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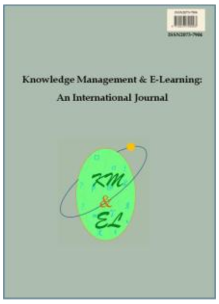

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Implementation of a mobile peer assessment system with augmented reality in a fundamental design course

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Abstract: This study proposes a framework that incorporates mobile peer assessment and augmented reality (AR) technology to enhance interaction and learning effectiveness. According to the framework, a mobile AR peer assessment system has been developed to facilitate students to improve work interpretation, frequently interact with peers, represent their thinking and reflect upon their own works anytime anywhere. Moreover, the mobile AR technology provides personalized and location-based adaptive contents that enable individual students to interact with the mixed reality environment and observe how works are possibly applied to the real world in the future. In a fundamental design course, students used the system to acquire sufficient information in indoor and outdoor situations and mark peers' work accurately based on appropriate assessment criteria. The experimental results showed that the system really assisted students in acquiring useful information, proposing their viewpoints, and further fostering critical thinking skills and reflection. During the process of interviews, most students made positive responses and provided meaningful suggestions. The system allows students to concentrate on observing and understanding the relative explanation and representation of works within a combined real–virtual environment and apply appropriate assessment criteria that produce sufficient assessment results to mark peers' works. Rich feedback can encourage students to reflect upon their own works and improve the quality of their works.

Keywords: Augmented reality; Peer assessment; Mobile learning

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1. Introduction

Peer assessment has become increasingly popular in education due to the support of group learning and the enhancement of learning effectiveness. In peer assessment process, students join cognitive activities including doing assignments, devising assessment criteria, reviewing, summarizing, clarifying, providing feedback, diagnosing errors, identifying missing knowledge or deviations and evaluating the quality of peers' works (Van Lehn, Chi, Baggett, & Murray, 1995; Liu, Chiu, Lin, & Yuan, 1999; Sitthiworachart & Joy, 2003). The majority of previous studies emphasize conditions, methods and outcomes of peer assessment and focus on the quality of students' works, domain-specific skill and peer assessment skill for outcomes (Van Zundert, Sluijsmans, & Van Merrienboer, 2010). In recent years, mobile technology has increased the potential of creating innovation learning experiences. Students can acquire learning materials, share ideas, and construct knowledge anytime anywhere by using their own handheld devices. In order to eliminate the limitation of space and time, mobile peer assessment positively influences the assessment methods and outcomes and enables students to submit their own works, review peers' works, and mark and provide feedback conveniently.

However, during the peer assessment process, providing students with sufficient information to review peers' works is critical. Augmented reality (AR) is a technology that can make that happen by providing the right contents at the right place at the right time. The mobile AR technology is able to overlay virtual objects on the real work of peers to present rich information to students and construct meaningful presentation by combining location-awareness and contextual learning. Considering the advantages of AR for education, the application of state-of-the-art AR technology has been suggested for its potential (Duh & Klopfer, 2013; Martin et al., 2011) and significance (Cheng & Tsai, 2013; Wu, Lee, Chang, & Liang, 2013). There is a positive relation between providing students with the opportunity to review peers' works based on the mobile AR technology and reflecting upon their own works. Several AR studies in education have indicated the enhancement of students' motivation for learning with the AR technology (DiSerio, Ibáñez, & Kloos, 2013; Martín-Gutiérrez & Contero, 2011). Through the mobile AR guidance, students engaged more in gallery experience and performed better on painting appreciation (Chang et al., 2014). Researchers also considered the AR technology to be integrated in the physical classroom environment (Bujak et al., 2013) and proposed AR design principles for classroom (Cuendet, Bonnard, Do-Lenh, & Dillenbourg, 2013).

In order to provide full insight into effective peer assessment processes, issues regarding content presentation as well as assessment methods require more attention. Therefore, this study presents a conceptual framework for providing intelligent and mobile supports through incorporating the AR technology to enhance work presentation and the effectiveness of peer assessment. In this framework, students are able to review peers' works by using various dimensions and receive assessment results immediately. The difficulty of reviewing peers' works and understanding peers' thinking can be resolved and sufficient information representation can enable accurate assessment. Most importantly, appropriate assessment criteria and rich feedback can encourage students to reflect upon their own works and improve the quality of their works.

