Impact on Student Motivation by Using a QR-Based U-Learning Material Production System to Create Authentic Learning Experiences

Kai-Yi Chin, Ko-Fong Lee, and Yen-Lin Chen, *Senior Member, IEEE*

Abstract—This study developed a QR-based U-Learning Material Production System (QR-ULMPS) that provides teachers with an education tool to motivate college level students enrolled in a liberal arts course. QR-ULMPS was specifically designed to support the development of u-learning materials and create an engaging context-aware u-learning environment for students. A quasi-experimental research design was used to evaluate the overall effectiveness of QR-ULMPS; the Unified Theory of Acceptance and Use of Technology (UTAUT) assessed the feasibility of using QR-ULMPS to implement teaching activities; while the Instructional Materials Motivation Survey (IMMS) was used to measure the students' learning motivation after using the proposed u-learning system. From the results of the UTAUT questionnaire, we found that teachers rated the system postively and were willing to accept and adopt QR-ULMPS into their course content. Teachers also agreed that QR-ULMPS was a useful tool to motivate students' learning during outdoor teaching activities. Moreover, results of the IMMS questionnaire indicated that students assigned to the proposed u-learning system achieved better results than participants learning via conventional methods. We believe that the proposed u-learning system is advantageous because it enhances student motivation and allows for higher levels of engagement, particularly during outdoor learning activities. Thus, we conclude that the proposed u-learning system can create a learning experience that both interests and engages students. Although QR-ULMPS is not mature enough to be used across a sundry of educational domains, it provides an innovative opportunity for teachers to integrate a novel teaching methodology that challenges traditional educational norms.

Index Terms—Computer-assisted instruction, context-aware ubiquitous learning; educational technology, student motivation

1 Introduction

In modern societies, the pervasive nature of handheld mobile devices such as tablet computers, personal digital assistants (PDAs) or smartphones can extend the learning environment far beyond classroom walls [1], [2], [3]. Such rapid development of technology has forced digital learning to adopt a mobile learning (m-learning) platform. This mobile learning model provided a new delivery mechanism to overcome time and space limitations of traditional classroom learning [4], [5]. Recently, the concept of context-aware ubiquitous learning (u-learning) was identified as a novel learning environment, an environment through which students can be taught appropriate content at the right time and in the right place [6], [7], [8]. This novel learning environment can detect contextual information in the real world and adapt accordingly to provide customized learning content through mobile devices in response to different learning contexts or situations.

In present day classrooms, teachers often introduce conceptual theories such as cultural differences to students in the following ways: filmstrips during class time, traditional outdoor teaching methods, or through field trips to help students understand differences between local and aboriginal cultures [4]. As such, liberal arts courses focused around the exploration of cultural heritage or aboriginal cultures must frequently incorporate field trips or outdoor experiences, which are regarded as the most appropriate teaching models. However, conventional outdoor teaching approaches may be time-consuming and rather labor-intensive for both teacher and learner. Conventional teaching models may only provide one-way knowledge transmission in the real world, and is thus less effective as it lacks meaningful interaction with students during the knowledge transfer phase [1]. In addition, students usually do not learn sufficient information without teacher guidance, and they are easily distracted during outdoor teaching activities. For these reasons, the application of context-aware u-learning technologies to support authentic learning activities has become a popular research topic in recent years [7].

Over the past decade, the continual development of the radio-frequency identification (RFID) technique has spurred the advancement of context-aware u-learning environments. With the help of the RFID technique, u-learning

- K.-Y. Chin is with the Department of Digital Humanities, Aletheia University, No. 32, Zhenli St., Danshui Dist., New Taipei City 25103, Taiwan (R.O.C.). E-mail: au0292@mail.au.edu.tw.
- K.-F. Lee is with the Department of Information Engineering and Computer Science, Feng Chia University, No. 100, Wenhwa Rd., Seatwen, Taichung 40724, Taiwan (R.O.C.). E-mail: P0300318@fcu.edu.tw.
- Y.-L. Chen is with the Department of Computer Science and Information Engineering, National Taipei University of Technology, 1, Sec. 3, Zhongxiao E. Rd., Taipei 10608, Taiwan (R.O.C.). E-mail: ylchen@csie.ntut.edu.tw.

Manuscript received 28 Aug. 2014; revised 16 Feb. 2015; accepted 15 Mar. 2015. Date of publication 26 Mar. 2015; date of current version 11 Dec. 2015. For information on obtaining reprints of this article, please send e-mail to: reprints@ieee.org, and reference the Digital Object Identifier below. Digital Object Identifier no. 10.1109/TLT.2015.2416717

systems can detect and record students' learning behaviors in the real world, and enables students to learn content found in the real world "actual space" rather than in cyberspace [9]. However, many teachers do not have sufficient programming knowledge and they lack coding skills to use the RFID technique [10]. It is not uncommon for educators to face a number of issues when working with RFID systems, particularly when dealing with the complexities of RFID tag. This is because RFID tags cannot be printed using traditional printers, but rather requires either industrial grade or specially designed printers. This problem complicates the production process and hinders the likelihood of incorporating RFIDs into regular course content, especially when the RFID technique is used in a mobile context [11], [12].

