most attitudinal measures; moreover, they found booklet could help their learning on TheFruitAR more meaningful, while the mobile AR application could help motivate their learning to inquire more conceptual understanding, as they rated high satisfaction.

Table 2: Student's satisfaction attitude towards TheFruitAR

Measures	Mean	SD	Satisfaction
1. TheFruitAR makes my learning more interesting.	4.34	0.75	High
2. Interactivity helps me inquire more understanding.	4.27	0.86	High
3. With the guide provided on booklet, my learning is meaningful.	4.68	0.74	Highest
4. Feedback helps me improve learning.	4.36	0.78	High
5. Interactive multimedia on TheFruitAR motivates me to learn.	4.71	0.68	Highest
6. I like to learn with TheFruitAR.	4.43	0.74	High
7. I would recommend TheFruitAR to my friends.	4.33	0.65	High

6. Conclusion and Discussion

This study attempted to enhance students' scientific conceptual understanding on Types of Fruits and Their Flowers via our proposed AR learning package, TheFlowerAR. Students were guided to follow the inquiry learning strategy on the booklet while learning process, students enjoyed learning by interact with the application and were prompted with interactive multimedia learning materials, questions and feedback to help their learning more effective and interactive. Based on the comparative experimental study, we found that the proposed TheFlowerAR could enhance their conceptual understanding and gained positive attitude.

This finding is aligned with other studies. For example, learning on mobile could enable them to inquire the conceptual understanding by interacting with the prompts and questions (Parsons, Ryu and

Cranshaw, 2007), and AR could make learning activities more meaningful and interesting (Kaufmann & Schmalstieg, 2003). In addition, students could interact with the virtual object in the real environment simultaneously on their mobile devices.

As this application developed during the pilot phase, it was studied to be a supplementary aid to facilitate and motivate students' scientific inquiry; however, there are limitations which could be further enhanced. For example, the learning activity could adjust to fit student's learning situation. Teacher could keep tracking students' learning progress by having students' learning logs stored and analyzed. In addition, the findings of this study could not generalize to other different subject if the nature of that content is different.

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