Based on the proposed framework, a mobile AR peer assessment system (MARPAS) has been developed and applied in a fundamental design course. The system allows students to concentrate on observing and understanding the relative explanation and representation of works within a combined real–virtual environment and apply appropriate assessment criteria that produce sufficient assessment results to mark peers' works. In order to validate the effectiveness of the system, the MARPAS has been evaluated to analyze participants' attitudes toward the use of peer assessment, mobile service and AR. Evaluation findings revealed that MARPAS facilitates students to review peers' works and reflect upon their own works according to meaningful feedback and suggestions.

2. Literature review

2.1. Peer assessment in mobile learning

Peer assessment has been widely recognized as an educational arrangement in which students assess peers' works and provide feedback (Van den Berg, Admiraal, & Pilot, 2006), as well as a learning tool for improving student's performance in collaborative learning environment (Topping, Smith, Swanson, & Elliot, 2000). Various studies related to education, business, health and science on self and peer assessment in higher education have been proposed (Searby & Ewers, 1997; Ballantyne, Hughes, & Mylonas, 2002; Prins, Sluijsmans, Kirschner, & Strijbos, 2005; Price & O'Donovan, 2006). These studies reveal that students who involve in the interactive assessment process can enhance their interpretation and reflection. Regarding how to effectively involve students in peer assessment, these processes, including exploration of assessment criteria, presentation of works, assessment methods, coordination of assessment and feedback, are very critical (Chen, 2010; Lan, Lai, Chou, & Chao, 2012). Most of the studies have focused on the conditions, methods and outcomes (Van Zundert, Sluijsmans, & Van Merrienboer, 2010) and have proposed computerized-based peer assessment systems to support the assessment process (Davies, 2000; Lin, Liu, & Yuan, 2001). Appropriate technology applied in peer assessment can assist the reviewing and assessing activities. Computer networks facilitate students to participate in assessment activities anytime anywhere and enable teachers to review assessment progress. On-line peer assessment systems that can do away with conditions restricting various assessment activities in classrooms can eliminate the time and the cost in communicating with each other and printing out student work or assessment forms.

In recent years, students attempt to learn in various locations, and therefore mobile learning is becoming widespread. Mobile technology provides the potential for creating innovative learning experiences that can take place anytime and anywhere (Shih, 2010). Because of the characteristics of mobile technology such as ubiquity, smaller size, comparative affordability, and the prevalence of wireless networks, more and more researchers have developed applications on handheld devices such as mobile phones, tablet computers and PDAs to support learning activities. Some studies have proposed the critical issue of how to use handheld devices to enhance assessment (Penuel, Lynn, & Berger, 2007; Shin, Norris, & Soloway, 2007). Students can use handheld devices to flexibly conduct project-based learning and self-assessment inside and outside classrooms. A few researchers have reported the findings about how to use mobile technology for self- and peer-assessment (Chen, 2010). Chen indicated that combining mobile technology with the concept of round-table presentations, the mobile self- and peer-assessment system can assist teachers in arranging assessment activities more flexibly and making students more attentive to presentation, interaction and feedback in the assessment process. However, most of these studies emphasize the exploration of assessment criteria, marking process and the promotion of feedback to enhance the effectiveness and reflection of self- and peer assessment. Actually, it is critical that students' works can be presented in detail during the assessing process. Through reviewing peers' works, students can understand how to mark and reflect upon their own works.

According to the characteristics of mobile technology, students' works can be shown in various ways by considering the locations and situations; moreover students can communicate with peers as well as observe peers' works anytime anywhere. This study proposes a novel mobile peer-assessment system which incorporates augmented reality into the review and assessment process. The mechanism enables students to enhance work interpretation, frequently interact with peers, represent their thinking, and reflect upon their work. Through the review and interaction process, assessment accuracy and quality can be improved. The overall process facilitates students in fostering critical thinking skills and reflection as well as promoting meaningful learning.