For all the reasons listed above, it is clear that teachers face many barriers when building their own context-aware u-learning environments in which students can interact with and learn from real-world problems. Virvou and Alepis argued that the development of educational programs is an arduous task that demands much effort from domain and computer experts [13]. Tsou et al. also indicated that teachers face difficulties in integrating relevant instructional content into digital learning platforms [14]. It has been well documented that most teachers do not possess necessary programming knowledge, they lack the capability to create RFID tags and are usually unable to properly execute RFID techniques. If teachers want to customize a context-aware u-learning environment, they require help from experts.

To overcome the aforementioned barriers, our study proposed the use of Quick Response (QR) codes in conjunction with a context-aware u-learning system, which allows teachers to create customizable context-aware u-learning materials without expert assistance. The integration of QR codes can connect users to information quickly and easily [15], while the low technical barrier of creating u-learning educational materials along with easy accessibility to code readers allows teachers to build modern learning environments without hassle. As QR code-decrypting software is practically available on most mobile devices, QR codes have become increasingly popular and widely used in mobile learning applications [16]. For this study, we felt that the application of QR code technology would be suitable in the context-aware u-learning environment.

Our study endeavored to create a QR-based U-Learning Material Production System (QR-ULMPS), which includes three sub-systems: a QR-based multimedia materials editing system; a multimedia material sharing server; and a context-aware u-learning system. Through the editing system and the sharing server, teachers can produce unique teaching content, share u-learning materials, and engage students in authentic learning activities. The u-learning system allows students to gain substantial learning knowledge through observation and practice in outdoor settings. To test the real-life applicability of our system, 12 teachers and 48 students were recruited to participate in our experiment, and they were asked to demonstrate whether or not QR-ULMPS could improve the outdoor teaching and learning process. The goal of this study was not only to support teachers in building context-aware u-learning environments, but also to support students in enhancing their learning motivation and interest in authentic educational activities.

The remainder of this paper is organized as follows: Section 2 provides reviews of current research related to this study. Section 3 describes the system architecture of QR-ULMPS by thoroughly explaining the authoring process used by teachers and presenting details about the basic student-learning environment. Section 4 outlines the research methodology used in this study, showcasing features of the study settings and assessment. The experimental results and participant responses to the qualitative survey are presented in Section 5, while the discussion of our study findings and experimental outcomes are found in Section 6. Finally, Section 7 offers concluding remarks and explores potential topics for future research.

2 Literature Review

In recent years, researchers have investigated various ways of incorporating tiny computer sensors into context-aware u-learning applications [17], [18], [19]. Examples of these tiny sensors may include RFIDs, contactless smart cards, barcode tags or sensor network nodes. Sensors can be used in the u-learning environment to provide both active and adaptive support to students, promoting curiosity and encouraging initiative in the classroom. Among tiny computer sensors, QR code technology is a very suitable pairing tool for u-learning applications for three main reasons. First, QR codes can scan and encode large amounts of data, including, but not limited to URLs, text, and numerical characters [16]. Second, the low technical barrier of creating and reading QR codes allows educators to include teaching content in the context of u-learning [15]. Third, most mobile devices are equipped with QR code readers. Therefore, QR code technology can be feasibly accessed via mobile devices in different context-aware u-learning environments.

The potential use of QR code technologies in an educational context has been investigated quite recently. Law and So presented a comprehensive review on the use of QR codes in education [15]. The researchers introduced a number of examples that covered a wide variety of educational applications, integrating QR codes and mobile devices into subjects ranging from life science to math, English listening exercises, and even accessing library catalogs. Hwang et al. developed a web 2.0-based u-learning system that combined mobile phones with QR code and web 2.0 technologies. This system allowed students to generate QR codes and download related learning materials directly onto their mobile devices. The students could also collaboratively build a database of learning materials to share their individual knowledge and personal learning materials with peers [20], [21]. Alternatively, Chen and Choi proposed a learning project that integrated an online mapping service with a comprehensive content management system [22]. This system allowed for the connection of physical locations or objects, such as books and digital artifacts and documents, through QR codes. All of these studies reveal the vast potential of applying QR code technologies in support of educational applications as an innovative teaching tool.

