Original article

doi: 10.1111/jcal.12199

Journal of Computer Assisted Learning

Using augmented reality to support a software editing course for college students

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Abstract This study aimed to explore whether integrating augmented reality (AR) techniques could support a software editing course and to examine the different learning effects for students using online-based and AR-based blended learning strategies. The researcher adopted a comparative research approach with a total of 103 college students participating in the study. The experimental group (E.G.) learned with the AR-based contents, while the control group (C.G.) learned with the online-based support. The findings demonstrated the potential of AR techniques for supporting students' learning motivation and peer learning interaction, and the AR-based contents could be used as scaffolding to better support blended learning strategies. The AR-based learning interaction could also be a trigger arousing learners' interest in becoming active learners and the students presented great learning involvement after the AR-based supports were removed, while the learners in the C.G. were passive once the supports had been removed. Moreover, it was found that (1) their lack of experience with AR interaction and applications, (2) the slow speed of the Internet in the school, (3) the affordances of each learner's mobile learning devices, (4) the screen size of the learning interface and (5) the overloading of the learning information from the AR contents and teacher lectures might be the reasons why the learners were still more used to the online-based support. It was therefore concluded that when integrating AR applications into a course, technology educational researchers should take into careful consideration the target learning content design, the amount of information displayed on the mobile screen and the affordances of the learning equipment and classroom environment so as to achieve a suitable learning scenario.

Keywords augmented reality, college education, evaluation, learning technology.

Introduction

Digital native learners prefer and are used to learning with e-things (Prensky, 2001), while how to maintain their engagement and motivation is an issue that still needs to be explored (Ivanova, Aliev, & Ivanov, 2014). With the rapid development of state-of-the-art technology, the applications of augmented reality (AR) may be one way to engage and sustain learners' attention to and motivation regarding learning contents (Ivanova, Aliev, & Ivanov, 2014). Specht et al. (2011) defined AR as a system that enhances a person's primary senses (vision, aural and tactile) with virtual or naturally invisible information made visible by digital means. The AR techniques merge elements of a real-world environment with virtual-generated imagery and present interactive visualizations and simulations next to 2D textual-based contents, to make the learning more interactive (Yuen, Yaoyuneyong, & Johnson,; Botella et al., 2011; Specht, Ternier, & Greller, 2011). Augmented reality applications have been used in various areas such as for vehicle technology to display maps and alternative routes (Krevelen & Poelman, 2010) and for the field of fashion to present clothes or objects from different angles (Kim & Cheeyong, 2015). Besides, AR applications are also used for educational purposes, with Rice (2007) stating that the three-

Accepted: 23 April 2017
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dimensional graphics in AR offer learners opportunities for better cognitive processing. Currently, AR in education has been implemented in the field of astronomy (Fleck & Simon, 2013), library applications (Chen & Tsai, 2012), engineering education (Liarokapis et al., 2002), history (Martin et al., 2011), physics (Coffin et al., 208), language (Liu & Tsai, 2013) and in the contexts of elementary (Fleck & Simon, 2013), middle-school (Di Serio, Ibáñez, & Kloos, 2012; Cowan & Butler, 2013) and college education (Cheng & Tsai, 2012). The integration of AR into the educational field brings new possibilities for teaching, learning and interaction (Wu, Lee, Chang, & Liang, 2013), and the integration of AR with pedagogical strategies such as scaffolding or blended learning brings positive learning effects for learners (Abas & Zaman, 2011; Tsai & Huang, 2014; Yoon & Elinich, 2012).

Meanwhile, Matcha and Awang Rambli (2011) and Wu et al. (2013) stated that the application of AR is still in its infancy, especially for the education field compared to other mature learning technologies, and more experiments and studies are needed to ascertain the advantages of using AR to facilitate learning (Wu et al., 2013). Researchers have suggested that more quantitative and qualitative research should be conducted to explore how AR techniques and related learning patterns could support teaching and learning in detail (Schmitz, Klemke, & Specht, 2012). Besides, research has pointed out several issues that need to be carefully dealt with during the integration of AR applications. For example, in terms of the practical issues, AR applications require additional and often expensive settings and hardware. Meanwhile, students who use AR to acquire knowledge might encounter cognitive overload while reading learning information from AR settings (Dunleavy et al., 2009a, b), and one challenge of learning in an AR environment is that the students may lack the necessary skills of AR operation (Kerawalla et al., 2006; Klopfer & Squire, 2008a, b), and thus may feel confused while learning (Kerawalla et al., 2006). Regarding the pedagogical issues, course design with AR applications might change the way in which instructors give and prepare learning materials (Kerawalla et al., 2006; Mitchell, 2011); thus, teachers need to realize the gap between conventional teaching methods and the AR learning environment when implementing AR techniques to support instruction (Wu et al., 2013), such as the teaching pedagogy changing from teacher-centred to student-centred learning (Kerawalla et al., 2006; Mitchell, 2011). Meanwhile, Ke and Hsu (2015) also suggested that related AR studies could explore various effects of learning via AR-based activities compared with learning from existing media contents.

Research purpose and research questions

Based on the above rationale, the researcher summarized the possible directions and issues regarding AR applications as follows. First, more quantitative and qualitative evidence-based research such as quasi-experimental designs should be implemented (Wu et al., 2013). Second, AR studies could explore the various learning effects of existing media contents compared with AR applications (Wu et al., 2013), and third, the research learning contents could be extended to beyond science, technology, engineering and mathematics learning. Moreover, while adopting AR applications for course instruction, technology educational researchers should take into consideration the instructor's ability to develop customized and flexible AR instructional design and contents. Therefore, this article proposes a comparative research study exploring the effectiveness of using existing media contents, online-based content, and AR-based learning contents to assist learners taking a college software editing course. To promote the students' use of online-based and AR-based learning contents, and to find an optimal way of presenting the contents, the blended teaching and learning strategy was used. To enable the researcher to confirm the learning effects during the comparison, a quasi-experimental design research was conducted. To understand the effectiveness of the various learning supports, the following research questions were investigated: What are the students' perceptions of using AR-based and online-based learning contents to support learning? How could the AR-based and online-based learning content affect students' learning motivation and performance?

