Development of a Mobile Augmented Reality System to Facilitate Real-World Learning

Kai-Yi Chin, Ko-Fong Lee and Hsiang-Chin Hsieh

Abstract A number of research studies have explored the impact of applying Augmented Reality (AR) technology to real-world learning environments. These studies have asserted that AR can improve students' perceptions and enhance overall cognitive abilities when engaged in real-world learning activities. However, it is not easy for teachers to implement AR-based learning systems in classrooms because many teachers lack the skills and abilities of computer professionals or coding experts. In this study, we created an easy to use mobile augmented reality system that can support teachers in creating and designing AR materials. This mobile system provides teachers with the ability to combine course content and multimedia materials in a way that promotes learning within an engaging and intuitive AR-based environment. A quasi-experimental research design was used to evaluate the feasibility of using our proposed system to implement a variety of teaching activities. From the results of the questionnaire survey, we discovered that respondents rated the proposed system positively and were willing to formally incorporate mobile augmented reality into their future teaching plans. Therefore, we believe that teachers do regard our mobile augmented reality system as a useful tool that can supplement existing real-world learning activities with distinctive AR capabilities.

Keywords Augmented reality · Mobile learning · Mobile AR system

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1 Introduction

In recent years, Augmented Reality (AR) technology has become more widely used in a number of different applications. This technology allows users to combine observable, real-world phenomena with animated graphics, textual information or inserted images, and creates an enhanced and augmented reality that can assist in amassing knowledge [1–3]. The exciting new possibilities of teaching traditional classroom concepts using AR are welcomed by educational researchers since the opportunities associated with enhanced learning is greatly fostered through technical advancements. As such, it has been demonstrated that AR enhances students' senses through the use of virtual or naturally invisible information superimposed on top of real-world objects or spaces [2, 4]. Therefore, it is accepted that AR can transfer educational experiences and knowledge from the classroom to applications in real-world learning environments. Such documented benefits to the field of education will promote AR as the key emerging technology preferred by educators for supplementing course content over the next decade [1].

Several studies have emphasized that AR can improve students' perceptions, knowledge, and interaction with the real-world, and it is known that AR has been used to enhance students' cognitive abilities during real-world learning activities and tasks [5, 6]. For example, Angela Di Serio and her colleagues proposed the implementation of an AR system to motivate middle-school students tasked with learning key facts about Italian Renaissance Art. In their study, AR was used to enhance each artistic masterpiece with added textual facts explaining specific details unique to the work of art, while simultaneously superimposing digital data (such as text, audio, 3D models, etc.) directly on top of the masterpiece [2]. The researchers also proved that the use of AR technology can promote higher levels of engagement in students utilizing enhanced learning tools, and thus it was found that educational activities with AR could confer a positive effect on students' learning outcomes. In another study, Chih-Ming Chen and his colleagues proposed an AR library instruction system that trained students to learn how to use libraries. This system integrated interactive 3D virtual technology with the physical library environment to generate a novel context-aware library instruction module. This learning module could enhance students' perception of reality, improve the effectiveness of new knowledge acquisition specific to their library and made the process of learning much more alluring for students using the interactive AR system [7].

However, like many educational and technological innovations introduced within the past century the incorporation of AR systems into classrooms may encounter resistance among teachers [1]. The opposition to widespread adoption of AR systems into classrooms stems from two main issues that educators face. First, most AR systems on the market today offer limited and non-customizable learning activities that come pre-programmed with integrated learning content. Thus, teachers usually do not have the opportunity to incorporate appropriate learning materials specific to their students into existing AR systems. Second, the development of educational programs is an arduous task that demands much effort, input

and skill from computer experts [8, 9]. It is commonly known that many teachers do not have sufficient programming knowledge and they lack the capability to create AR systems by themselves. If teachers want to be able to independently customize an AR system, specialized training and continuing education courses must be provided by computer professionals. For the above reasons, it is likely that AR systems cannot be strongly promoted or applied to a variety of educational endeavors.

To overcome the aforementioned limitations, we developed a mobile augmented reality system that was designed as an instructional adjunct to aid teachers in the creation of AR enhanced educational activities. This system not only provided a convenient authoring tool to support teachers in managing and designing multimedia materials from scratch, but also combined educational materials with AR technology to create an engaging AR-based learning environment. In other words, our mobile augmented reality system allows teachers to create AR-based multimedia learning systems without any previous experience with computers and prior coding knowledge is not required. Teachers can easily provide an interactive AR-based learning environment that fosters students' interest and engagement in real-world learning activities.