For this current study, the application of QR code technology not only supported students in accessing online information materials via mobile devices, but also fulfilled all of the context-aware u-learning environment needs of teachers

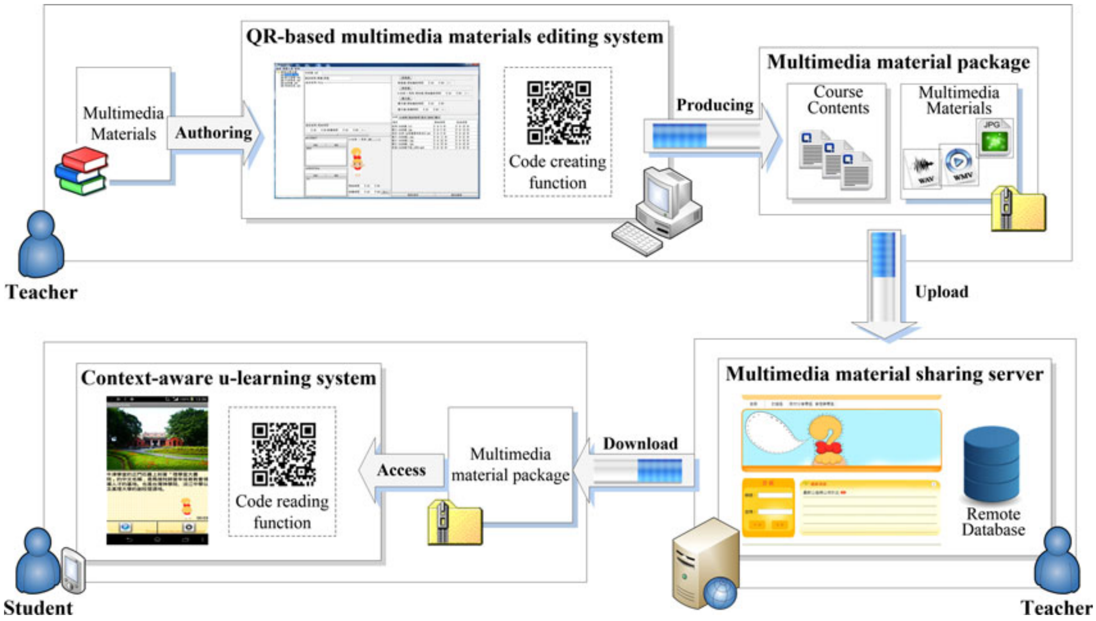

Fig. 1. The overall system architecture of QR-ULMPS.

using the system. QR-ULMPS enables teachers to create u-learning materials and related QR codes directly through the simple user interface, and this proposed system provides personalized learning opportunities which offers students a more authentic and memorable learning experience.

3 System Design and Architecture

This study describes QR-ULMPS, a proposed system that serves to improve the creation of u-learning materials, enhance learning during outdoor activities, and further develop context-aware u-learning environments. The principal goal of the study was to provide an alternative method for teaching concepts related to cultural heritage in an outdoor environment. As portability and mobility are necessary factors for an authentic outdoor learning experience, our QR-ULMPS needed to incorporate touchscreen mobile devices [18]. For this study, we employed smartphones to access information contained in the QR-ULMPS, and equipped each smartphone with wireless communication abilities to achieve both portability and mobility. The proposed QR-ULMPS was implemented on the Android-based smartphone platform, and can offer cross-platform capabilities for additional commercial and educational applications.

As shown in Fig. 1, QR-ULMPS is made up of three sub-systems: *(i) the QR-based multimedia materials editing system, (ii) the Multimedia material sharing server*, and (iii) *the Context-aware u-learning system*. The QR-based multimedia materials editing system supports teachers by making it simple to author teaching content and create QR codes. Once teachers create course content, multimedia material packages are automatically generated by the editing system and subsequently can be delivered to students. In this study, the multimedia material package was regarded as a metadata, which was then used to transmit teaching content between the three sub-systems. In effect, the multimedia material package could be used to combine course content and multimedia materials in a way that provided an enhanced lesson to students. Teachers would be able to upload entire multimedia material packages onto the Multimedia material sharing server, and further define the specifications unique to particular u-learning environments. This server acts as a remote database that is used to share and transfer teaching content and resources on the Internet with students. Once the multimedia material package has been defined as a lesson, students in any learning context can scan the linked QR codes and download predetermined u-learning materials via the context-aware u-learning system. The system will command appropriately related content to appear on the screen of the smartphone.

3.1 The Authoring Process for Teachers

The QR-based multimedia materials editing system strives to support teachers seeking innovative teaching methods through a variety of ways. Via the editing system, teachers can create, modify, and delete multimedia material packages in an easy to use and intuitive manner. Most importantly, teachers do not need to have prior programming knowledge or understand how to generate QR codes to easily produce high quality, multimedia-rich teaching content using this system.

