Making Without Makerspace, Another Study of Authentic Learning with Augmented Reality Technology

Chung-Ming Own

Abstract A "makerspace" is an area in a library where users can use tools and equipment to design, build and create all sorts of different things. It may be a dedicated room or a multipurpose space in which a collection of raw materials and resources can be utilized as desired. However, the makerspace is not always in everyplace and for everyone to use. In this study, we explore a new way to integrate advanced display technology into educational activities for students with different disabilities. An interactive augmented reality application was developed to facilitate the learning of robot building. The result shows that AR system could help the school students to finish their robot building independent of teacher's assistant. With the use of AR display technology, the participants demonstrated improve ability to complete construction tasks when compared to the use of traditional paper-based methods. Performance data indicated that the use of AR technology could enhance learning motivation and frustration tolerance in students and the authentic learning principle is further identified.

Keywords Authentic learning · Makerspace · Augmented reality

1 Introduction

Recently, the learning theory provides the ideas and thought to implement the student-centered, realistic and effective learning environments. However, it is not sufficient to supply suitable examples from real-world situations to illustrate the concept being thought in our daily life. It needs to create a physical environment with the knowledge we can use, and supplies the resources to exam from distinct perspectives (Honebein 1993). That is what we called the makerspaces.

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1.1 Constructionism and Representation

Makerspaces are comprised of participants with different ages and levels of experience; these spaces all are based on the making and developing ideas and constructing them into the reality. The centrality of developing an idea and creating an external representation of that idea is the core doctrine of constructionism (Harel and Papert 1990; Kafai 1995). Constructionism builds on the perspective of the psychological sciences, which holds knowledge as the activities constructed by learners via their experiences treats learning as the revision of mental representations. This thought extends the theory of constructivism to focus on the making of external artifacts, which can support them on the conceptual understanding. From the constructionist point, the functions of artifact are combined with the learner's thinking; hence, the learner could interpret the artifact as their representing object and this process is referred as the improving knowledge.

1.2 Learning Environments for Making

To understand makerspaces as learning environments, we draw from the literature on both formal education environments for making and informal communities of practice the diverse learning and teaching arrangements present in these spaces. Many makerspaces resemble studio arts learning environments, where participants work independently or collaboratively with materials to make (Halverson and Sheridan 2014b). Based on analysis of intensive visual arts classes, Hetland et al. (2013) identified four key "studio structures" as central to the design of studio learning environments: (1) in demonstration lectures, teachers pose open-ended challenges, show exemplars and demonstrate processes to engage and inform students, (2) in students-at-work, students work on their art and teachers circle the room observing and giving "just-in-time" instruction, (3) in critiques, the working process is paused as the group collectively reacts on student work and (4) in exhibitions, students' work is shared with a community beyond the studio classroom. Figure 1 is the makerspace in the Tianjin International School, Tianjin, China.

2 Making Without Makerspace

However, do we really need the well-functioned makerspace? Can you remember the first time you see a 3D printer in your working laboratory? It is unlike the slim LED TV or a washing machine, the magic idea can be made in my own place. That's why our first thought was: we need to buy one of those as possible as we

Fig. 1 The makerspace in Tianjin International School

can. However, we had a second thought about it, do we really need it or do we know how to operate this machine?

Instead of buying a fairly expensive machine in the makerspace, we got hold of someone who actually knew about the newly machine. The local makerspace had lots of experts, and they were happy to share their knowledge. Hence, we can conclude the three main practices we defined from the makerspace: they are sharing, creating and participating. Generally, in the makerspace, we all focus on the sharing, but perhaps we are lacking the last two. Besides, the budget of maintaining makerspace is limited, makers have not so many chances to practice their idea for real, and let alone the remote places have no money to maintain the makerspace.

