A context-aware progressive inquiry-based augmented reality system to improving students' investigation learning abilities for high school geography courses

Hui-Chun Chu
Department of Computer Science and Information Management
Soochow University
Taipei, Taiwan
carolhcchu@gmail.com

Yu-Hsuan Sung
Department of Computer Science and Information Management
Soochow University
Taipei, Taiwan
winters908@hotmail.com

Engaging students in constructing their knowledge during real-world observation and inquiry-based learning activities has been recognized as an important issue for improving students' learning achievement and motivation. However, researchers have indicated that due to a lack of effectively connection between observation in real-world and inquiry problems, it is a challenge to lead an effective outdoor inquiry-based learning activity. In this study, a progressive inquiry-based approach with augmented reality technology is proposed for improving students' high-level thinking and problem solving abilities by asking students to answer different layer of questions in in-field inquiry learning activities. An experiment will be conducted to evaluate its performance on high school geography courses. A total of 60 first-grade high school students from two classes will participant in this experiment. The students in the experimental group will learn with the progressive inquiry-based augmented reality system; while those in the control group will learn with the conventional AR contextual u-learning approaches. The students' learning achievements, learning attitudes, learning motivation, and problem solving ability will be investigated after the experiment. It is expected that the proposed approach will effectively enhance the students' learning achievement in comparison with the control group.

Keywords—progressive inquiry-based learning; augmented reality; context-aware u-learning; geography course

I. BACKGROUND AND OBJECTIVES

Much research has been carried out on the potential benefits of conducting context-aware u-learning activities in the last decade. Inquiry experiences can provide students with good opportunities to deep and meaningful learning of both science content and scientific practices [9]. Much work have shown that inquiry-based learning strategy not only can improve students' learning achievement but also encourage their high-level thinking abilities, such as complex problem solving ability, critical thinking, and collaborative learning [6] [11][22][25].

Researchers have proposed many kinds of theories of inquiry-based learning [18]. It is found that inquiry-based learning is a concept about nature of "learning" and "teaching", by the teacher encouraging students to observe the environment, assume the issue, explore the solution, validate, explain the question, discuss and share real problems in the real-world. Li et al. [17] defined five step of inquiry activity, including: (1) Ask, an unsolved issue or problems in the real word to motivation, (2) Investigate, investigate the way to answer the question, (3) Create, construct the answer found in step two, (4) Discuss, share the knowledge with others, and (5) Reflect: receive the opinion from classmates or teachers and modify the inquiry content, that is, one of the important thing of inquiry based learning is ensure that students immersing in the learning context.

Prince [23] pointed out the advantage of using inquiry-based learning to increase students' scientific literacy, maintain long-term memory of the knowledge acquired from activity, enhance students' operation ability, facilitate meaningful learning. These results show that inquiry-based learning is more effective instead of the tradition teaching. A successful inquiry-based learning activity depends on the question assumed by students, which affected the whole inquire process's quality [2][7][10][24].

Hung et al. [21] indicated three types of questions made by students during an inquiry-based field trip learning activity: 1) Informative facts, which can learn from textbook, internet, 2) Science procedural, propose a question which can validate by science experiment, 3) Conceptual science, a question based on certainty science concept, in order to support students' field learning activity.

Although inquiry-based learning is recognized to be an effective strategy to increase students' motivation and learning achievements, it is still a challenge to conduct outdoor inquiry-based learning activity due to the less of connection between observation and inquiry problems. In the last decade, owning to

978-1-4673-8985-3/16 $31.00 © 2016 IEEE
DOI 10.1109/IIAI-AAI.2016.112

the popularity of mobile technology, wireless communication and sensor technologies, many researchers have conducted context-aware u-learning activities to develop mobile inquiry-based learning systems [4][31]. Those mobile systems play the role to sense students' learning condition in order to provide relatedly resource helping them focus on learning objects.

Augmented reality (AR) combines the real world with virtual information to improve the observation which cannot observe by naked eye. The advantages of AR include integrating reality with virtual, real-time interactive, accurately locating 3D objects [1], AR supported system allows students interact with context instead of paper on the traditional course, even more, immerse students in a knowledge from learning activity and enhance the communication between group members [3][15]. Scholars have reveled through AR learning systems in a field trip, adequate guiding students focus on the learning objects, helping them operate science tools, quick response to understand learning condition [6][14][30]. More important, since AR apply to aware students' location in order to implement "context-awareness" which sensing students' current location and provides relative learning materials [26]. Similar sensing technology, for example: RFID [8], GPS [19], AR [5], have shown that analyze students' condition, provide real-time reflect had effectively aid students assimilate the knowledge from the learning context through system.