Fig. 2 shows the graphical user interface (GUI) of the editing system, as displayed on a computer screen. There are four main components: *Lesson Management*, *Teaching Content Setting*, *Multimedia Materials Setting*, and *Current Presence Sequence*. The *Lesson Management* section provides drop-down menus for teachers to create new files and maintain/organize their existing multimedia material packages. In addition, teachers can call up other functions using the *Lesson Management* section to prepare customized u-learning materials or generate associated QR codes. Once teachers have created a multimedia material package, they are able to edit individual teaching contents and add reference data using features found in the *Teaching Content Setting* section. In the *Multimedia Materials Setting* section, teachers can select related multimedia objects (e.g., images, audio/video files) to reinforce learning enjoyment. Once teachers have uploaded multimedia objects, they can pre-program the implementation sequence of different multimedia objects joined together

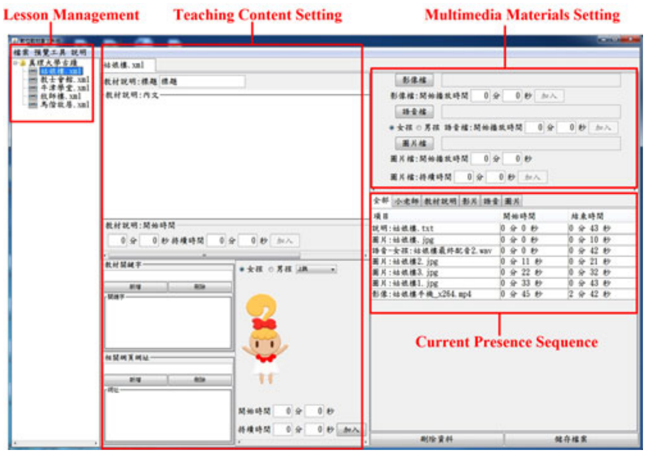

Fig. 2. Screenshots of the QR-based multimedia material editing system.

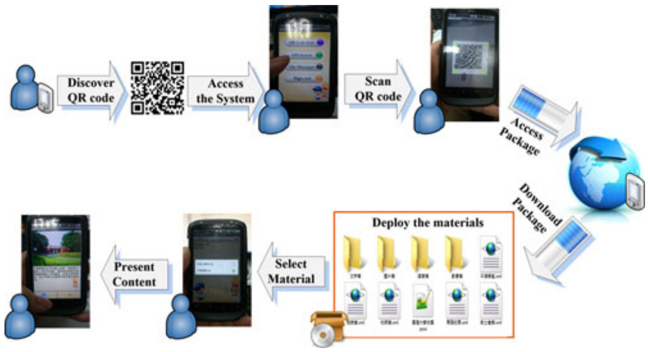

Fig. 4. Schematic flowchart of using the context-aware u-learning system.

to form relevant teaching content using the *Current Presence Sequence* section, which also contains tools for controlling the amount of screen time allocated to each object.

By using the QR-based Multimedia materials editing system, teachers can select source multimedia objects (i.e., images, video/audio files, etc.) and integrate them directly into the teaching content, in accordance with previous domain knowledge (See Fig. 3a). Once teachers have composed content for the necessary authoring segment, they can combine all of the inputs to generate related multimedia material packages. Next, teachers can use the editing system to generate QR codes and also choose the folder where the QR codes will be stored. This allows teachers to easily build and print out a physical copy of the QR code at the press of a button (See Fig. 3b). QR codes embed data that links the corresponding multimedia material package to the appropriate content and makes it possible for students to use their smartphones to scan QR codes placed in the real world and links them back to relevant class materials.

Finally, the multimedia material sharing server provides a dynamic web page for teachers to manage their collection of u-learning materials (See Fig. 3c). This function enables teachers to upload multimedia material packages onto the server, and teachers are given greater control in defining the nature of the u-learning materials. Once the multimedia material packages are properly defined, teachers can give authorization for students to access the relevant u-learning materials.

3.2 The Basic Learning Environment for Students

This study used small handheld devices enabled with wireless connectivity to allow the context-aware u-learning system to be both portable and mobile. Since the u-learning system was installed onto smartphones, students were able to locate and scan QR codes attached to corresponding real-life objects and instantaneously receive related teaching materials on the screen of their smartphones. In this unrestricted learning space, where real objects in natural environments can be used to impart knowledge to the learner, students were able to engage in u-learning activities without traditional educational constraints imposed by classroom walls.

As shown in Fig. 4, once students discover a QR code, they can access related course content by selecting the system icon on their mobile devices and scanning the QR code. The u-learning system decodes the internal information contained in the QR code, and accesses the corresponding multimedia material package according to the coded instructions. This ensures that the correct package is selected by the u-learning system, which processes and deploys the multimedia materials to the active mobile device(s). Then, students can interact with the relevant materials designed by the teacher, without hassle directly from their mobile devices.