2.1 New Technology of Augmented Reality

Based on the real-world and abstract objects, usage 3D data set to describe an environment is the virtual environment; the term VE can refer to a technology of Virtual Reality (VR), which uses the computer graphics systems in combination with various display devices to provide the effect of immersion in the vivid 3D computer-generated environment. Besides, technology of augmented reality (AR) creates the sensation of virtual objects which present in the real world. Combining the technologies of AR and VR is the mixed reality (MR), which not only provides rich learning patterns and teaching contents, but also helps to improve learner's ability to analyze problems and exploring new concepts; Fig. 2 shows all of these productions. Users can explore and experience in the virtual environment is unlimited; MR technology in education also can be viewed as the next generation of blended learning sued as the realistic and authentic environment. MR can be referred as the system which combined real and virtual, interaction in real time and surrounding environment. Brett explained that AR interface combines aspects of virtual reality and the real-world environment by providing a person a chance to view one or more virtual 3D objects in real space (Brett 2003). Milgram defined the virtually continuum spans from the real environment to a pure virtual environment (Milgram and Kishino 1994).

Recently, some governments have implemented initiatives with the aim at improving the quality and effectiveness of the teaching and learning process. For example, Malaysia has their poor teaching problems; they follow the chalk and talk teaching method and use the static textbooks but fail to engage students. In 2007, Teoh and Neo reported that it was boring to just hear the lecturer talking in front of them (Teoh and Neo 2007). The researchers conclude that the integration of technologies could help them in the improvement of learning process. One of the students suggested that an expert should be present in the classroom to provide them with the relevant context for the subject and make the classroom activities more interesting (Bevins et al. 2005). Students prefer to learn in interactive ways than the traditional teaching methods; besides, they commonly find science subjects requiring a depth of understanding and skills. When students have difficulties in understanding the concept well, it can interfere with the students' learning of scientific principles and concepts.

Fig. 2 **a** VR demonstration (Oulus), **b** AR production (MASVIS), **c** MR production (Microsoft)

Thus, to avoid and minimize the students' misconception, visualization technologies have exciting potential for facilitating understanding and preventing misconceptions in the scientific domain. Kozhevnikov and Thornton (2006) found that it is possible to improve students' visualization skills by presenting a variety of abstract visual images and allowing the students to manipulate and explore the images. There is a wide range of available technologies that can be used for the visualization of abstract concepts. Robertson et al. (2008) found that animation together with fascinating data and an engaging presenter helps the audience understand the results of an analysis of information. These visualization technologies can be used to address the problem of misconception and help students understand better.

In 2011, Martin et al. proposed that AR is a new technology that is likely to have an impact on education (Martin 2011). AR is distinct from VR, because AR combines the real world with computer graphics, while VR immerses the user in a computer-generated world. AR is a new way to improve the learning of the virtual information help. According to Cerqueira and Kirner (2012), there are several advantages of using AR techniques for educational purposes. For example, AR can minimize the misconceptions that happen with the inability of students such as chemical bonds. AR can allow detailed visualization and object animation. The other advantage is the macro- or micro-visualization of objects, because some of them are too difficult to be seen via the naked eye. With the AR help, students can understand the subject by displaying their information at different viewing angles.

Besides, many researches show that students are excited to learn with the AR technology. For example, Klopfer and Squire proposed that students gave positive feedback about their experience on the combining of virtual and real environment (Klopfer, 2008). Burton reports a similar result with the participants in the study of potential of AR technology of sharing information and learning on new concepts (Burton et al. 2011). In addition, AR makes students become more active in the learning process by the interactivity of the applications (Lamounier et al. 2010). It would encourage students to work creatively by improving their experiences and understanding. The advantages of AR indicate that there is significant potential to integrate virtual information and real environment in teaching and learning, especially for the subjects that require to visualize.

2.2 *The Limit of AR*

A number of limitations exist in the AR technology. For example, according to Hsu and Huang (2011), various participants in an AR learning exercise agreed that the AR tools are good but most participants did not consider the tools to be as effective as reading textbooks. They also argue that using AR tools was not easy to obtain learning information. Although AR tool is easy to operate, the procedure of sending the image, recognizing the text and understanding the meaning of the text is troublesome and time-consuming. Besides, the user may need to wait for the location decoding and information to be transmitted back from the server.

Another experience is reported by Folkestad and O'Shea (2011); they discussed when they tried to use AR technology outdoors and had to resort to asking their teacher for help, because of the using frustration. The results indicated that although the students encountered technical problems, they have to find assistance, persist with the task and engage effectively in the unique learning process. Despite all the difficulties, the involvement of AR technology was still popular in the outdoor (Folkestad and O'Shea 2011). Moreover, research should be conducted to investigate the latest technology called the mobile augmented reality (MAR) system which is a smartphone application that is integrated with the AR itself. This new form of AR technology offers a learning experience that is linked to the formal classroom so that students can learn outside of class hours and outside of school limits (Burton et al. 2011).

