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Students' online interactive patterns in augmented reality-based inquiry activities

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ABSTRACT

Inquiry learning has been developing for years and many countries have incorporated inquiry learning into the scope of K-12 education. Educators have indicated the importance of engaging students in knowledge-sharing activities during the inquiry learning process. In this study, a location-based augmented reality (AR) environment with a five-step guiding mechanism is developed to guide students to share knowledge in inquiry learning activities. To evaluate the effectiveness of the proposed approach in terms of promoting the knowledge sharing behaviors of students, an experiment has been conducted in an elementary school natural science course. The participants were 57 fourth-grade students from an elementary school in Northern Taiwan, divided into an experimental group of 28 students who learned with the AR-based approach and a control group of 29 students who learned with the conventional in-class mobile learning approach. The students' learning behaviors, including their movements in the real-world environment and interactions with peers, were recorded. Accordingly, the learning patterns and interactions of the two groups were analyzed via lag-sequential analysis and quantitative content analysis. It was found that, in comparison with the conventional inquiry-based mobile learning activity, the AR-based inquiry learning activity is able to engage the students in more interactions for knowledge construction. The findings of this study provide guidance for helping teachers develop effective strategies and learning designs for conducting inquiry-based learning activities.

1. Introduction

In recent years, many researchers have applied location-based augmented reality (AR) to inquiry-based science education (Bressler & Bodzin, 2013; Chang, Wu, & Hsu, 2013; Sollervall, 2012). This application has become a major trend in contemporary science education (Cheng & Tsai, 2012), and emphasizes learning through observation, multifaceted thoughts and inquiries, and knowledge sharing (van Zee & Roberts, 2006). A hands-on approach is also encouraged for completing experimental activities. Inquiry learning methods encourage students to extend personal experiences from exploration, gain knowledge in the process of finding answers, summarize the data collected, and share their findings and conclusions with peers during the learning process. Undergoing these processes can correct mistakes in the learner's original knowledge and ideas, and guide the formation of correct knowledge and cognition. More importantly, sharing findings and discussing with peers enable students to learn and think from different perspectives. Inquiry-based teaching methods correspond to the teaching philosophies valued in natural science education (Capps & Crawford, 2013). Nevertheless, different guidance approaches might lead to different influences on the effectiveness of peer interactions and collaborations. Therefore, this research aims to analyze students' knowledge-sharing behaviors, such that feasible suggestions can be provided to teachers or educators as a reference when developing activities or adopting guiding strategies for knowledge sharing or cooperative learning activities.

The prevalence of outdoor education has increased considerably in recent years (Bloom, Holden, Sawey, & Weinburgh, 2010). Students can use those outdoor learning experiences to understand and establish new knowledge and concepts regarding the topic being studied

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(Auer, 2008; Upadhyay & DeFranco, 2008). On the other hand, Teachers can incorporate knowledge regarding ecology that students gained through outdoor learning into formal classroom instruction to improve student comprehension (Eick, 2012). However, inquiry learning in an outdoor environment is challenging. Students are easily distracted during interactions and communication with many peers, and excessive knowledge and information can cause interference, rendering it difficult for students to concentrate on learning tasks related to the current topic. This makes it difficult for learners to apply the knowledge gained through outdoor learning to classroom learning or daily life (Kamarainen et al., 2013). Therefore, designing a mechanism that assists learners in group discussions is essential for enhancing the knowledge construction phase (Hou, Sung, & Chang, 2009). Previous research has indicated that group discussions generated by peer cooperation to find answers to questions can result in higher level thinking and cognition. However, the lack of appropriate strategies or mechanisms for facilitating the discussion process in cooperative group discussions can severely affect and limit the knowledge construction phase of students. Regarding this issue, numerous scholars have proposed the use of technology mechanisms to assist in knowledge sharing during the cooperative discussion process, thereby guiding the learners to achieve higher levels of knowledge construction (Hou, 2012).