2.2. Mobile augmented reality

Augmented reality (AR) is the technology that shows the right contents for the right device to the proper person at the right place and at the right time (Chang & Tan, 2010; Chang, Tan, & Tao, 2010). It can overlay virtual objects on the real world to fulfill the feeling of immersion and therefore supplements user's everyday life with information, images, sounds, and other sensory information from their device. In short, through putting a virtual layer of information over the real world, AR pretends that virtual objects are real and presented at the right place. The widely accepted definition of AR is as follows: "Augmented Reality allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. AR supplements reality, rather than completely replacing it." (Azuma, 1997; Azuma, et al., 2001). AR is thought to present certain advantages over more traditional ways of accessing information (Anastassova, Burkhardt, & Megard, 2007) which are presented below.

Alongside mobility, development of positioning technologies has made it possible to keep track of students and provide them with tailored learning contents based on their real-time locations. Furthermore, location-based e-learning provides a personalized learning experience and helps in keeping the students engaged in the learning activities and enhancing their effectiveness (Chen, Li, & Chen, 2007). Previous studies have indicated that the combination of location-awareness and a contextual learning approach can enable students to better construct meaningful contextualization of concepts (Michie, 1998; Patten, Sanchez, & Tangney, 2006). For the purpose of locating virtual information at the right place in real word, tags or markers are necessary for recognition. AR recognizes the tag and gets its position as the position of the corresponding virtual information. There are two types of tags: one is so called "AR ToolKit marker". It's a monochrome graph surrounded by a square frame. The other one is full-on image recognition. The square frame of "AR ToolKit marker" transforms to a parallelogram when it is projected on the screen. By reversing this procedure of mapping a parallelogram to a square, the position and direction of the square frame in the real world can be detected, and then the virtual object information can be overlaid on the screen of the handheld device. Since real objects can be observed in various dimensions, it is more difficult to recognize real objects than "AR ToolKit marker". Currently, it is still not quite at the stage of full-on image recognition, but many researchers are working on it. Because real object recognition does not need extra tags, it would become the most popular approach in the near future.

Few years ago, if someone wanted to show virtual information on real objects, he/she needed to wear some equipment on his/her neck. However, it is not a convenient situation. In recent years, significant advancements related to wireless and mobile technologies have made handheld devices, which combine several utilities, to be the most convenient platform for the AR technology. The camera on the handheld device can capture images of real world, a compass can detect the direction of user's face, the GPS receiver can locate the position of users, and the monitor can show the images of the outcome that the mobile AR technology create, which can be text, table, image, video, etc. and their combination. Even more, extra components such as buttons or tables can be included for interaction. The mobile AR technology provides pliable mobility and a location independent service without constraining the individual to a specific area. According to the NMC Horizon Report 2012 K-12 Edition, AR supports visual and highly interactive forms of learning in education. Students can use it to construct new understanding based on interactions with virtual objects that bring underlying data to life as it responds to user input (NMC Horizon Report, 2012). Numerous researches have proposed that the AR technology can help students to learn in serious games, language learning, e-books, storytelling, driving guidance, and so on (Azuma, 1997; Van Krevelen & Poelman, 2010; Chen & Tsai, 2010). In this way, AR holds the possibility to revolutionize the way in which information is demonstrated to people and has great potential for on-demand, context-aware, and collaborative training (Hollerer et al., 2001). For example, Chang et al. (2014) developed a mobile guide system for painting appreciation that guided visitors to view the painting and provided them additional information by incorporating AR. Moreover, the mobile AR technology provides personalized and location-based adaptive contents for individual students to interact with the mobile viewing environment and see how works are applied to the real environment in the future at the current place.

3. System implementation

3.1. System architecture

According to the above discussion, the mobile AR technology can obviously support students to review peers' works during the peer assessment process. Formerly, in a design course, students could only review the work based on assessment such as originality, production skills, colour scheme and so on but could not view the usability of the work in the future in this environment where the assessor was located. The most important functionality of a location-based mobile AR technology is to provide the proper contents according to students' current location. The relevant applied contents in students' vicinity would be presented by the mobile AR technology automatically while students walk in the area. For example, how a painting can be hanged on the wall or become a fresco or how a handiwork will be if it is rebuilt to a sculpture and put in this environment. "The incorporation of various rich sensors into new phones such as GPS location, wireless sensitivity, compass direction, accelerometer movement as well as sound and image recognition is enabling new ways in which we are able to interact with the world around us." (Nokia Research Center, 2009). The mobile AR technology can fuse digital media with the physical world to create proper conditions for locative, contextual and situation-based demo scenarios. In this study, during the peer assessment process, assessors not only assess the works presented in front of them but also view the future application of the target works. Therefore, assessors can judge the design skill of designers as well as the usability of the work in the future.