Literature review

Augmented reality in education

The growing dossier of the state of the art learning technology has created new environments for improving the way of interaction between learners and instructors (Bujak et al., 2013; Chang et al., 2014). Augmented reality is one of the emerging technologies that have potential for teaching and for increasing students' motivation in learning processes (Bujak et al., 2013; Chang et al., 2014). Azuma (2001) defined AR as 'the combination of virtual and real objects in a real environment, a system that aligns/registers virtual and real objects with each other; and that runs interactively in real time'. Augmented reality allows the overlaying of layers of virtual information on real scenes (cite), and although AR in the educational field is in its initial phase (Wu, Lee, Chang, & Liang, 2013; Cheng & Tsai, 2012), several studies have proposed and conducted studies with promising learning benefits of using AR to support learning. Liarokapis et al. (2002) proposed the MARIE system which used AR techniques to support engineering education. The system used images, animations, text and sound information to provide students with learning interaction. In Liarokapis et al.'s (2002) study, learners had to wear Head Mounted Displays (HMD) and use them to read a trained marker that provided learning information. Liarokapis et al. (2002) indicated that the advantages of using AR applications were the real-time augmented presentation which enhanced the interaction of the e-learning environment, and they also suggested that related learning contents such as cultural heritage, archaeology, surgery operations, military service and architecture could be included. Related studies could further explore the use of other hepatic devices to track objects. Coffin et al. (2008) used augmented video to assist students in learning physics concepts, whereby the learners received information through stimulation that was previously invisible to the human eye. Kamphuis et al. (2014) indicated that AR applications valued medical education in training psychomotor skills and the capacity to visualize the invisible, and Martin et al. (2011) used AR technology with the game-based learning strategy to enhance history learning for culture museums and archaeological sites.

The above applications of AR for educational purposes have been proved to have positive effects on learning, and with the rapid advances in the development of the learning technology, the media for delivering AR contents could be extended from computer and large equipment to easy-to-carry personal learning devices such as tablet PCs and mobile phones, thus bringing more flexible interaction and applications adopting AR techniques (Papagiannakis, Singh & Magnenat-Thalmann, 2008).

Mobile-supported augmented reality applications

With the rapid development of learning technology, mobile-based AR applications have matured and expanded rapidly to a level such that using both mobile devices and computer-based equipment could benefit from AR interactions. Smirnova and Bordonaro (2014) stated that using mobile learning devices helps teachers and students change the lecture-driven instructional model to a more interactive approach because learning is hands-on as well as minds-on. With the increasing pervasiveness of the applications utilized through mobile devices, Augmented reality applications (AR apps) are available in large numbers for commercial, advertising and educational purposes (Bitter & Corral, 2014). The exemplary uses of mobile-based AR apps in education include archaeological learning (Ardito, Buono, Costabile, Lanzilotti, & Piccinno, 2009), historical knowledge acquisition (Huizenga, Admiraal, Akkerman, & Dam, 2009), recycling concept learning (Juan, Furió, Alem, Ashworth & Cano, 2011), biological learning for butterfly ecology (Tarng & Ou, 2012) and so on. For example, Liu and Tsai (2013) adopted AR technology to support outdoor language learning activities and English composition for college students. In their study, the researchers adopted global positioning with AR techniques to assist students in exploring university scenes, and when they got to a designated location, the introduction of the scene was shown on their mobile phones using AR techniques. After the learners finished the exploration of the location, they were asked to write an English composition to introduce the scene. The results suggested that the participants were engaged in the learning activities constructing linguistic and content knowledge and thus produced good quality and meaningful English essays. Chen, Chen, Huang and Hsu (2013) adopted radio frequency identification (RFID) and AR techniques based on mobile devises for outdoor geography course learning activities. The findings suggested that the use of AR with mobile devices and using the situated learning strategy could stimulate students' learning intention and enhance their retention of the learning contents. More recently, Lin et al. (2015) used AR-based mobile learning tools to support children with disabilities to learn geometry and found that the learners improved their ability to complete the learning task independently, and with the use of the AR technology, they had better learning motivation and frustration tolerance. Lindgren, Tscholl, Wang, and Johnson (2016) used mixed reality simulation to help middle school students experience gravity and planetary motion. Their findings indicated that using mixed reality simulation led to more significant learning gains than using a desktop version of the same simulation. Chang et al. (2016) developed a mobile-based AR interactive game to assist senior high school students in investigating a socio-scientific issue on radiation energy and pollution. Their results indicated that the AR interactive game was helpful for enhancing the high school students' knowledge and perceptions of target learning contents.