The limitations stated above mostly highlight the issues related to the technical aspects of using AR in the learning process. Such technical issues must be improved in the future in order for AR to be widely applied in education. Lamounier et al. (2010) also pointed out that there need to be improvements in Internet portability in order to facilitate user access to AR systems for learning. Increased Internet access will give students the opportunity to use AR via a smartphone. This has the potential to make AR a powerful learning tool that can help students to gain content knowledge and maintain that knowledge through their interactions with the smartphone activities.

3 The AR Application

Some of the significances of the AR applications are listed as follows:

- Draws people's attention: As a new technology, AR draws people's attention. Drawing students' attention is an important factor in teaching.
- Constructivist learning environment: AR technology can be utilized to create a constructivist environment to enhance learning. In 2006, Chen used AR as an alternative way to view the chemistry world and allowing students to engage with the system and discover knowledge on their own (Chen 2006). Sensorimotor feedback: AR can increase reliance on sensory information, allowing users to interact with the system by using their body, especially hands which provide "sensorimotor feedback." Users also can obtain a sense of spatial feeling.
- Authentic Learning: The question of authenticity hinges on the context in which the task can be perceived as authentic. The core idea of authentic learning is to provide real materials and real activities. MR ability to annotate real elements and the ability to add to reality by superimposing virtual aids will aid in instruction and learning for those disciplines where a specific spatial configuration of elements must be learned and remembered.
- Realistic models: AR provides a means of "seeing" phenomena in 3D, thereby bringing the contextual three-dimensional nature of the real world to their learning. Textual and pictorial information in the typical two-dimensional print-based resources loses much of the richness of the "real" world elements and involves an element of interpretation that is rather difficult for some students.

Thus, according to our previous discussion, some of the AR systems applied in the authentic learning are listed as follows.

3.1 Book of Augmented Reality

Nowadays, we have many presentation ways of the learning books. For example, an electronic book can be an electronic version of a traditional text; conversely, a traditional book can have the audio or multimedia CD ROM electronic features. Marshall et al. show that users love the physicality of the real book, because it offers a broad range of advantages, like flexibility, robustness (Marshall 2005). However, traditional textbooks or any form of printed publication suffer two disadvantages:

inability to directly portray three-dimensional object and the inability to convey time-evolving information in a dynamic way (Craig and McGrath 2007). Besides, the combination of physical books with new interaction offered by AR/MR media is the newly trendy. This kind of book is an interactive paper implementing some form of physical-to-digital link where physical artifact particularly paper documents becomes augmented with digital information. Figure 3 shows the example of Disney Research book.

3.2 App of Augmented Reality

Most people who interact with AR for the first time have a mind-blowing experience but fail to consider classroom applications. In our elementary school classrooms, we use AR to create active learning experiences, those are inconceivable to prepare the real environment, and in the process we redefine the learning space! Educators know that learning deepens, not just through reading and listening, but also through creating and interacting. With augmented reality system helping, students manipulate and combine elements during the learning, rather than just reading about them in a textbook.

For example of AR app, Aurasma allows users to engage in and create AR experiences of their own. Educators and students can use this open-source tool to essentially bring their learning to life. We have seen Aurasma used several different ways in the classroom; some cases are shown as follows:

- Homework Mini-Lessons: When students scan a page of their homework, the page reveals a video of their teacher helping them solve a problem.