Augmented reality is defined as a real-world environment whose elements are built upon computer-generated sensory input such as sound, video, graphics or GPS data. In the educational field, there are many situations that cannot be experienced in the classroom. Augmented reality is the latest technology that can accommodate or modify students' learning experience to their specific needs. So what AR allows us to do is to see virtual objects in a real world environment with the aid of camera and some display devices (monitor or head mounted display). Following discussion describes the procedure of peer assessment enriched by the mobile AR technology. This procedure shows how mobile AR can enhance the effectiveness of reviewing and assessing during peer assessment.

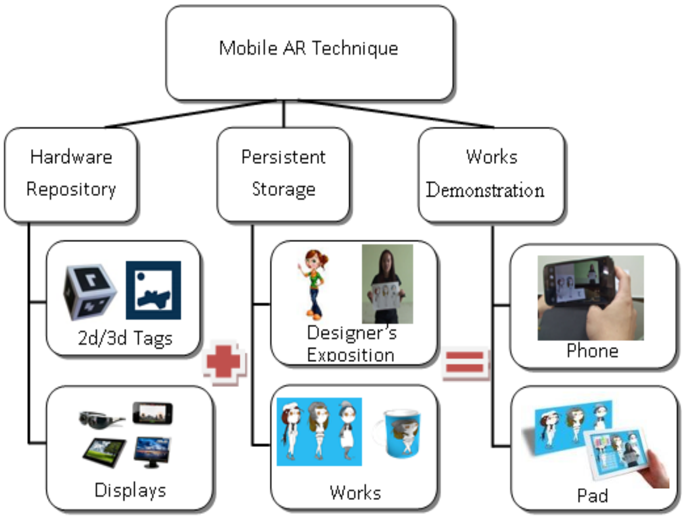

Fig. 1. The architecture of the mobile AR technology

The architecture of the mobile AR technology includes three parts, namely hardware repository, persistent storage, and works demonstration, as shown in Fig. 1. *Hardware repository* includes 2d/3d unique tags which are able to recognize and present virtual objects in right locations, and mobile displays. That is, the location of tag is recognized in real world and then the virtual objects are shown on the recognized location of mobile display. Students' works and expositions of design about these works are categorized into *persistent storage*. These materials provide extra information of virtual objects. In the part of *work demonstration*, results that overlay virtual object images on real object images can be presented on handheld devices such as mobile phones or tablets.

Through incorporating the mobile AR technology into peer assessment, Fig. 2 shows the framework of the mobile-AR peer-assessment system (MARPAS). There are three databases in the cloud, including the student profiles, the AR and virtual object database and the assessment database. At the beginning of the assessment activities, students must login to authenticate their identities. All data including students' ID for authentication, works information and virtual objects, activities which students can join and assessment records is stored in the user database, Subsequently, the target work shows up in front of assessors, the context-aware module is aimed at getting all information including assessors' location, the direction that they face and the situation such as indoor or outdoor. This local data is collected by handheld devices and sent to the context-aware module, as well as the function information of handheld devices. Thus, the current situation of assessor is collected. During the peer assessment process, all procedures are divided into three modules, namely the authentication module, the context aware module, and the AR interactive module. The authentication module enables right people to get right information to assess right works. The context aware module enables assessors to use right device to receive right context for assessment, and the AR interactive module enables assessors to review peers' works conveniently and intuitively such that the assessment can be more diversified and every assessee learns more from other works. In the context aware module, the system judges the local data and then selects a proper context for the assessor from the virtual object database. All data are prepared for the AR technology to overlay on the real world image, and thus assessors mark these works more conveniently and accurately.