This study attempt constructing a progressive inquiry-based augmented reality learning system to aid students conducting a field trip geography inquiry learning activity and aiming to address the following research questions:

- Can the progressive inquiry-based mechanism benefit the students in terms of improving their learning achievement?
- Is there a significant difference between the students who learned with the progressive inquiry-based AR and the conventional AR contextual u-learning approaches in terms of their learning attitudes, learning motivation, and problem solving ability?
- Is there a significant difference between the students who learned with the progressive inquiry-based AR and the conventional AR contextual u-learning approaches in terms of their cognitive load?

II. THE PROGRESSIVE INQUIR-BASED AUGMENTED REALITY SYSTEM

A progressive inquiry-based augmented reality context-awareness learning system is design to reduce the additional cognitive load form the complex context, helping students focus on their learning object. The system includes GPS, note, camera, AR display, forum, e-library. The GPS system sense the students' current location and provide them related learning materials. The note and camera allow students to record the observation during the learning activity, and share the note to others via AR display. By locating the students' current location, a map displays the learning objects in orders to prevent students get lost. Finally, AR display shows the learning materials, notes from the others, students can browse the notes and give comments.

Figure 1 shows the designs of the progressive inquiry based learning [12][21][28], the first layer "Factual problems" classified the basic geography knowledge related to the learning environment then uses multiple choice and blank-fill to help students clarify the knowledge and immerse them in learning context. The second layer "Scientific problems", the start of the inquiry guide, provides simple architecture aiding students to collect data by camera and take notes then share to the others and allows to give comments, reply the comments, the system will update the topic uploaded by students immediately. The third layer "Opening issues" ask students to answer the issue related to the learning environment, students required clear knowledge about the learning context to answer, there is no absolutely correct answer, the answers is based on the personal feelings and how much they know about the learning objects.

The System architecture is shown in Figure 2. The system involves camera function, notes function, forum function, personal inquiry process function, e-library. Students can record any observation and take notes through the camera and notes functions, then the data will upload to the database that every student can browse and make comments. The personal inquiry process function allows students monitor their own inquiry process during the activity. The e-library provides material related to the learning activity to let students review the knowledge when they got questions.

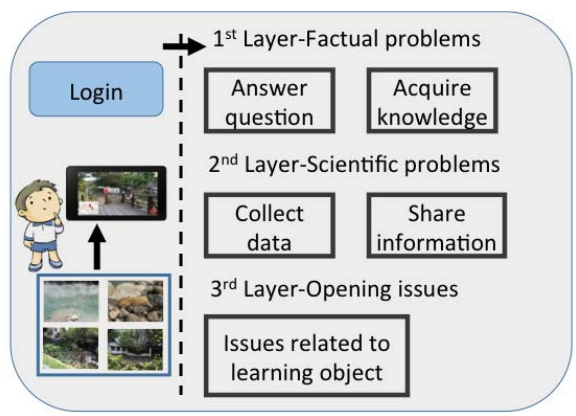

Figure 1. The progressive inquiry learning design

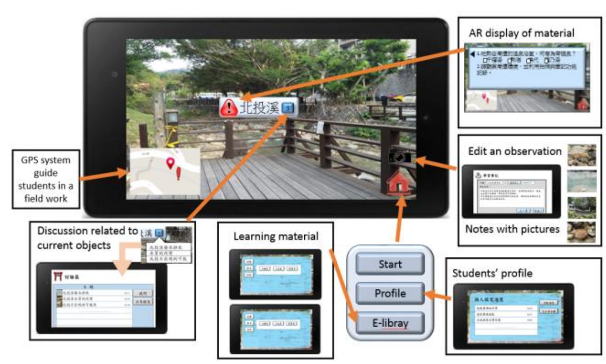

Figure 2. Three progressive layers of inquiry-based learning activity

III. EXPERIMENT DESIGN

A. Participants

The participants in the study are sixty high school first grade students from two classes teach by the same teacher. One class of students (30 students) assign to the experimental group and the other one assign to the control group (30 students). Experimental group will have two hours field trip in the Thermal Valley in Taipei City, Taiwan with the proposed system. Furthermore, the students in the control group will experience the learning activity with the conventional AR contextual u-learning approach.