In addition, this study also included a trial experimental survey that collected insights from teachers' remarks on the overall usefulness of our proposed system. The questionnaire survey was used to assess the feasibility of implementing teaching tasks using mobile augmented reality systems. The results of the questionnaire demonstrated that teachers rated the system positively and were willing to accept and adopt our AR system into their classrooms. Teachers also agreed that our system was a useful tool that could enhance the quality of outdoor educational activities. All in all, these findings reveal that our proposed mobile augmented reality system could in fact give teachers the chance to add pedagogical value to their courses, and further help learners engage in authentic exploration of resources found in real-world environments.

2 Related Work

The term AR is regarded as a novel interactive technology that can add virtual information to users' physical contexts, and enhance sensory perceptions of the real-world with the addition of a computer-assisted contextual layer of information [2, 6]. According to the above mentioned studies, AR can be broadly defined as "a situation in which a real world context is dynamically overlaid with coherent location or context sensitive virtual information". From this definition, AR can assist users through technology-mediated immersive experiences in which real and virtual worlds are blended, and further augment the interactions and overall engagement of the user [10]. Additionally, AR could be initiated and implemented through a number of available technologies, including desktop computers, mobile devices, head-mounted displays, wearable computers and so on [1, 11]. This

technological compatibility across multiple platforms means that AR can be used in many domains and applications, such as medical visualization [12], maintenance and repair [13], robot path planning [14], and entertainment [15].

Nowadays, research teams are enthusiastic about applying AR technologies to different teaching and learning activities [2]. For example, Tsung-Yu Liu and his colleagues proposed an AR-supported mobile system that supplied interesting learning activities to increase students' motivation in learning English [11]. Researchers You and Neumann developed a mobile AR system that provided an efficient interactive online virtual assistant to enhance students' performance in their museum guide course [16]. Additionally, Utku Kose and colleagues proposed a mobile AR tool that led to improved learning experiences for students enrolled in abstract or technical courses [5]. Of note, Jose Manuel Andujar and his colleagues proposed the creation of augmented remote scientific laboratories that would allow students open access to the lab to practice development boards via an Internet connection [17]. The study by Andujar went on to prove that the interactive online laboratory platform could actually improve students' learning outcomes in the fields of science and engineering.

The above-mentioned studies all clearly indicate that AR in the educational context can be very valuable. However, we noticed that despite the demonstrated benefits of using AR within the classroom, few research studies examined the benefits of providing tools for teachers to actually create AR enhanced systems on their own. Thus, in contrast to the studies highlighted in this paper, our study specifically focused on supporting teachers in building and maintaining the AR-based learning environment. We anticipated that the proposed mobile augmented reality system could support teachers in creating and updating instructional materials, while also enabling them to combine relevant teaching content with AR technology to provide enhanced lessons to students.

3 System Overview

This study describes a proposed mobile augmented reality system that serves to improve the process of creating AR materials, enhance students' motivation during real-world learning activities, and develop authentic AR-based learning environments. As portability and mobility are necessary factors for using AR in real-world learning experiences, our proposed system requires the use of touchscreen mobile devices. Moreover, our mobile augmented reality system possesses cross-platform capabilities, so it has many exciting applications for enterprise, tourism and entertainment purposes.

As shown in Fig. 1, the mobile augmented reality system is composed of two major sub-systems: an AR-based mobile learning system and an AR materials remote server. The AR-based mobile learning system allows students to access AR materials via their mobile device, and has the ability to overlay virtual content on top of the QR code. The AR materials remote server enables teachers to combine

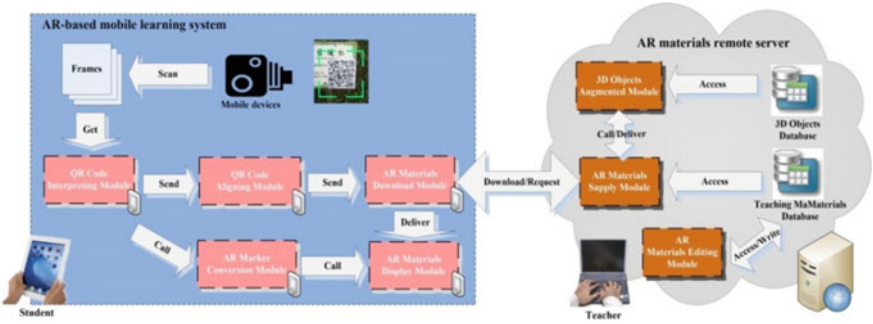

Fig. 1 The architecture of the mobile augmented reality system

course content and multimedia materials in a way that yields a complete AR learning package. Our design allows the two sub-systems to work together and enables teachers to create AR-based learning environments through a simple user interface. Together, the sub-systems make it possible to provide personalized learning opportunities for students and offers a more interesting learning experience. A detailed explanation of both sub-systems is presented in sections A and B of this paper.