Researchers have stated that the uses of mobile-based AR apps in education have been proven to be more effective than traditional textbooks (Bitter & Corral, 2014), and can also increase students' collaboration and learning motivation (Matcha & Awang Rambli, 2011); meanwhile, there are still barriers and issues which need to be taken care of when integrating AR apps in education such as lack of experience of operating AR interactions, excessive information displayed on the screen, instructors resistant to change to teaching with AR, advanced learners not getting enough learning information through AR interaction, the limitation of the small screen devices, and other factors including equipment budgets, being too time-consuming, Internet connectivity issues and administrative support (Bitter & Corral, 2014; Di Serio, Ibanez, & Kloos, 2013). Wu et al. (2013) proposed several issues related to the implementation of AR for educational purposes such as the fact that the expensive and cumbersome AR equipment may cause discomfort and depth perception problems when learning (Kerawalla et al., 2006). How to assist instructors in changing contents in the AR system to create flexible learning materials according to their educational purpose is also an issue to be considered. Besides, researchers have indicated that learners might suffer from cognitive overload due to encountering too much learning information (Dunleavy, Dede & Mitchell, 2009a, b), and sometimes the learners might lose their way in the AR environment or need scaffolding to help them adapt to the system (Klopfer & Squire, 2008a, b).

Augmented reality with various pedagogical and learning designs

The use of AR applications can foster collaborative learning, problem-based learning and blended learning (Wagner, Schmalstieg, & Billinghurst, 2006; Lim & Jung, 2014; Wojciechowski & Cellary, 2013). Lim and Jung (2014) found that incorporating multimedia learning materials might disrupt the flow of the class due to the fact that contents such as videos have to be played on a projector, and when playing, the lecture and instruction are delayed. Thus, they proposed the AR-based learning blended mode to solve this problem, so that learners could listen to the teacher's instruction and view the supporting contents at the same time via their personal learning devices as needed.

Content presentation is another issue that teachers or developers need to carefully design when using AR apps for learning (Nincarean et al., 2013; Diaza, Hincapiéb, & Morenoc, 2015). Diaza, Hincapiéb, and Morenoc (2015) explored how the style of learning contents presented in an AR app affected students' learning and indicated that dynamic contents like animations or videos helped learners' comprehension of the targeted contents more than when they used static content such as text and images. Chen and Tsai (2012) indicated that presenting learning information through AR mode helped the students transform the learning information from short-term to long-term memory. According to the dual coding theory, learning information presented through textual, audio and video formats helps learners promote their learning performance; however, researchers have to be careful to avoid cognitive overload (FitzGerald et al., 2013).

Wagner, Schmalstieg, and Billinghurst (2006) explored whether using various learning media such as a paper and computer-based environment, and mobile-based AR application would have differing learning effects on the learners; their study pointed out that there was no significant difference in the educational outcomes from the three learning media, but the learners revealed that the paper and mobile-based AR version promoted collaboration with peers more than using the computer-based environment. It was the fun factor and the suitability of the AR environment that supported learning (Wagner, Schmalstieg, & Billinghurst, 2006). Munnerley et al. (2012) and FitzGerald et al. (2013) suggested that further AR research could focus on how learning occurs in formal education, and recommended designing activities to support collaboration and critical thinking. Moreover, FitzGerald et al. (2013) indicated the potential challenges of AR applications including the technical challenges (e.g., lack of accuracy), the pedagogical challenges (e.g., considering the learning objectives and goals) and the social challenges (e.g., AR widens the digital divide between learners).

Summary of the literature

The above-mentioned literature has reported the promising advantages of integrating AR techniques to support teaching and learning and has indicated that the multimedia elements presented in AR contents can have positive learning effects on students' learning. Besides, integrating AR interaction through blended learning strategies might be a way of not interrupting learning and teaching flow and could support students in solving learning problems at the same time through their personal learning devices. Hence, in this study, the researcher aimed to explore whether integrating AR techniques into a college software editing course could support college students' learning and also to examine whether there were different learning effects for students using online-based and AR-based learning contents for self-learning.

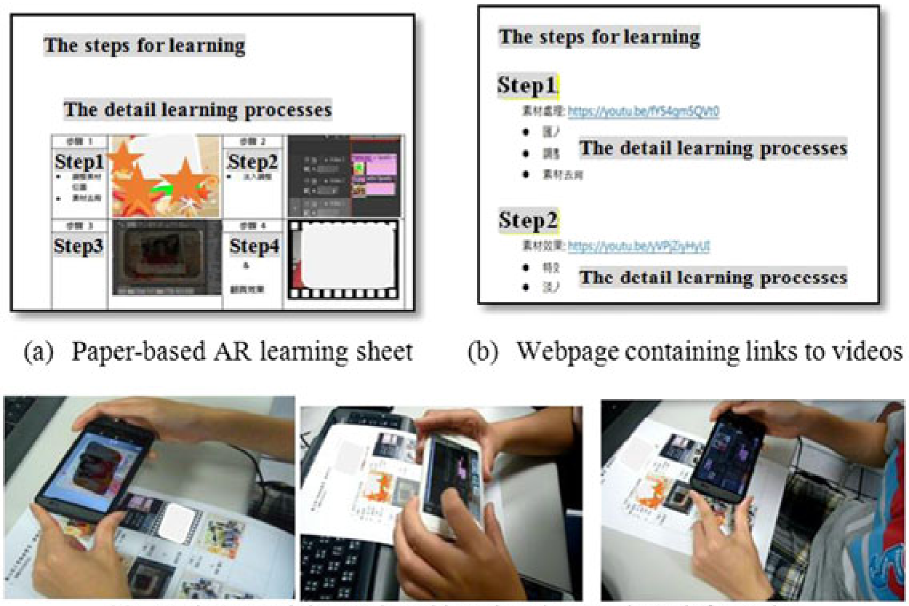
Methodology

Participants and experience design

A quasi-experimental design was adopted in this study which used comparative test data and empirical experiments to report on the performance and perspectives of integrating AR techniques into a digital video editing and practice course in a university. A total of 103 educational technology majors from two classes of a university in Taiwan participated in this study. None of the learners in the study had participated in the digital video editing and practice course before the experiment, but they had taken a digital *audio* editing and practice course. Hence, before the experiment, the learners of the two groups had basic skills of audio editing. The teacher adopted two kinds of learning technology to support blended learning. The experimental group (E.G.) consisted of 59 learners who participated in the course with the AR-based blended strategy, while the control group (C.G.) consisted of the other 54 students who learned with the online-based strategy. The learners in the E.G. were given paper-based learning sheets (Figure 1a) listing the rough steps of the software operation, and further operational processes were embedded into the paper-based learning sheets through AR interaction. The learners read and got detailed instruction through the AR interaction via their personal mobile devices (Figure 1c). On the other hand, the learners in the C.G. got a webpage containing the links to software demonstration information (video of steps) on the YouTube platform (Figure 1b). Besides, the instructor of the two groups was the same.