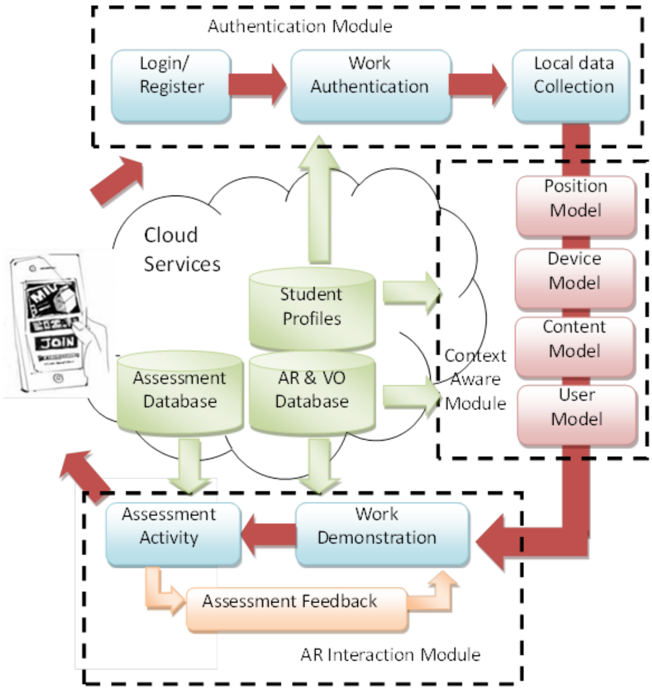

Fig. 2. The framework of the mobile augmented reality peer assessment system

3.2. System demonstration

The mobile augmented reality peer assessment system has been developed on Android platform. Users can use any mobile device with the Android operating system to review and assess students' works and acquire assessment information. The system provides three functions including observation, assessment and interaction and supports two situations of indoor assessment and outdoor assessment. The interfaces of MARPAS are presented in Fig. 3.

In the indoor situation, assessors go to the exhibition to capture the tag through their own camera on handheld devices. Then, they can see the work that is constructed as a physical production in the real world. The introduction of assessees' work and the assessment criteria can be shown on the device at the same time. In the outdoor situation, assessors go outside to capture the tag on the wall, and then the visual work is presented on the wall in the real world. Assessors can review the assessees' information and assessment criteria as well. However, assessment criteria are different based on the varied situations. Four criteria including colour scheme, originality, exquisite, suitable for assignment, were used in the both situations. But the criteria, usability, had specific standard for the individual situation. As virtual objects integrated with the real environment were showed in the monitor, assessors can assess the suitability of the work in the environment. By this way, meaningful suggestions could assist assessees to revise their design. Due to the use of these criteria, assessors can focus on critical points that students should learn, and assessees can understand what teachers hope them to learn. Meanwhile, all assessment related to the work can be presented simultaneously on the device, as shown as Fig. 4, and therefore assessors are able to review other assessors' assessment and assessees can receive the assessment results.

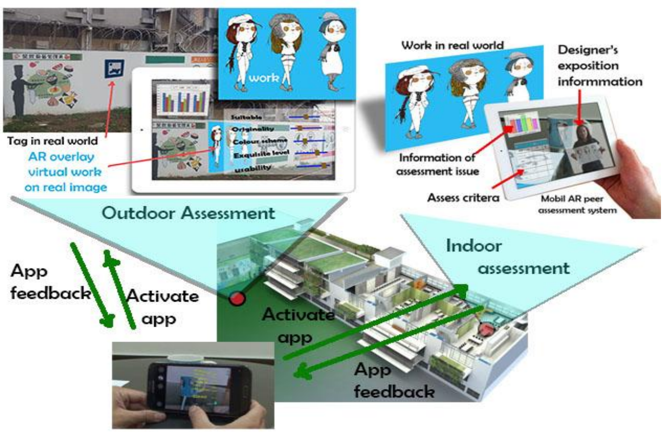

Fig. 3. The demonstration of the MARPAS

According to the different surroundings, students are not only able to acquire the relative explanation and representation of work but also apply appropriate assessment criteria that produce adequate assessment results to mark peers' works. MARPAS facilitates students to observe other assessors' marking as well as receive assessment feedback. Therefore, students can reflect upon their work according to the various and meaningful feedback received.