3.1 The AR Materials Remote Server

As shown in Fig. 1, the AR materials remote server has three main modules (the AR Materials Supply Module, the 3D Objects Augmented Module and the AR Materials Editing Module) along with two databases (the Teaching Materials Database and the 3D Objects Database). When the AR Materials Supply Module receives a request to provide AR materials, the module will first access the related teaching content and resources from within the Teaching Materials Database and then follow up with a call to the 3D Objects Augmented Module. The 3D Objects Augmented Module is able to locate existing 3D virtual objects from the 3D Objects Database and subsequently instruct the delivery of virtual objects to the AR Materials Supply Module. Then, the AR Materials Supply Module can integrate all of the instructional materials into one AR enhanced material, which is defined as a lesson. The AR Materials Editing Module is equipped to provide a webpage-style visual editor from which teachers can create and maintain existing AR materials using just a personal computer and Internet connection.

Figure 2 shows screenshots of the visual editor that is an integral part of our proposed mobile AR system. Teachers must first select course content and multimedia materials using the visual editor upload page (see Fig. 2a). Then, teachers can choose one of many pre-programmed 3D virtual objects from the 3D Objects Database (see Fig. 2b) and select the corresponding QR code from the visual editor

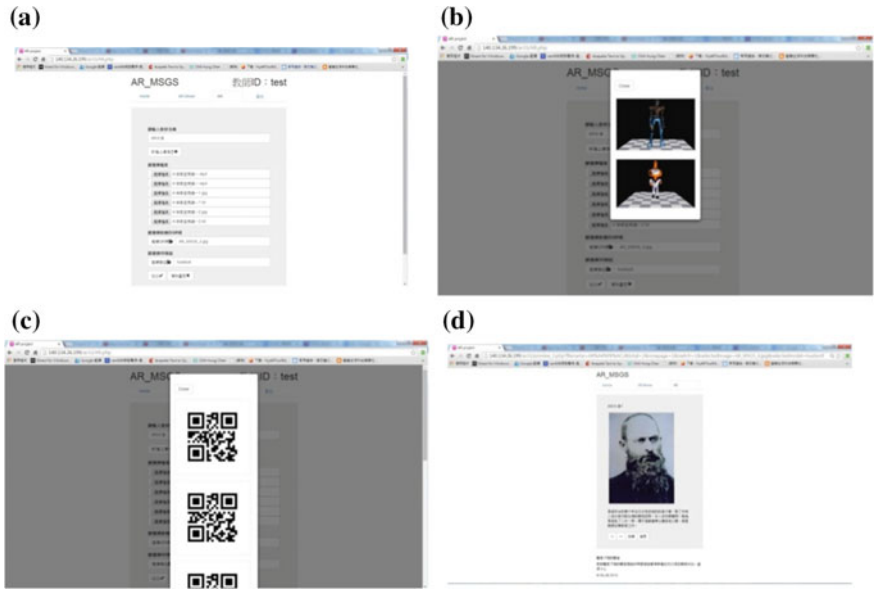

Fig. 2 Screenshots of the webpage-style visual editor

panel (see Fig. 2c). After the completion of the course, this visual editor also provides teachers with the option of reviewing the completed instructional content that was presented to the students (see Fig. 2d). Finally, the easy to use, and familiar webpage-style layout of the visual editor can help teachers more effectively integrate teaching content and resources into an interactive AR platform.

3.2 The AR-Based Mobile Learning System

Figure 1. shows how the five modules of the AR-based mobile learning system interact with each other to perform necessary tasks. Our proposed system consists of the following modules: the QR Code Interpreting Module, the QR Code Aligning Module, the AR Materials Download Module, the AR Marker Conversion Module and the AR Materials Display Module. When students scan the QR Code through a camera-equipped mobile device, the QR-based mobile learning system will automatically identify frames and get the embedded information contained within the QR code. Then, the QR Code Interpreting Module functions to interpret the QR code information and convert the coded information into text that will be passed to the QR Code Aligning Module. The QR Code Aligning Module is used to align QR code information, and then send a message to the AR Materials Download Module to correctly download the corresponding AR materials and 3D virtual objects., The AR Marker Conversion Module works in parallel to the QR Code