Fig. 5 shows an example of a scenario where students engage in an outdoor learning activity while using our context-aware u-learning system. Students using mobile devices pre-installed with the u-learning system are able to scan QR codes during the outdoor teaching activity (See Fig. 5a). Once students have scanned the QR code, the u-learning system employs a windows-style GUI to present the relevant information onto the phone screen, along with two functional buttons (See Fig. 5b). The left button is used to call up a control panel that displays a set of navigation buttons (See Fig. 5c). The control panel allows students to call up other related multimedia objects (i.e., videos, audios, web pages, etc.) that suits their own personal needs and better caters to individual learning styles. Students can begin

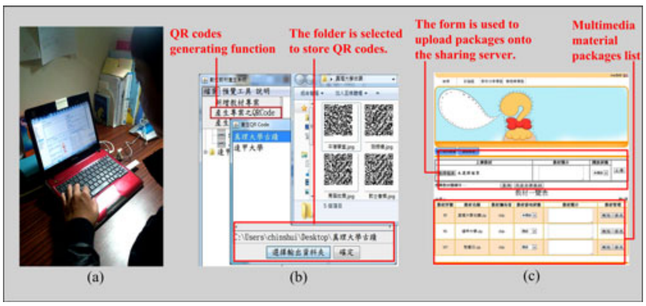

Fig. 3. Working process to create the authoring work materials.

Fig. 5. Overview of the outdoor learning activity.

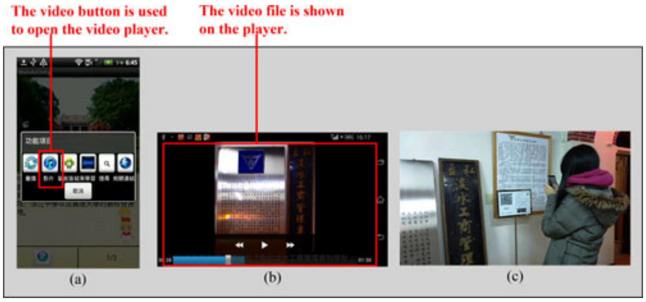

Fig. 6. Process of displaying the multimedia object(s).

Fig. 7. The typical supplementary knowledge acquisition cycle.

and pause the teaching content via the button located on the right-hand side, allowing greater control of the content delivery to match personal learning pace.

Fig. 6 shows the run-through of how students can access various multimedia objects using our context-aware u-learning system. When students call up the control panel, they can press "the video button" to display the relevant video file, which is displayed on the screen (See Figs. 6a and 6b). By using the u-learning system, students can gain knowledge from multimedia objects and also associate these objects with relevant entities (See Fig. 6c).

Fig. 7 shows an example of how students can gain supplementary learning knowledge from our context-aware u-learning system. When students call up the control panel, they can press the "search" button to transfer the keyword (s) found in the teaching content to a Google web search page and be presented with relevant supplementary information (See Figs. 7a and 7b). Moreover, students can also press the "link" button to show a pop-up list providing relevant web pages meant to re-inforce learning knowledge demonstrated throughout the lesson (See Figs. 7a and 7c).

4 Methodology

This study was conducted in conjunction with "*Introduction to Taiwanese Cultural Heritage*", a liberal arts course taught at the Aletheia University in Taiwan. This course was created to introduce indigenous art and historical monuments located in the north of Taiwan to college level students. Two segments of the course were dedicated to describing the impressive lifetime achievements of Dr. Reverend George Leslie Mackay. During the active learning phase of the course, the teacher made arrangements for all students to visit Oxford College, the Taiwanese institution founded by Dr. Mckay. Important artifacts such as private journals and personal mementos were carefully preserved at the college to commemorate the reverend's legacy.

To avoid potential negative impacts and minimize any disturbance to the course, the instructional content was designed by a teacher who was directly responsible for administering the course. This teacher prepared all outdoor teaching activities and materials without any input from the researchers of this study. The teacher also ensured that all students could access the same course content and both the control and experimental groups used identical learning environments for the duration of this study. The learning goals of the course were as follows: 1) to understand Dr. Mackay's educational background and lifetime experience; 2) to understand the healthcare services provided by Dr. Mackay in Taiwan; 3) to understand the preaching of Dr. Mackay in Taiwan; 4) to understand the history of establishing the Presbyterian Church in Taiwan; and 5) to understand the history of establishing Oxford College in Taiwan. The goal of this course was to enhance the students' knowledge of Dr. Mackay and his contributions to Taiwan; students would spend time delving into the details of his background, his life in Taiwan, his religious endeavors and his professional career.

4.1 Research Objectives

Our study required a two-fold investigation: first to determine the teachers' acceptance of QR-ULMPS and also to assess students' learning motivation after using our context-aware u-learning system. Thus, we designed two separate experimental processes to investigate the effectiveness of this new tool.