Introduction of the course

The digital video editing and practice course is an elective course for second-year college students. The purpose of the course is to help students acquire the concepts of video production and the abilities of video editing and creation. Each week of the course introduced a topic via theory-based concepts (in the first hour) and software practice (for the other two hours). For the software practice session, the instructor gave demonstrations of the software and reserved time for the students to practice. However, the instructor found that due to the English interface of the software and the complicated procedures of the software's operational steps, some students had problems keeping up with the progress of the steps during the two hours of software practice instruction. The teacher had to slow down the operational processes which subsequently delayed the course schedule. However, the teacher also noticed that if the teaching progress was slowed down, some of the advanced students reflected that they felt bored about the repeated and slow progress. Before conducting the experiment, the instructor collected the students' feedback through questionnaires and summarized their expected learning supports as: (1) providing step-by-step operational progress of the software, (2) providing demonstration of the operational processes of the software and (3) showing the hardest part of the operational steps then leaving the students to practice on their own. The course instructor thus aimed to integrate the learners' suggestions and so adopted learning technology to form a blended learning environment for supporting software practice sessions during the course.



(a) Paper-based AR learning sheet (b) Webpage containing links to videos

(c) Students used the AR-based learning sheets to learn information

Figure 1 AR-Based and Online-Based Learning Materials [Colour figure can be viewed at wileyonlinelibrary.com]

The learning contents and contexts of the study

The instructor designed three learning topics for the three weeks of the experiment including captions and subtitles, dynamic albums and special video effects. The first and third topics were taught following the original teaching method, that is, the instructor used PowerPoint to lecture followed by a step-by-step software demonstration, then gave the students time to practice. The learning contents of captions and subtitles (Topic 1) and special video effects (Topic 3) were to teach students how to use the software to add subtitles and various effects to video. The learning contents first instructed the learners how to add subtitles and then led them to adjust the various property parameters to present advanced subtitle effects and video effects step by step.

For the second topic, the learning contents of the dynamic albums (Topic 2) aimed to assist the students in acquiring the ability of importing static materials into the software and outputting dynamic clips with subtitles and transitions. The learning context for the second topic also involved the teacher adopting PowerPoint for lecturing but integrated the blended strategy with AR-based contents for the E.G. and online-based contents for the C.G. to support their software practice. These two kinds of learning materials were produced by the same instructor, and the processes and steps of the direction were the same. The design of the experiment is presented in Figure 2.

Example of augmented reality-based and online-based learning contents

The AR-based contents were designed based on marker-based AR techniques. The coloured images were triggers stuck to the paper-based learning sheets, and when the trigger images were recognized, the AR system loaded the input database and overlaid the supporting learning materials on the screen (Figure 3). The learners could run multimedia contents and interact via the touch-sensitive screen of their learning devices, allowing for more intuitive communication with the AR learning information. The handling of the AR learning information entails direct manipulation and control of the learning materials, thereby enabling learners to listen to the teacher’s demonstration of the learning processes and then to double-check the operational processes through the AR information at the same time, forming interactive, proactive and self-directed learning. The online-based learning contents were presented on the YouTube platform, and the learners followed step-by-step video demonstrations as a reference for the software operation.

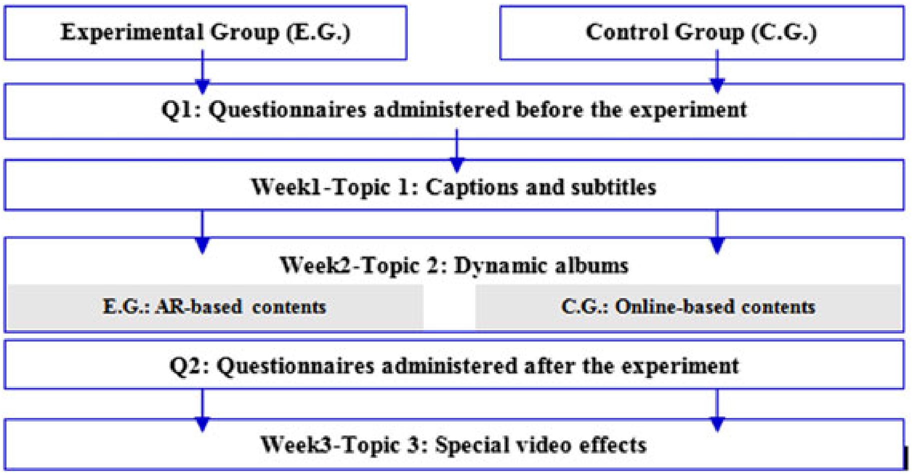


Figure 2 The Design of the Experiment [Colour figure can be viewed at wileyonlinelibrary.com]