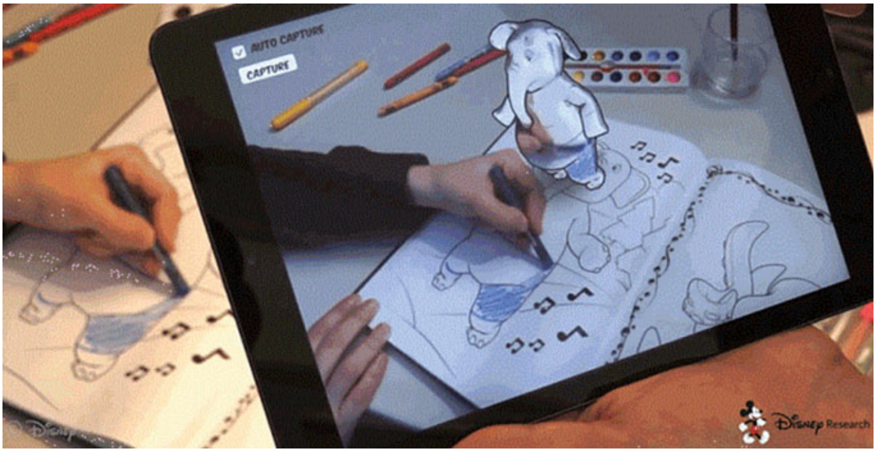

Fig. 3 The example of Disney Research book (Disney Research)

- Faculty Photo Wall: Set up a display of faculty photographs near the school entrance. Visitors can scan the image of any instructor and see that figure comes to life, telling more about him- or herself.
- Book Reviews: Students record themselves giving a brief review of a novel that they just finished and then attach that "aura" (assigned digital information) to a book. Afterward, anyone can scan the cover of the book and instantly access the review.
- Parent Involvement: Record parents giving brief words of encouragement to their child, and attach a trigger image to every child's desk. Anytime students need to hear encouraging words from their parent, they can scan the image on their desk for virtual inspiration.
- Yearbooks: From tributes to video profiles, from sports highlights to skits and concert footage, the ways that AR can enhance a school yearbook are limitless.
- Word Walls: Students can record themselves providing the definitions of different vocabulary words on a word wall. Afterward, anyone can use the Aurasma app to make a peer pop up on screen, telling them the definition and using the word in a sentence.
- Laboratory Safety: Put triggers (images that activate media when scanned by an AR-enabled device) all around a science laboratory so that when students scan them, they can quickly learn the different safety procedures and protocols for the laboratory equipment.
- Deaf and Hard of Hearing (DHH) Sign Language Flashcards: With AR, flashcards of vocabulary words can contain a video overlay that shows how to sign a word or phrase.

Besides, in an astronomy class, students learn about the structure of the universe, and the relationships among earth, moon and sun. Sometimes, it is hard to explain how the universe evolved; for the sake of students understanding, teachers may employ AR technology with 3D-rendered celestial body. For example, in Shelton's (2004) study, he described the virtual sun and earth are manipulated on a small mobile device that changes its orientation in coordination with the viewing perspective of the student. Besides, Johnson et al. designed the AR application to introduce the Google SkyMap; users can browse the sky with the see-through view from the camera on their smart phone (Fig 4).

3.3 Car Repair with Augmented Reality

AR—a digital layer superimposed on top of the real world—is being used for car applications today. Manufacturers are tapping the technology to help service technicians make repairs by putting on special goggles or pointing iPads. Even better, app makers are on the verge of releasing consumer apps that will help you repair your car in your own garage—perhaps allowing you to avoid an expensive trip to the mechanic.