2. Literature review

2.1. Inquiry-based learning

Inquiry-based learning is primarily a pedagogical method based on the investigation of questions, scenarios or problems (Kuhn, Black, Keselman, & Kaplan, 2000). By the process of investigation and collection of science data, inquiry activities provide a valuable context for learners to acquire, clarify, and apply an understanding of science concepts (Edelson, Gordin, & Pea, 1999). Furthermore, many teachers try to develop learners' investigation skills, data analysis and critical thinking using inquiry-based learning. They adopt activities related to the natural world to allow students to observe events and objects in the physical world from various facets, and to develop an understanding of how scientists explore the natural world (Hmelo-Silver, Duncan, & Chinn, 2007).

The advantages of inquiry learning are that it can lengthen the retention period of new knowledge, increase problem solving flexibility and creativity, and increase student learning motivation (Lord & Orkwiszewski, 2006). When inquiry learning is used in science subjects, it shows great potential for increasing students' understanding of scientific knowledge and their engagement in science. Rather than forcing students to learn according to a fixed process, students should be encouraged to explore, research, and think about the knowledge they have gained. They should use appropriate assistive technology to gather data, then process and formulate a reasonable explanation for the collected information. Students should then analyze the explanations of others while communicating their own viewpoints. Finally, the knowledge that students have learned should be assessed (Wilhelm & Walters, 2006; van Zee & Roberts, 2006).

The main elements of the inquiry learning process are how to define the research questions, the focus of learning, and the roles played by both students and teachers. Students play a crucial role in learning. Field explorations, interviews, research, and other guided methods encourage students to actively explore, stimulating new cognitions about the learning objectives and resulting in a more profound understanding and awareness. The role of teachers is to guide students and to establish a learning environment that facilitates the students' learning process.

The traditional approach to informal education has been criticized for creating artificial classroom contexts wherein the learning activities and resources become divorced from their meaning in real life situations (Herrington, Reeves, & Oliver, 2010). The advocates of authentic learning argue for the creation of more meaningful learning situations. Authentic learning requires that the contexts used for learning reflect real world contexts in which the skills and competencies will be deployed. Mayer (2001) also emphasizes that presenting text and corresponding illustrations in an integrated manner could benefit students more than in a separate mode. These AR-based inquiry scenarios can cover a wide range of domains from observation and interaction through to accessing real scientific instruments over the Web to conduct more realistic experiments.

The inquiry learning model was proposed by scholars and researchers at the University of Illinois at Urbana-Champaign (Li, Moorman, & Dyjur, 2010). The characteristics of inquiry-based instruction include (a) a project focus on authentic problems and issues that are relevant to the learners and the real world, (b) defining questions for learners to be studied and directions that learning takes, (c) learning what happens (and how it happens?) through fieldwork, design, construction, interviews, experiments, and other explorations that lead learners to new insights, and (d) deep understanding after thinking. The 5-stage learning strategy is explained as follows: first, the appearance of a question can stimulate the curiosity of students; this is the "ask" stage. Through observing phenomena and testing to gather data, students attempt to answer and resolve questions; this is the "investigate" stage. When students begin to form connections among the gathered information, they develop creative thinking regarding the information; this is the "create" stage. Learners share the knowledge they have learned through discussion; this is the "discuss" stage. Finally, through reactions to the questions and the research process, a new conclusion may be formed; this is the "reflect" stage. The results of the reflect stage may generate a new cycle (Li et al., 2010).

2.2. Augmented reality

In contemporary education, many educators and researchers have enthusiastically used location-based AR in teaching and learning (Bower, 2008; Dalgarno & Lee, 2010; Dunleavy, Dede, & Mitchell, 2009; Kye & Kim, 2008). Because acquiring information through this technology is more intuitive, it can stimulate learners during the learning process to actively observe, to formulate multiple assumptions through observations, to carefully assess the validity of observed phenomena and the rationality of proposed hypotheses, and to formulate a final hypothesis after refuting multiple proposed hypotheses. Location-based AR can increase the frequency of the described learning process, enabling students to be more immersed in scientific thinking while learning. Increased student immersion and frequent peer interactions during the learning process can result in high-level thinking, a thorough understanding of the topic, and enhanced absorption of the course material (Dalgarno & Lee, 2010; Squire & Jan, 2007). In addition, students who use location-based AR have demonstrated increased initiative and concentration in analyzing, finding, sharing, and discussing what they have discovered. Portable location-based AR has the characteristics of mobility, location awareness, interoperability, seamlessness, situation awareness, social awareness, adaptability,