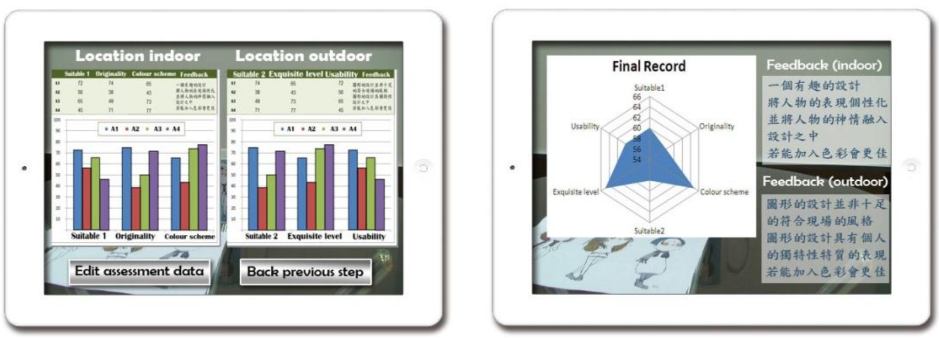

Fig. 4. The representation of assessment results

4. Experiment and evaluation

4.1. Experimental setting and participants

In order to validate the proposed framework and the effectiveness of the system, an experiment and a survey were conducted. In the study, participants were 48 undergraduates majoring in visual communication design and enrolled a fundamental design course at an institute of technology in Taiwan. According to Van Zundert, Sluijsmans, and Van Merrienboer (2010), peer assessment is facilitated by working in small groups of three to four students. These students are better able to compare feedback from different peers to determine its relevance. Therefore, in our study, the students were arranged in 12 small groups of 4 students each.

First, all participants had to complete the training of peer assessment in order to understand the process of observation, assessment and interaction. Subsequently, each group joined two activities: assessment on papers and assessment on mobile devices by using MARPAS. The teacher assigned a painting work and then students had three weeks to prepare their drafts and the exposition of their design ideas after which these were uploaded onto MARPAS. The AR application constructed the relation between the image of the draft and the exposition. Subsequently, during the assessment process, the teacher designed two situations in which students marked peers' works in an indoor environment as well as in an outdoor environment. These drafts were printed out as tags and posted in an exhibition and on an outside wall. All students had to observe peers' works in indoor and outdoor environments and indicate their assessment and suggestions on papers and in MARPAS.

However, assessment criteria defined by the teacher were different based on the various situations. For example, assessment criteria including suitability, originality and colour scheme were defined for the indoor environment, and assessors marked the dimensions of suitability, exquisiteness level and usability in the outdoor environment according to the features of the outdoor situation. The assessment criteria represented the teacher's requests, and were also the basis for marking peers' works.

4.2. Data collection and analysis

Both qualitative and quantitative research designs were used in this study. The independent variables were the two activities of peer assessment: pen-and-paper peer assessment and mobile AR peer assessment. The dependent variables were learning effectiveness from peer assessment, the amount of time spent focusing on peer discussion, and students' attitude regarding the use and acceptance of MARPAS. Twelve groups undertook peer assessment on paper first, while the same groups employed the system to do peer assessment one week later.

After the experiment, the assessment process and results were recorded . In order to validate the proposed framework, the experimental results were analyzed. In addition, a survey was conducted to collect additional data from participants. Structured questionnaire was developed for this purpose and was sent to five experts to evaluate reliability and validity. Subsequently, the questionnaire was distributed to each student in 12 groups. This questionnaire contained four sections: the first section related to the experience in joining peer assessment, while the second section dealt with the feedback in using the mobile service. The third section figured out how AR technology assisted students in demonstrating their work, and the final section asked users about their habits of using digital devices.

In the questionnaire, there were 3 questions for personal infromation, 16 questions for the first section, 8 questions for the second section, 5 questions for the third section, and 4 questions for the fourth section. The questionnaire used five-point Likert scale to register students' answers. Collected data was analyzed using correlations, associations and descriptive statistics in order to assess the relationships existing between variables.

After students filled out the questionnaire, interviews were arranged with each group, where the aim was to explore the participants' attitudes toward the strengths and limitations of the system and any suggestion students may have for improvement. Qualitative approach was used to analyze the participants' feedback.

4.3. Findings and discussion

According to Kothari (2009), for sample sizes of more than 30, the t distribution is so closed to the normal distribution that one can use to approximate the t-distribution (Kothari, 2009). Therefore, the average test (t test) was utilized to validate the effectiveness of the system. Seven questions in the first section of the questionnaire were selected to analyze students' attitudes toward the use of peer assessment. The hypotheses are listed below:

H_0: Students did not agree on effect of peer assessment ($\mu \leq 3$)

H_1: Students agreed on effect of peer assessment ($\mu > 3$)

Since the significance level is below 5%, the results of the test indicate that the H_0 hypothesis cannot be accepted. In other words, students agreed on effect of peer assessment. The results of the test in Table 1 show that students' attitudes toward the use of peer assessment were positive. The results demonstrate that peer assessment activities enable students to understand the teacher's requests and engage their attention in learning. In addition, peer assessment activities increase positive interaction through their discussions with peers.