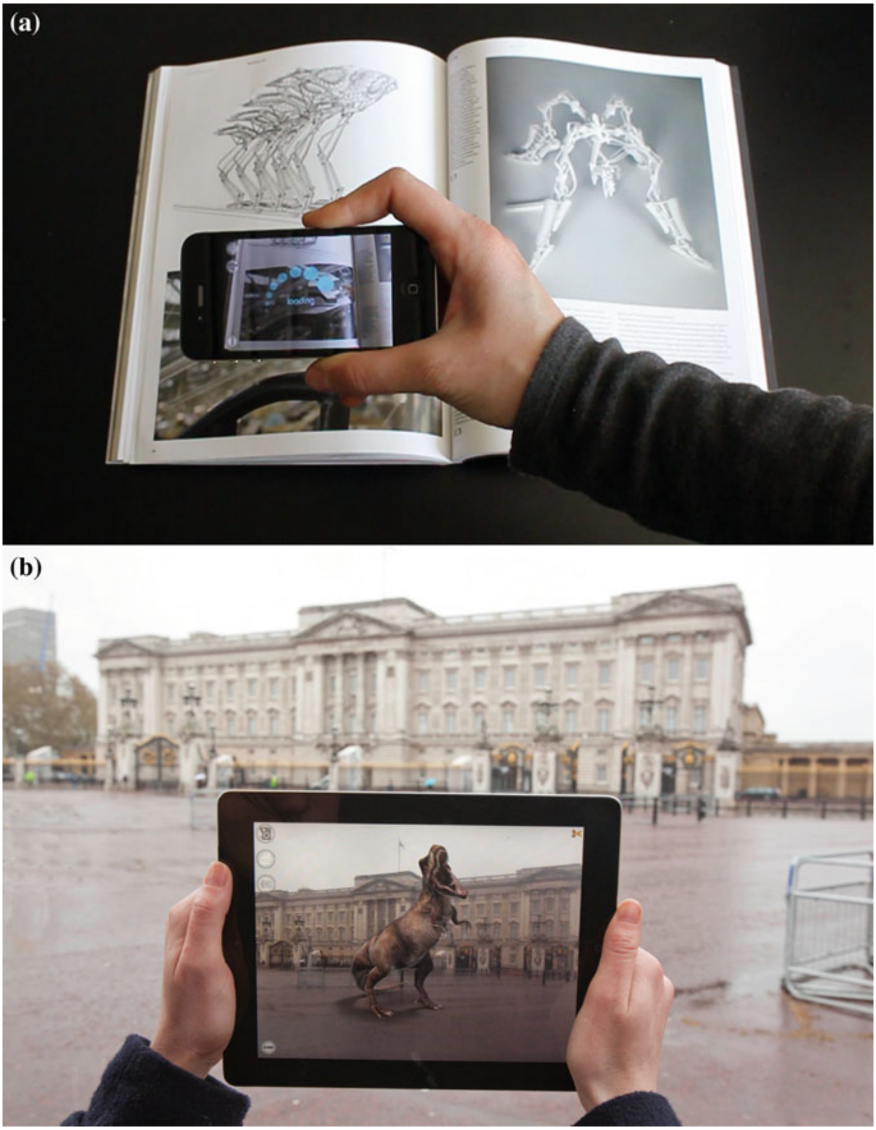

Fig. 4 The application of Aurasma, **a** the architecture representation, **b** T-Rex at Buckingham Palace

Volkswagen started dabbling with AR in its service training centers in 2010. Its research laboratory created a projector system that acted like a virtual X-ray, showing students components behind the car's exterior. It used video cameras to track students as they moved about the room, so the projector could adjust its image to display the correct perspective to the viewer—no special glasses were needed.

Fig. 5 ARmedia augmented reality 3D tracker

The AR must have proven an effective training tool because now Volkswagen is moving it out of training centers and into service centers. The German automaker has teamed up with Metaio GmbH to create Mobile Augmented Reality Technical Assistance (MARTA) for the iPad. Service professionals simply point the tablet's camera at a car engine and look at the screen to see virtual components, and step-by-step animations appear in relation to the real components to help them complete their task.

Mechanics only needed to calibrate the app by pointing the camera at the right angle to the car—indicated by a silhouette on screen—and could then begin a repair job. In addition to animations showing what must be done, the app even instructs what tool must be used. Figure 5 is the demonstration of the car repairing AR.

4 Conclusion

In this study, the AR approach is proposed for conducting authentic-based learning activities. The learning systems were developed based on advanced interaction with bared eyes. The usages result shows that the AR approach is able to improve people's learning performance in learning activities owing to the use of AR technology in linking the real-world contexts with the digital learning resources at the right place and the right time. Such learning scenarios that present relevant materials (e.g., images, texts, videos) in a well-integrated and organized form can avoid creating incidental cognitive mistakes and improve students' learning performance. On the other hand, in a traditional instructional approach or makerspace's rules, the targets and the corresponding materials are presented separately and asynchronously. When observing the real-world targets, the attenders need to read the corresponding materials from the printed sheet and put lots of efforts on organizing the information by themselves, which prevent them from viewing the learning targets and thinking in a higher-order manner.

Although the AR-based learning system benefited the students in this application, there are some limitations to be noted. First, positioning and recognition accuracy of the AR devices limits the display of the location of the learning objects; therefore, when designing a learning task, the teachers need to consider the size of the learning objects and the distance between them. These ideas can assist the system to locate the object area. Besides, to provide instant hints or learning guidance to individual students, the teachers need to develop learning processes for evaluation purposes and digital learning material to provide learning supports.

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