This study proposed that QR-ULMPS is a novel teaching tool that supports teachers in designing u-learning materials and allows for the creation of appropriate context-aware u-learning systems. Therefore, a comprehensive qualitative analysis can show the acceptability rate of QR-ULMPS among teachers. Our two research objectives in this experimental process are listed as follows:

1. What are the critical factors that can influence teachers to use QR-ULMPS in their outdoor teaching activities?
2. What factors would influence teachers to adopt QR-ULMPS into their lesson plans?

In addition, this study implemented two different teaching models by splitting student participants into one of two groups. The first group followed the conventional method, where the teacher explained different concepts to the group of students using traditional teaching methods. The second group used mobile smart phones containing our context-aware u-learning system to learn about new concepts in the real-world setting. Our goal was to evaluate the difference these two teaching models might make on student motivation and learning performance, where the independent variable would be the use or non-use of our u-learning system and the dependent variable would be the level of students' learning motivation.

Since this study utilized two teaching models, it was important for both groups to use materials based on the same instructional content, delivered in identical learning environments. In the first model with the control students, the teacher delivered the Oxford College teaching content and led all activities by herself. She used teaching aids such as the course textbook, a variety of Mackay's relics, and presentation teaching materials such as images, presentations, text, etc... In the second model, all teaching contents and materials were delivered through the u-learning system for the experimental group. Students could learn the content and engage in all activities in the Oxford College curriculum without being led by a teacher. Thus, the instructional content used and the real-world learning environment for all students were controlled for in this study. Of note, our study was conducted to answer the following four research objectives:

1. Is there a marked difference in the students' motivation and learning when comparing the two teaching models?
2. Are there variations between the two teaching models when evaluating the four factors measuring students' motivation?
3. What are the critical factors that motivate students to engage in the learning process when using the proposed context-aware u-learning system?
4. What factors would influence students to accept the context-aware u-learning system?

4.2 Participants

This study invited 12 teachers from the target school to volunteer as evaluators of this study. The teachers selected were contracted by the school to teach liberal arts courses, such as cultural heritage conservation, aboriginal cultures conservation, the aesthetics of architecture, understanding digital humanities, activation arts, community development, historical interest courses, etc. Among the teacher participants, five out of 12 were male and seven out of 12 were female. Each teacher possessed basic level computer skills.

Forty-eight first-year college students (aged 18-20, $M = 18.7$, $SD = 0.75$) from one class were surveyed. Among the student participants, 28 out of 48 were male and 20 out of 48 were female. None of the students were exposed to the design instructional materials in advance.

4.3 Assessment

This study adopted the Unified Theory of Acceptance and Use of Technology (UTAUT) model to evaluate teachers' overall acceptance and satisfaction of our system. UTAUT are technology acceptance guidelines formulated by Venkatesh et al. [23] and it evaluates four factors: Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions, which are used to explain the intention(s) of using an information system and can describe subsequent usage behavior [23]. Performance Expectancy measures the extent to which an individual believes that using an information system will help him/her to improve job performance. Effort Expectancy is related to the degree of ease associated with the use of the information system. Social Influence deals with the importance an individual places on whether *others* believe he/she should use a new information system. The final factor, Facilitating Conditions, evaluates how much the individual believes the existing organizational and technical infrastructure can support their use of the system. UTAUT has been used extensively to investigate the determinants of Information technology acceptance in several studies [24], [25], [26].

The UTAUT was adopted as the primary theoretical construct for designing the teachers' satisfaction questionnaire, and the four factors can validate the opinions each teacher had of the QR-ULMPS. However, in order to successfully apply UTAUT to the needs of this study, we modified the questionnaire slightly by applying changes to the Facilitating Conditions factor to reflect the degree to which an individual believes that he/she has sufficient abilities to use our system. The modified UTAUT questionnaire was composed of 14 questions that must be answered using a five-point Likert-scale, with responses ranked from 1 (strongly disagree) to 5 (strongly agree).

To evaluate the student experience, the IMMS was our surveying tool of choice because the IMMS was derived from the ARCS model as a way to quantitatively assess learners' motivation. Every question of the IMMS is relevant to one of the four factors in the ARCS model: Attention, Relevance, Confidence, and Satisfaction-and the questions measure an individual's level of learning motivation [27], [28]. The first factor, Attention, emphasizes that a lesson must gain and sustain a learner's curiosity, arousal, and interest. The second factor, Relevance, is related to how well a connection is made between the instructional content and a student's learning needs and goals. The third factor, Confidence, is related to how successful a student is in accomplishing the learning process. The final factor, Satisfaction, is related to the student's positive feelings about their learning experience(s). IMMS has been used as an evaluation technique administered in several studies to measure qualitative and quantitative findings [29], [30], [31].

With the successful application of the IMMS in previous studies, we chose to use a modified IMMS questionnaire to evaluate the motivation of college students towards the two different teaching models. Specifically, the terminology used in the survey was slightly modified to suit the field of u-learning. The IMMS used in our study contained 36 questions, all of which were also answered using the conventional 5-point Likert-scale.