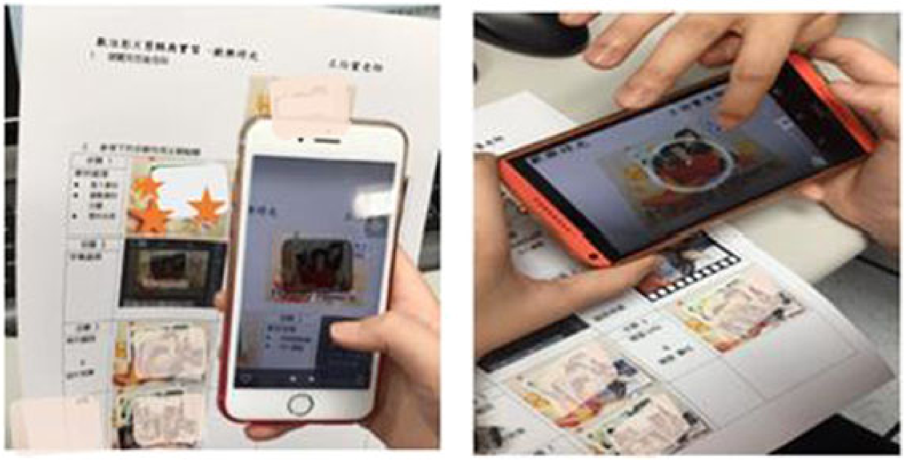


Figure 3 Demonstration of the Learning Sheets and AR-based Contents [Colour figure can be viewed at wileyonlinelibrary.com]

Data collection

The study collected both qualitative and quantitative data for data analysis (Table 1). In order to explore how various learning supports facilitated the students' learning and whether it contributed to the target learners' learning motivation and ability, questionnaire surveys were administered to elicit the learners' feedback on using the different learning supports. The questionnaires were composed of five-point Likert scale questions and open-ended questions. The Likert scale questions collected the learners' feedback on using the different learning supports for the course, while the three open-ended questions asked the learners to share their feelings, perceived advantages and suggestions regarding using the AR-based and online-based supports for learning. The Cronbach's α test was used to measure the reliability of the questionnaires, where an α value of above 0.7 is usually considered to indicate good reliability. The coefficient α of the measures of the questionnaires of this study was 0.73 thus confirming the reliability of the questionnaire.

Table 1. Qualitative and Quantitative Data

Quantitative data	Qualitative data
•Questionnaires (five-point Likert scale questions) •Grades of weekly learning works •Self-evaluation scores in weekly learning diaries	•Weekly learning diaries (feedback) •Questionnaires (open-ended questions) •Video recording data

During the experiment, the learners were asked to write a weekly learning diary after the course. They were asked to write down their learning reflections and a self-evaluation score regarding their learning performance for the week. The scores were graded according to a five-point Likert scale (from 5 to 1: perfect concentration, good concentration, followed the instruction but did not finish the work, low concentration, poor concentration). The diary and questionnaires were used to eliminate the bias of a single method. Besides, the learners were required to upload their weekly work to the learning platform, and the records of whether they handed it in on time and the quality of the work were also evaluated. The instructor checked each work and then graded it according to a five-point Likert scale (from 5 to 1: 100% completion, 75% completion, 50% completion, 25% completion, below 25% completion). The evaluation results were used for recording whether the learners completed all of the software functions taught each week during the course, and these grades were recorded for further analysis. Moreover, the students' learning involvement and emotion changes during the practice sessions were also video recorded.

Data analysis

The data from the questionnaires, weekly learning diary and grades of the weekly work were analysed according to the research questions. SPSS for Windows 12 was used as the main software for statistical analysis. Descriptive statistics were calculated to describe the means and standard deviations, and independent sample *t*-tests were adopted to compare the learning results and questionnaire results of the two groups. For the qualitative data from the weekly learning diaries, each participant was given a code, for example, EG-0001 represents learner 0001 in the experimental group (EG). The researcher translated the weekly learning diaries into raw data files for each participant and re-coded the raw data according to different themes. The final qualitative data were organized and displayed as reduced data from which the findings for each question could be highlighted.

Analysis of the grades of the work

The percentage of learners who were able to finish the work on time for the three weeks of each group are shown in Table 2 and Figure 4 according to which it was found that before integrating the learning technology to support learning, only 46 and 33% of the learners in the two groups were able to hand in the work on time, but up to 65% and 60% were able to finish the assigned work on time in the second week in which the AR-based and online-based blended learning strategies were adopted. However, after the learning supports were removed, the average grades of the E.G. work were slightly lower than those of the C.G. (all of the work handed in by the C.G. learners was complete), but only 21% of the learners in the C.G. could finish the work on time. It was also surprising to note that almost 66% of the learners in the E.G. were still able to conduct the work in the course without the support of the learning technology. The data revealed that the AR-based blended learning environment enhanced the students' learning motivation despite the fact that they did not present fully completed work; however, they were still engaged and active in doing the work. On the other hand, according to the learning records, the online-based blended learning environment was useful for learning, but it did not prove to be helpful for sustaining learners' learning motivation. The online-based strategy might be helpful for those learners who were advanced and had high interest in learning the software operation, but it was not appealing to those who were not good at or who had little interest in learning. The students in the E.G. presented great learning involvement after the AR-based supports were removed, while the learners in the C.G. were passive once the supports had been removed (Figure 4).