The second section of the questionnaire related to students' attitudes toward the use of mobile service for peer assessment. The hypotheses are listed below:

H_0: Students did not agree on effect of mobile service for peer assessment ($\mu \leq 3$)

H_1: Students agree on effect of mobile service for peer assessment ($\mu > 3$)

Taking into account the smaller than 5% significance level, the results of this test indicate that the H_0 hypothesis cannot be accepted. The results of this test reported in Table 2 point out students agreed on effect of mobile service which made peer assessment activities more convenient and fairer.

However, the significant value of the last question is calculated as 0.002. This can be explained according to students' responses in the fourth section. 12.6% participants felt that it was hard to use smart phone, and 18.8% participants could not use digital device proficiently. Because these students used personal computer or other digital device infrequently, they did not know the difference between mobile service and other services.

Table 1
Average test results for the effect of peer assessment

	Test value = 3						
						95% Confidence Interval of the Difference	
	Mean	Std. Deviation	t	df	Sig. (2-tailed)	Lower	Upper
I could understand the teacher's requests in this course more clearly from peer assessment activities.	4.00	.715	9.695	47	.000	.79	1.21
I could understand peers' recognition of my work from peer assessment activities.	4.56	.616	17.584	47	.000	1.38	1.74
Peer assessment activities increased my learning motivation.	4.06	.665	11.062	47	.000	.87	1.26
Peer assessment activities engaged my attention in the course.	4.25	.565	15.330	47	.000	1.09	1.41
Peer assessment activities increased the interaction with the teacher.	3.94	.665	9.761	47	.000	.74	1.13
Peer assessment activities increased the interaction with peers.	4.31	.589	15.435	47	.000	1.14	1.48
The suggestions from peers were helpful to me.	4.25	.565	15.330	47	.000	1.09	1.41

Table 2
Average test results for the effect of mobile service

						95% Confidence Interval of the Difference	
	Mean	Std. Deviation	t	df	Sig. (2-tailed)	Lower	Upper
Using mobile service could reduce the cost of traffic during peer assessment.	4.19	.734	11.211	47	.000	.97	1.40
Peer assessment activities could progress anytime anywhere by using mobile service.	4.38	.489	19.471	47	.000	1.23	1.52
It is fair to assess peers' works regardless of the relationship with peers by using mobile service.	3.81	.816	6.897	47	.000	.58	1.05
The limitation of the hardware location could be eliminated by using mobile service.	3.44	.943	3.214	47	.002	.16	.71

The third section of the questionnaire clarifies whether the use of AR technology to demo students' works during mobile peer assessment is helpful. The section includes five questions and associated hypotheses are listed below:

H_0: AR technology did not assist the activities of mobile peer assessment ($\mu \leq 3$)

H_1: AR technology assists the activities of mobile peer assessment ($\mu > 3$)

The test results show that the significance level is below 5%, which indicates that the H_0 hypothesis cannot be accepted. The results of the test in Table 3 reveal that participants thought using AR technology to enhance the work demonstration is helpful for students in the course.

Table 3
Average test results for the assistance of AR technology

						95% Confidence Interval of the Difference	
	Mean	**Std. Deviation**	**t**	**df**	**Sig. (2-tailed)**	**Lower**	**Upper**
I could get information about work immediately by AR technology.	4.19	.532	15.459	47	.000	1.03	1.34
I could review peers' works more clearly by using AR technology.	4.31	.589	15.435	47	.000	1.14	1.48
I could know the future application of peers' works by using AR technology	4.31	.468	19.413	47	.000	1.18	1.45
I could acquire detailed information about work to assess accurately by using AR technology	4.00	.715	9.695	47	.000	.79	1.21
I could know how work was created by using AR technology.	4.38	.489	19.471	47	.000	1.23	1.52

Regarding the attitudes toward the use of the system, most students believed that peer assessment helps them to acquire more information about self-work and peers' works and facilitates them to propose their viewpoints anytime anywhere by using the mobile service and AR technology. By contrast, most students expressed that it was inconvenient to interact with peers in pen-and-paper peer assessment, and thus no student would like to use it. After the experiment, these students continued using MARPAS to interact with peers.