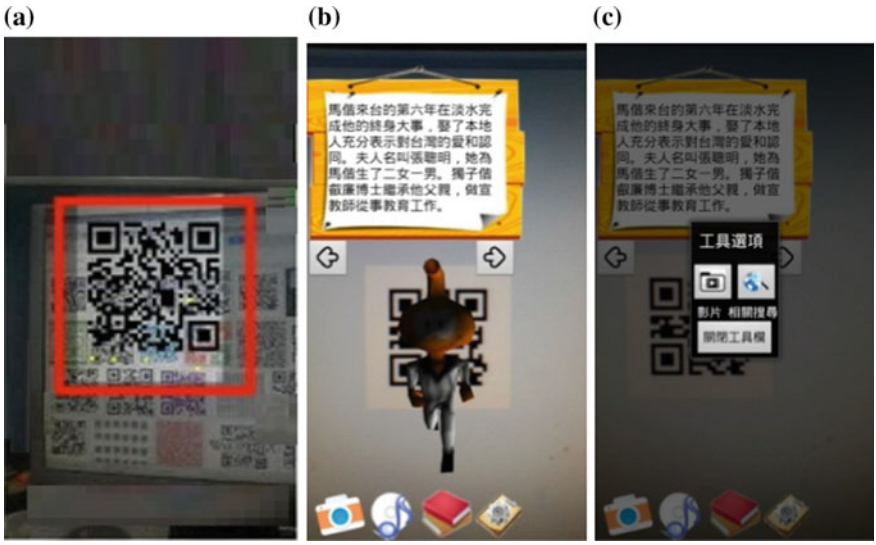

Fig. 3 Screen captures of the AR-based mobile learning system

Aligning Module to translate the information from the QR Code into registered images that can be identified and then played as 3D virtual objects on the mobile device. If the AR Materials Display Module receives AR materials from the AR Materials Download Module, relevant teaching information will become visible to students as 3D virtual objects that are superimposed on top of the real-world object that has contains the QR code.

Figure 3 shows screen captures of the AR-based mobile learning system as it is seen on a mobile device. When students scan a QR code using a mobile device, the AR-based mobile learning system will download corresponding AR materials from the AR materials remote server (see Fig. 3a). Once the information from the QR code is processed, the AR-based mobile learning system will combine course content with 3D virtual objects to present relevant course information (see Fig. 3b). If students want to learn about other related multimedia resources available for further exploration, they can open the related audio/video files through the use of pop-up buttons on the screen (see Fig. 3d).

4 Experimental Results

We invited five teachers to volunteer as formal evaluators of this study and the teachers were employed by Aletheia University in Taiwan for a number of years. Among the teacher participants, two out of five were male and the remaining teachers were female. Each teacher has prior experience with using computers and

Table 1 The attitudinal survey of teachers to the mobile augmented reality system

Question	Mean	SD
1. I believe that the mobile augmented reality system is a useful tool that supports my teaching	4.48	0.70
2. I believe that the mobile augmented reality system can better facilitate my course instruction	4.82	0.44
3. The webpage-style visual editor is an easy to operate method of creating AR materials	3.61	0.70
4. I think that the mobile augmented reality system is an easy-to-use tool	3.88	0.46
5. I feel more motivated to teach while using the mobile augmented reality system to create an AR-based learning environment	4.45	0.73
6. I wish to use the mobile augmented reality system within my formal courses	3.85	0.45
The overall average score	4.18	0.58

all possesses the basic skills for designing multimedia materials. At the beginning of the study, all teachers were requested to participate in a tutorial, which introduced our mobile augmented reality system to the participants in greater detail. When this training process was complete, all participating teachers were asked to create a simple AR enhanced course material that was presented using the AR-based mobile learning system. After completing the authoring work, the opinions and insights from participating teachers were collected using a questionnaire survey. The results of the questionnaire were measured using a 5-point Likert-scale, from which the answers provided were ranked from 1 (strongly disagree) to 5 (strongly agree).

Table 1 shows that the general mean value of consensus was 4.18 (SD = 0.58), indicating that the majority of the participating teachers were "satisfied" when using the mobile augmented reality system for course related endeavors. All mean values of the answers collected were higher than or equal to 3.50, which meant that the teachers held affirmative perceptions of our system. In fact, existing studies found that AR technology can render a learning system that is more entertaining or engaging for both teacher and student [1]. Therefore, we believe that the proposed system can be accepted as a useful tool for teachers interested in executing AR enhanced real-world learning activities.

5 Conclusions and Future Work

This study strives to support teachers in combining relevant instructional content with AR capabilities, by providing an easy to use mobile AR system that assists teachers in creating an engaging learning environment. Our development of a mobile augmented reality system to supplement real-world learning activities is unique when applied to the field of education. This advanced system provides

teachers with an AR materials remote server for writing course content and creating AR materials and the AR-based mobile learning system effectively presents customized course information to students. Moreover, a questionnaire survey was employed to measure the perceived usefulness of the proposed system from each of the participating teachers. The results of the survey showed that teachers were satisfied with the mobile augmented reality system, willing to continue using the system and strongly interested in integrating this system into their other formal courses.

In the future, we plan to use similar quantitative and qualitative methods to evaluate the effectiveness of our proposed mobile augmented reality system. All data from the statistical analyses must be collected to properly investigate the usability of the system in relation to current educational programs. The results obtained will be used to further demonstrate the effectiveness of using AR materials to enhance traditional classroom materials, and we hope to gain valuable insights from the student's perspective.

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