Analysis of the questionnaires

The results of the questionnaires are presented in Table 3 according to which a comparison of the questionnaire items indicates that the learners in the two groups were able to keep up with the course progress more easily with

Table 2. Analysis of the Grades of the Work

		Percentage of students who handed in the (assigned) work	Average grade	S.D.
Week 1	E.G.	46% (27/59)	4.00	1.209
	C.G.	33%(18/54)	4.33	1.237
Week 2	E.G.	65%(38/59)	4.71	.898
	C.G.	60%(32/54)	4.44	1.014
Week 3	E.G.	66%(39/59)	4.69	.731
	C.G.	21%(12/57)	5.00	.000

the AR-based and online-based learning supports, especially for the AR-based support group. Besides, the students reflected that they had better concentration during the course. The results of the questionnaire indicate that the learners were positive about using the learning supports to assist their learning, and the use of the learning supports facilitated course discussion. The instructor also reflected that the learning atmosphere of the two groups was quite diverse in Week 2. The learners in the E.G. had a lively discussion, with the learners exchanging their experience of how to correctly do the practice; in contrast, the C.G. class was quiet, with the learners concentrating on the online contents so as to complete the assigned work. However, it was noticed that in item Q2 and Q4 of questionnaire, the learners in the C.G. had higher average scores than the learners in the E.G. regarding the feedback of using the learning supports to assist self-directed practice, and hence, the researcher further analysed the qualitative results from the questionnaires.

The qualitative feedback of the learners' self-reflection regarding learning with the different learning supports are presented in Table 4. The learners in the two groups revealed that using the AR-based and online-based learning contents was useful in the software practice session. They indicated that this blended-learning model was helpful, especially when they had software operational problems. Previously, they had to go to the teacher for assistance when they had difficulties in the learning process, but they could now read the contents via the AR-based or online-based learning supports on their own to solve their learning problems. After organizing the learners' feedback, it was noticed that some students in the E.G. reflected that they were busy and lacked focus when they had to pay attention to the teacher's instruction and AR-based contents, and

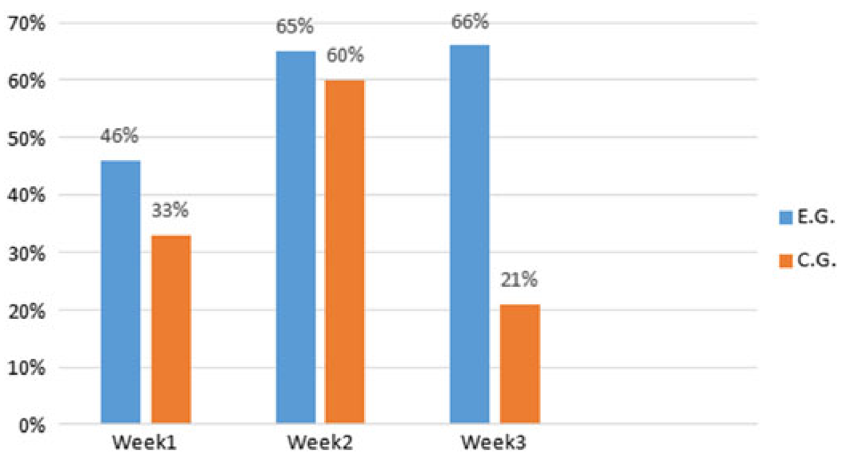


Figure 4 Percentage of Students who Handed in the (Assigned) Work [Colour figure can be viewed at wileyonlinelibrary.com]

Table 3. Analysis of the Grades of the Questionnaires

Questionnaire	E.G.		C.G.		t
	Avg	S.D.	Avg	S.D.	
Q1. The progress of software instruction is good	4.11	.567	3.65	.702	.038
Q2. With the assistance of the e-learning tools, I could know how to do the operation in the self-practice session	3.68	.478	4.18	.529	.006
Q3. With the assistance of the e-learning tools, I would like to follow up on the learning progress.	3.84	.688	4.00	1.00	.581
Q4. The e-learning tool is useful during the self-practice session.	3.89	.658	4.35	.606	.038
Q5. I am motivated to learn the target software because of the assistance of the e-learning tools.	4.21	.631	4.29	.588	.684
Q6. The use of the e-learning tool promoted course interaction between me and my classmates	3.84	.688	3.41	.795	.091

Table 4. The Learners' Qualitative Feedback

Advantages	Learning problems or suggestions
Feedback from the E.G. EG-0335: The AR-based learning support is quite good, and the teacher could speed up the teaching phase. EG-0335: Using AR-based support helps me to have a quick view of the final work of this week and I could know what my work would be like, then I would have motivation to get the work done. EG-0335: I hope AR-based learning support could be used in the following course EG-6525: I was a little busy in the course because I had to listen to the teacher's instruction and learn with the AR contents. But it was still good, because I could use the AR learning sheets when I got lost in the operating processes. EG-0129: I like this kind of learning very much. EG-0574: I could keep up with the teacher most of the time, so I did not use the AR support very often. However, it was still useful. EG-4033: I think the AR support is very useful and helpful. EG-4033: This could also be used for photography courses to show how to take good pictures. EG-0434: I could keep up with all the steps in the course, so I did not use the AR support. Feedback from the C.G. CG-1077: The online support is helpful; if I missed details I could watch the video to help myself. CG-1002: The use of online-based learning support impressed me. CG-0954: I enjoyed the way of online-based learning. CG-0897: I could keep up with the learning progress through reading the online-based learning support.	Feedback from the E.G. EG-0442: The interface of my phone is too small. EG-0814: This learning way was convenient, but the speed of the school Internet was slow and it took time to load the contents. EG-0061: The speed of the Internet in the classroom was slow. EG-0129: My phone was not good enough, so I had problems reading the AR contents. EG-0285: The AR support was good, but I was not familiar with the AR operation. Could the teacher demo how to use the AR function again? EG-0699: The AR contents could include the teacher's oral instruction. EG-0327: More information such as 3D modules could be included in the AR contents. EG-0442: More advanced learning information could be included so we could learn more in the limited time. EG-0285: The AR support could be used for other operating practice courses such as teaching us how to use 3Ds max software.

reflected that they had problems using the AR-based contents due to Internet connection problems, the small screen size of the learning devices and the limited affordances of their mobile phones for presenting AR interaction. Moreover, it was also found that some advanced learners in the E.G. did not experience AR interaction because they could already keep up with the teaching progress and they hence reflected that there was no need to use the AR-based learning supports. The above findings might explain why the average score of the C.G. was higher than that of the E.G. for item Q2 and Q4 in questionnaires.