For the qualitative analysis, the feedback from the interviews indicated the following opinions about the use of MARPAS.

G01: "I can get the interpretation and images of designer on the work immediately! It's so cool. I like this way of demonstration! "

G02: "There were no classmates beside when I assessed works by using this system. There was no pressure at all. And blind assessment could make me tell the truth."

G07: "By using mobile service for peer assessment and discussion, I am able to operate it at home or at school. Even on the way to school in traffic, I can do it, too. This is very convenient. This convenience motivates me to give opinions to other classmates, and I hope to receive suggestions from classmates, too."

G09: "Because of my inarticulateness, I cannot explain my works well. Now by using AR technology, I could prepare my illustration information and combine it with my works in advance. This is great to me. This will make me feel more confident about my works."

G03: "I am not good at memory, and I forgot things quickly. The information showed on the works can be read repeatedly by me. So I won't forget the detail of the works. This would make me do the correct assessment."

G04: "The virtual information about the work can be words, images, procedure recorded video, and even 3D digital model. It showed me things I have never seen before and things I would not see in physical work. This might affect my assessment. "

The above examples clearly show that AR technology did assist students during the assessment process.

Analysis of the interviews revealed that most participants credited the system with five advantages: high autonomy, good visual effects, prompt responses and rich assessment information from all assessors, convenient content management, and flexibility in using the system anytime anywhere. Students also suggested that the system design could be improved.

G05: "I prefer hand painting by myself and do not feel comfortable in using digital devices. Hence I spent a lot of time to familiarize myself with the use of the system. I still like the pen-and-paper mode. But, on the other hand, when I put my phone in front of the works I want to assess, I enjoy the information showing up immediately very much! I like the presentation of the introduction about the work, but it is hard for me to produce the information and combine it with my work! "

G06: "I did not have my own smart phone and tablet! I had to borrow them from school or classmates, so I felt a little troubled. By the way, the system is what I want."

G08: "Sometimes the virtual information occupied the image of the work on the monitor. It would be better if I could view only the physical work when the above problem happens. The cause of the problem is the layout of AR virtual objects. Could the location of virtual object be changed during reviewing peers' works?"

5. Conclusions

This study has presented a framework and implemented a system for providing intelligent and mobile supports to enrich peer assessment. In this framework, students can review and assess peers' works represented with AR technology through combining virtual objects with the real world. Mobile AR technology provides flexible mobility and location-based adaptive digital contents to interact with the assessed work in real world. Students can bring their own handheld devices to capture and acquire appropriate information at the right time in the right situation. By incorporating the techniques of AR, the proposed framework enables students to review peers' works in various ways and students can receive the assessment results immediately. The difficulty of reviewing peers' works and understanding peers' thinking can be resolved and sufficient information representation can enable accurate assessment. In addition, appropriate assessment criteria and rich feedback facilitate students in reflecting upon their own works and improve the quality of their work.

Through the experiment, the data collected in the survey demonstrated that students not only agreed about the positive effect of peer assessment and mobile service, but also confirmed the usefulness of AR technology in learning. The analysis results demonstrated that peer assessment activities enabled students to understand the teacher's requests and increase positive interaction through their discussions with peers. Most students believed that peer assessment helped them to acquire more information about self-work and peers' works and facilitated them to propose their viewpoints anytime anywhere by using the mobile service and AR technology. In addition, the qualitative analysis revealed that most participants thought that the system provided high autonomy and good visual effects. Importantly, the system helped students in acquiring rich and proper information while reviewing work, interacting with peers and receiving assessment results. Moreover, use of the mobile service enabled students to propose their viewpoints anytime anywhere. The approach also eliminated the limitation of time, space and devices.

Although the system has been proven to be of assistance in incorporating AR in peer assessment, considerable work remains to be done, including: (1) further large-scale classroom experiments in comparing with systems without AR technology; (2) improvements of the system in recording browsing time and progress; (3) analysis of behavioral patterns; and (4) extended applications in formative assessment and other courses.

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