B. Experimental process

Figure 3 shows the experiment design of this study. The experimental group will conduct a field learning activity with progressive inquiry-based learning augmented reality system while those in the control group will use the conventional AR contextual u-learning approach to engaging students in outdoor learning activity.

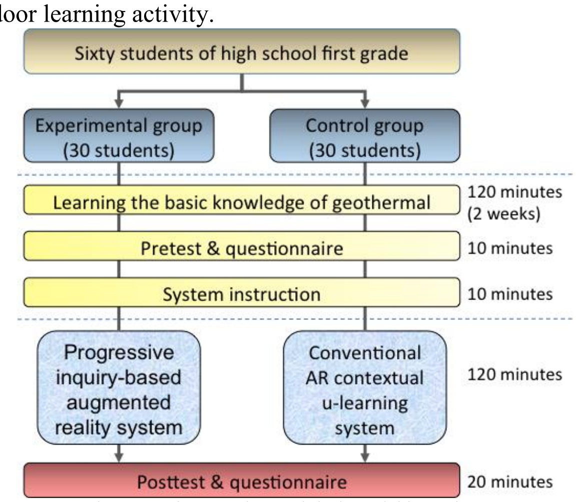

Figure 3. The experimental design of this study

C. Measuring tools

The pretest aims to assess the students' basic knowledge of geography of two groups before the learning activity. The posttest aims to evaluate the students' learning performance after the learning activity. Both the pretest and posttest are designed by two geography teacher who had more than ten years teaching experiences.

The questionnaire of complex problem solving ability proposed by Kyndt et al. [16] was adapted to measure students' complex problem solving ability after the learning activity, it contained eight questions with a 6-Likert scale.

The learning motivation questionnaire was modified from the questionnaire developed by Wang and Chen [29], It consisted of seven items using a six-point Likert scale and contained two sections, intrinsic motivation and extrinsic motivation, aim to explore the influences after the learning activity.

The cognitive load assessment was developed by Hwang et al. [13] based on the cognitive load measures proposed by Paas, Renkle, and Sweller [20] and Sweller, van Merrienboer, and Paas [27]. It consists of eight items based on a seven-point Likert rating scheme and divided into mental load and mental effort. Mental load aims to reveal the proper of learning objects or material; on the other hand, mental effort aims to address students' loading due to system design. The total Cronbach's alpha value of the questionnaire was 0.96.

IV. EXPECTED RESULT

In this study, a progressive inquiry-based approach with augmented reality technology is proposed for improving students' high-level thinking and problem solving abilities by asking students to answer different layer of questions in in-field inquiry learning activities. The expected results is that the proposed system will support the students to answer the questions in the different difficulty of questions in in-field observing activities. Moreover, it is expected that the guiding of progressive inquiry-based learning strategy combined with AR will help students focus on the learning objects, helping them observing, and immersing students in the learning environment. At least, the progressive design to learn the knowledge from the learning environment, facilitating students developing the complex problem solving ability.

ACKNOWLEDGMENT

This study is supported in part by the Ministry of Science and Technology under contract number MOST 103-2511-S-031 -001 -MY2 and MOST 104-2511-S-031 -003 -MY4.

REFERENCES

[1] Azuma, R. T. (1997). A survey of augmented reality. Presence: Teleoperators and virtual environments, 6(4), 355-385.

[2] Biddulph, F., Symington, D., & Osborne, R. (1986). The place of children's questions in primary science education. Research in Science & Technological Education, 4(1), 77-88.

[3] Billinghurst, M. (2003, July). No more WIMPS: Designing interfaces for the real world. In Symposium on Computer Human Interaction (SigCHI NZ).

[4] Bodzin, A. M. (2008). Integrating instructional technologies in a local watershed investigation with urban elementary learners. The Journal of Environmental Education, 39(2), 47-58.

[5] Chang, K. E., Chang, C. T., Hou, H. T., Sung, Y. T., Chao, H. L., & Lee, C. M. (2014). Development and behavioral pattern analysis of a mobile guide system with augmented reality for painting appreciation instruction in an art museum. Computers & Education, 71, 185-197.

[6] Chiang, T. H., Yang, S. J., & Hwang, G. J. (2014). Students' online interactive patterns in augmented reality-based inquiry activities. Computers & Education,78, 97-108

[7] Chin, C. (2002). Student-generated questions: Encouraging inquisitive minds in learning science.

[8] Chu, H. C., Hwang, G. J., Tsai, C. C., & Tseng, J. C. (2010). A two-tier test approach to developing location-aware mobile learning systems for natural science courses. Computers & Education, 55(4), 1618-1627.