Analysis of weekly learning diaries

The researcher used paired samples *t*-tests to compare the learners' self-evaluation scores within the groups. According to Table 5, the self-evaluation scores of Week 2 which adopted AR-based and online-based learning contents were higher than the scores for Week 1, with significant improvement for both groups. However, the scores in Week 3 of the C.G. were lower than the scores in Week 2, and the scores in Week 3 of the E.G. were much higher than the scores of the C.G. in Week 3. Besides, the scores in Week 3 of the C.G. were significantly lower than their scores in Week 2. The data analysis results seem to support the finding that the learners in the E.G. were active and concentrated on learning even after the AR-based learning support was removed, while the learners in the C.G. showed little interest in conducting the weekly work without the online-based learning support.

On the other hand, the qualitative feedback from the learners' weekly diaries revealed that the learners with the AR-based support were quite motivated in practicing using the software through the new interactive way, with one student commenting that '*If I had problems in the course progress, I could seek help from the paper-based learning sheet and it showed me how to do the next step. This was really helpful despite it taking me more*

Table 5. Analysis of the Grades of the Weekly Learning Diaries

E.G.	Average	S.D.	*Paired sample t-test*	*t*	Sig
Week1	3.87	.846	Week1–Week2	−2.160	.039
Week2	4.23	.717	Week1–Week3	−1.941	.062
Week3	4.23	.845	Week2–Week3	.000	1.00
C.G.	Average	S.D.	*Paired sample t-test*	*t*	Sig
Week1	3.62	.852	Week1–Week2	−2.575	.016
Week2	4.12	.711	Week1–Week3	−.214	.832
Week3	3.65	.797	Week2–Week3	2.739	.011

time to get familiar with the things, but it was really an impressive learning way (EG-0327)', and another student reflected that '*I was totally concentrated on the course, and with the AR-based contents, when I wanted to speed up or slow down the operational progress, I could do it at my own pace (EG-30392)*'. However, there were other negative comments regarding the small size interface and the Internet connection problem. The learners in the C.G. also gave positive feedback about using online-based contents to support learning, with such comments as '*I could find the answer when I met a problem in operating the software without waiting for the teacher's help (CG-1077)*' and '*I used to give up learning when I couldn't keep up with the teacher's steps, but with the assistance of the online-based contents, I could keep on learning (CG-0962)*'.

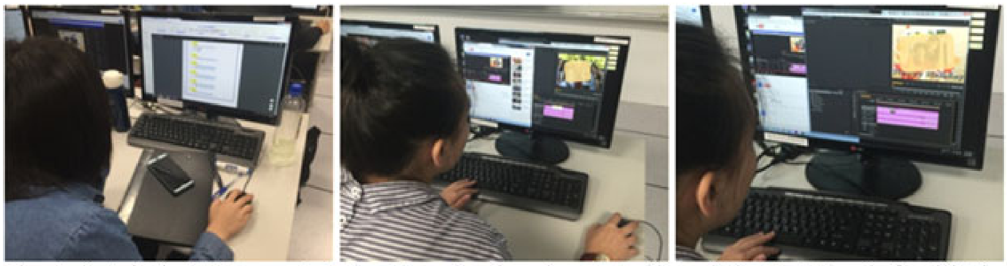
Analysis of the video records

According to the classroom observations from the video records and the instructor's feedback detailing the learners' learning interactions and behaviors, it was indicated that the learners in both groups showed great involvement during the software practice session with the assistance of the AR-based and online-based contents, and they showed much more concentration in doing the self-directed software operational practice compared to Week 1. The situation was particularly obvious for the learners in the C.G. The learning atmosphere in the C.G. was very quiet, and almost all of the students paid attention to the online contents and practiced the operational processes (Figure 5a). The learners in the E.G. had a lively discussion about how to run the AR techniques and how to use the AR-based contents to assist themselves in solving their operational problems (Figure 5b).

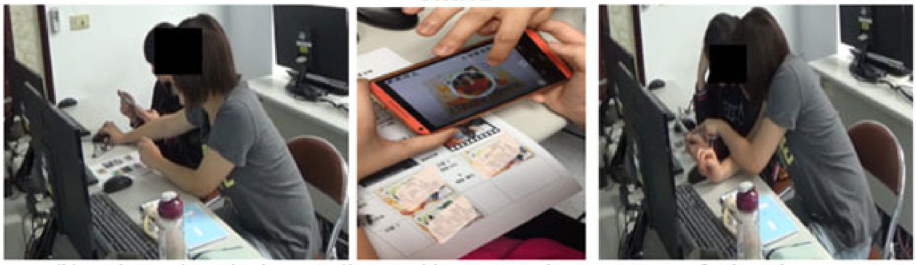
Discussion of the findings

The results of the percentage of students who handed in the designated work indicated that the AR-based and online-based blended learning strategies both had positive impacts on the learners' self-directed software operational learning. More specifically, the self-evaluation scores of the weekly learning diaries showed significant gains in both the AR-based and online-based groups. That is, both groups' self-evaluation scores in week 2 were significantly higher than their week 1 scores. However, when the two groups' scores in week 3 were compared, it was observed that the learners in the E.G. were much more motivated than those in the C.G. after the learning supports were removed. The results of the quantitative analysis of the self-evaluation scores supported the finding that the learners in the E.G. were active and concentrated on learning even after the AR-based learning support was removed.