4.4 Procedure

Before starting our study, we asked all student participants to sign informed consent forms to indicate their willingness to participate in the study with permission. During the informed consent process and pre-screening for our study, we asked each student to write down any background knowledge they had about Dr. Mackay. This baseline information was used as a benchmark to assess students' prior knowledge on the experimental materials, and further support the teacher in designing suitable instructional content for these students.

All participating students were randomly assigned into either the experimental or control group in this study. The experimental group consisted of 25 students using the proposed u-learning system, and the control group had 23 students learning about the course content via the traditional education model. The results were collected using the IMMS questionnaire after both groups completed their respective learning activities. Moreover, three weeks after

TABLE 1
Mean Scores and Standard Deviations of the Performance Expectancy Factor from the Teacher Experience

No.	Question	M	SD
1	QR-ULMPS can help me motivate students' learning.	4.20	0.46
2	QR-ULMPS can help me develop u-learning activities more quickly.	4.00	0.73
3	QR-ULMPS is a useful tool to support my outdoor teaching work.	4.17	0.62
4	I believe that QR-ULMPS can better facilitate my course instruction.	4.13	0.66
	The overall average score	4.13	0.62

the experiment was finished, all participating students were scheduled to write the midterm exam of the course. All questions in this exam were designed by the teacher who was responsible for administering the course. As only some of the examination questions were directly related to the instructional content of our study, we picked these questions out from the exam to explain the differences in students' learning effectiveness.

Descriptive statistics were applied to evaluate the experimental results obtained from each student experience. All statistical analyses were conducted using a two-sided alpha level of 0.05. The quality of population variances was checked before the use of any test that required this information. Finally, the independent samples t-test and the Mann-Whitney U test were applied to analyze the difference in the students' motivation between the two teaching models.

In statistics, the independent samples t-test is used to detect differences between two normally distributed groups on a single variable. In contrast, the Mann-Whitney U test, which is also used to compare two groups, evaluates a single, ordinal variable with no specific restrictions on the distribution. Both statistical tests require two independently sampled groups and the test assess whether two groups differ on a single, continuous variable. The main difference between these two tests is that the Mann-Whitney U test tends to be more appropriate for data on non-normal distributions, whereas the t-test has greater efficiency for data with normal distributions [32].

The qualitative data was collected in two parts. The first part was gathered through observation of students interacting with the context-aware u-learning system. The second part of the data collection was from administering the survey and through individual interviews. These data were used to illustrate students' personal comments and opinions of the proposed u-learning system.

Moreover, all participating teachers were invited to use and experience the proposed QR-ULMPS prior to the start of the test phase involving student participants. At the beginning of the experiment, we explained that the purpose of this evaluation was to provide teachers with the opportunity to add a novel tool to their outdoor teaching activities, and we asked teachers to give feedback on our QR-ULMPS so we could implement further improvements. We also asked all teacher participants to sign the informed consent form and obtained their permission to collect information for the study. With the approval of all teachers who participated in the study, each teacher consented to partake in a two-week mandatory training course to learn how to author u-learning materials via guidance classes focused on QR-ULMPS. When this training process was complete, all participating teachers could independently create simple u-learning materials.

The opinions from participating teachers were collected using the UTAUT questionnaire after the authoring work was produced; the responses of each survey question averaged, and the standard deviation (SD) was obtained. After completing the questionnaire, teachers were interviewed individually to obtain their personal observations on the QR-ULMPS.

5 Experimental Results

This study collected statistically relevant data from teachers and students, and gathered evaluation results from two experimental trials. We conducted several one-on-one interviews to obtain feedback from all participants and used the comments to improve our proposed system. The findings of our experimental results are discussed in the following sections.

5.1 Results of the Teacher Survey

Twelve teachers were invited to participate in this research study. The experimental results indicated that the majority of the participants had a positive outlook towards QR-ULMPS.

5.1.1 Research Objective 1

Tables 1, 2, 3, and 4 show descriptive statistics for the four factors used to describe teachers' acceptance and satisfaction after using the QR-ULMPS. The highest mean scores were achieved in the Performance Expectancy factor ($M = 4.13$), while the Facilitating Conditions factor scored the lowest average ($M = 3.79$).

Table 1 lists the four questions that the participating teachers responded to, which represents the Performance Expectancy factor of the UTAUT model. All mean scores were higher than or equal to 4.00 and all responses were positive and satisfactory. This indicates that a majority of the teachers participating in this study believed that QR-ULMPS could be helpful to their course delivery. From this table, the highest mean score corresponded with Question 1 ($M = 4.20$), indicating that teachers believed the QR-ULMPS was helpful to students' learning. Such findings reveal that QR-ULMPS is useful in enhancing pedagogical value. It should be noted that the scores for Question 3 ($M = 4.17$) were higher than the average, and this suggests that teachers strongly agree that our QR-ULMPS enhances outdoor teaching activities.