[9] Edelson, D. C., Gordin, D. N., & Pea, R. D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. Journal of the learning sciences, 8(3-4), 391-450.

[10] Getzels, J. W. (1979). Problem finding: A theoretical note. Cognitive science,3(2), 167-171.

[11] Hung, P. H., Hwang, G. J., Lin, Y. F., Wu, T. H., & Su, I. H. (2013). Seamless Connection between Learning and Assessment-Applying Progressive Learning Tasks in Mobile Ecology Inquiry. Educational Technology & Society, 16(1), 194-205.

[12] Hwang, G. J., Tsai, P. S., Tsai, C. C., & Tseng, J. C. (2008). A novel approach for assisting teachers in analyzing student web-searching behaviors. Computers & Education, 51(2), 926-938.

[13] Hwang, G. J., Yang, L. H., & Wang, S. Y. (2013), A concept map-embedded educational computer game for improving students' learning performance in natural science courses, *Computers & Education, 69*,121-130.

[14] Kamarainen, A. M., Metcalf, S., Grotzer, T., Browne, A., Mazzuca, D., Tutwiler, M. S., & Dede, C. (2013). EcoMOBILE: Integrating augmented reality and probeware with environmental education field trips. Computers & Education, 68, 545-556.

[15] Klopfer, E., & Squire, K. (2008). Environmental detectives: the development of an augmented reality platform for environmental simulations. Educational Technology Research and Development, 56(2), 203–228.

[16] Kyndt, E., Janssens, I., Coertjens, L., Gijbels, D., Donche, V., & Van Petegem, P. (2014). Vocational Education Students' Generic Working Life Competencies: Developing a Self-Assessment Instrument. *Vocations and Learning, 7*(3), 365-392.

[17] Li, Q., Moorman, L., & Dyjur, P. (2010). Inquiry-based learning and e-mentoring via videoconference: a study of mathematics and science learning of Canadian rural students. Educational Technology Research and Development, 58(6), 729-753.

[18] Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. Journal of research in science teaching, 47(4), 474-496.

[19] Ogata, H., & Yano, Y. (2008). Supporting a decision making for task assignments in language learning outside classroom with handhelds. In Proc. The 16th International Conference on Computers in Education (pp. 713-720).

[20] Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational psychologist, 38*(1), 1-4.

[21] Pi-Hsia, H. U. N. G., Hwang, G. J., I-Hsiang, S. U., & I-Hua, L. I. N. (2012). A concept-map integrated dynamic assessment system for improving ecology observation competences in mobile learning activities. TOJET: The Turkish Online Journal of Educational Technology, 11(1)

[22] Price, B. (2001). Enquiry-based learning: an introductory guide. Nursing Standard, 15(52), 45-52.

[23] Prince, M. (2004). Does active learning work? A review of the research. Journal of engineering education, 93(3), 223-231.

[24] Runco, M. A., & Chand, I. (1994). Problem finding, evaluative thinking, and creativity. In M. A. Runco (Ed.), Problem finding, problem solving, and creativity (40-76). Norwood, NJ: Ablex Publishing Company.

[25] Salovaara, H. (2005). An exploration of students' strategy use in inquiry-based computer-supported collaborative learning. Journal of Computer Assisted Learning, 21(1), 39-52.

[26] Schilit, B. N., & Theimer, M. M. (1994). Disseminating active map information to mobile hosts. Network, IEEE, 8(5), 22-32.

[27] Sweller, J., Van Merrienboer, J. J., & Paas, F. G. (1998). Cognitive architecture and instructional design. *Educational psychology review, 10*(3), 251-296.

[28] Tsai, M. J., & Tsai, C. C. (2003). Information searching strategies in web-based science learning: The role of Internet self-efficacy. Innovations in Education and Teaching International, 40(1), 43-50.

[29] Wang, L. C., & Chen, M. P. (2010). The effects of game strategy and preference ‐ matching on flow experience and programming performance in game ‐ based learning. *Innovations in Education and Teaching International,47*(1), 39-52.

[30] Wojciechowski, R., & Cellary, W. (2013). Evaluation of learners' attitude toward learning in ARIES augmented reality environments. Computers & Education, 68, 570-585.

[31] Zucker, A. A., Tinker, R., Staudt, C., Mansfield, A., & Metcalf, S. (2008). Learning science in grades 3–8 using probeware and computers: findings from the TEEMSS II project. Journal of Science Education and Technology, 17(1), 42-48.