According to the data analysis results from the questionnaires and the qualitative data of the weekly learning diaries, the learners revealed positive feedback regarding using online-based and AR-based contents to support the digital video editing and practice course. The learners indicated that with the assistance of the learning technology, it was much easier for them to find learning information to help them overcome their learning problems. Besides, the instructor revealed that the learners in the E.G. had better learning interaction during the course. The learning atmosphere in the E.G. was vivid, and the classroom was full of the sound of learning discussion, and some of the learners left the sites to check the learning progress with peers for further learning. This finding was similar to previous research (Wagner, Schmalstieg, & Billinghurst, 2006; Ke & Hsu, 2015; Bressler & Bodzin, 2013; Bower, Howe,



(a) The students in the C.G. concentrated on the online-based contents (through the YouTube platform) in the practice session



(b) The students in the E.G. discussed how to use the AR-contents for learning

Figure 5 The Learners in the Two Groups in the Course [Colour figure can be viewed at wileyonlinelibrary.com]

McCredie, Robinson, & Grover, 2014) which suggested that using various learning media might not result in significant differences in educational outcomes, but that using AR supports facilitated collaborative learning and peer discussion better than did using the computer-based environment.

Despite the results of the learners' feedback all being quite positive, it was found that (1) the lack of experience of AR interaction and application, (2) the slow speed of the Internet in the school, (3) the limited affordances of each learner's mobile learning devices, (4) the small screen size of the learning interface and (5) the overloading of the learning information from the AR contents and the teacher's lectures might be why the learners were still more used to the online-based support approach. These reasons may explain why there were higher average scores in the questionnaires for the learners in the C.G., and these results echo previous research findings that the potential challenges of AR applications are the technical challenges and cognitive overloading (FitzGerald et al., 2013).

Nevertheless, according to further analysis of the learners' learning performance in the experiment, the learners with the AR-based content supports showed better learning motivation after the learning supports were removed. The learners in the E.G. still presented great learning involvement in the activity and worked hard to finish the weekly work after the AR-based supports were removed, while only the advanced learners and those who had great interest in software operation in the C.G. showed good motivation to learn without the learning supports; the majority of students in the C.G. were unable to hand in the work, or even gave up learning during the practice session. These findings are similar to the previous research results (Wagner, Schmalstieg, & Billinghurst, 2006) which indicated that the fun factor of AR supported and sustained learning.

Conclusions

This was a pilot study with the aim of exploring whether the use of AR applications could support and facilitate students' learning in a college digital video editing and practice course. The researcher adopted the quasi-experimental method to collect the data. The findings of the study demonstrated that both the online-based and AR-based learning supports were helpful for the students in learning software operation; however, possibly because of the target learners' learning level, combined with their inexperience and the limitations of their mobile devices, the learners felt more suited to the online-based blended learning, and thus gave the online-based contents more positive feedback than the AR-based contents.

Meanwhile, the study found the potential of AR techniques to support students' learning motivation and peer learning interaction. The AR-based contents could not only act as scaffolding for blended learning but could also be a trigger to arouse the learners' interest in being active learners. Besides, the findings of the study were also in accordance with previous research (Wagner, Schmalstieg, & Billinghurst, 2006; Ke & Hsu, 2015; Bressler & Bodzin, 2013; Bower et al., 2014) which confirmed the positive learning effects brought by AR applications. The AR-based blended learning strategy could be a form of scaffolding to help students achieve their learning goals without interrupting the course flow because the learners could use their personal devices for self-directed learning to solve their learning problems as needed while listening to the instructor's lecture at the same time. However, despite the fact that the learners' feedback on the AR-based learning mode was positive, it was found that the learners' lack of experience with AR interaction and applications, the affordances of each learner's mobile learning devices, and the overloading of the learning information from the AR contents and teacher lectures might be the reasons why the learners were still more used to the online-based support. It was therefore concluded that when integrating AR applications into courses, the content design, the amount of information displayed on the mobile screen, and the affordances of both the hardware devices and the classroom environment should be carefully integrated to achieve a suitable learning scenario. Moreover, which kind of learning subjects and learning interaction might be suitable for the integration of AR applications could be further explored.

Suggestions and future work

Further work regarding AR applications in education could focus on designing firstly, the AR-based contents for remedial teaching to help less-advanced students learn target knowledge, because the advanced learners can already keep up with the pace of the course, and the extra AR support might be a disturbance that interrupts their learning. Secondly, the interaction model between AR presentation and learners could be improved. For example, further studies could redesign the AR interface to solve the problem of when learners remove the camera lens from the AR triggers but still need more time to read the AR information. Thirdly, technology educational researchers should take into consideration the affordances of the learners' current learning equipment, the whole educational scenario, and the instructors' ability to develop customized and more flexible AR instructional design and contents when adopting AR applications for course instruction. Besides, further studies could continue designing AR techniques to support both lectures and operational courses through blended learning strategies, because the AR contents could be presented and deployed parallel with face to face instruction, and thus might not interrupt the students' learning. Moreover, other research issues could focus on whether using AR applications in non-operating skills courses such as literature or language learning courses will have different research findings compared to the current study.

Acknowledgements

This research project is jointly funded by the Ministry of Science and Technology in Taiwan, 105-2511-S-032 -002. The authors would like to thank Ministry of Science and Technology for their support.

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