Table 2 showcases the mean scores and standard deviations of the four questions employed in this study for measuring the Effort Expectancy factor of the UTAUT.

TABLE 2
Mean Scores and Standard Deviations of the Effort Expectancy Factor from the Teachers

No.	Question	M	SD
5	I can clearly understand how to operate QR-ULMPS.	4.23	0.54
6	I think that QR-ULMPS is an easy-to-use tool.	3.80	0.98
7	The editing system can provide an easily operation method to create u-learning materials.	3.53	0.93
8	It is not difficult to design u-learning activities through the use of QR-ULMPS.	4.00	0.78
	The overall average score	3.89	0.81

TABLE 3
Mean Scores and Standard Deviations of the Social Influence Factor from the Teachers Perspective

No.	Question	M	SD
9	My colleagues/students would encourage me to design u-learning activities through the use of QR-ULMPS.	4.13	0.52
10	My colleagues/students believe that I should incorporate QR-ULMPS into my teaching work.	3.77	0.96
11	My colleagues/students have a positive attitude towards QR-ULMPS.	3.73	0.70
	The overall average score	3.88	0.73

TABLE 4
Mean Scores and Standard Deviations of the Facilitating Conditions Factor from the Teachers

No.	Question	M	SD
12	I believe that I had enough knowledge and skills to design u-learning materials by myself.	3.32	0.94
13	I believe that I can find the related information of u-learning easily through the use of Internet or other ways.	3.83	0.76
14	I believe that I can quickly get into operating and using QR-ULMPS.	4.23	0.45
	The overall average score	3.79	0.72

All questions yielded the mean score of 3.89 and this indicated that the participating teachers did not find it difficult to operate and use QR-ULMPS. However, Question 7 ($M = 3.53$) had the lowest mean score, which may be because not all teachers were comfortable with operating the QR-based multimedia material editing system. In fact, some teachers mentioned in the interview that although the editing system was great, it was more difficult to use compared to other programs (such as Microsoft PowerPoint) because they were not as familiar with the commands and operations of the editing system. Thus, it may be the main reason that Question 6 and Question 7 achieved lower agreement scores from the participants.

Table 3 summarizes the mean scores and standard deviations of the three questions that were posed to the participating teachers in our study, each question focused on measuring the Social Influence factor of the UTAUT model. The overall mean value of participant consensus was 3.88, so generally speaking, the teachers in our study agreed that their colleagues/students have positive viewpoints on the teachers using QR-ULMPS. It should be noted that the scores for Question 9 ($M = 4.13$) was higher than the average, and this indicates that the teachers strongly agreed that their colleagues/students would have encouraged them to design u-learning activities using QR-ULMPS.

Table 4 shows the mean scores and standard deviations of the three questions targeted at measuring the Facilitating Conditions factor of the UTAUT model. The mean score was 3.79, which indicates that the participating teachers had confidence that they could understand the concept of u-learning and be able to use QR-ULMPS by themselves. The scores obtained for Question 14 resulted in the highest mean score ($M = 4.23$), showing that most of the teachers agreed that they could quickly learn how to operate and use QR-ULMPS. However, Question 12 ($M = 3.32$) obtained the lowest mean score, perhaps because some teachers believed they needed additional practice before they could create enhanced multimedia materials. In fact, during the interview, a few of the teachers mentioned that with additional practice and use of the system, they would highly agree that QR-ULMPS is more convenient than other comparable systems.

5.1.2 Research Objective 2

For this research objective, the participating teachers were interviewed to provide any opinions and suggestions in evaluating the acceptability of integrating the QR-ULMPS into their teaching curriculum. The comments were all related to QR-ULMPS, and researchers collected information from participants encompassing overall satisfaction and usability of the system, as well as remarks about the difficulties faced while operating the system.

Regarding overall satisfaction of QR-ULMPS, the participating teachers stated that they would like to adopt the u-learning materials produced by our system into their current instructional activities. Several teachers gave positive opinions once they completed the training process. Some of the comments from teachers are as follows:

"If I can first gather the necessary multimedia resources, the editing tool can help me create an ideal context-aware u-learning environment."

"If I had enough practice in creating multimedia materials beforehand, I could confirm that this editing tool is in fact very easy to understand and simple to use."

"This is a wonderful system that could be used to enhance my instructional methods. This allows me to use a different method of teaching the history of Taiwan."

"I think that this system provides an opportunity for teachers to improve the effectiveness of outdoor teaching. We can use this system to replace conventional teaching approaches."

"In my opinion, this system provides an intuitive way to combine my teaching content and QR code technology. I can easily create context-aware u-learning materials by myself rather than rely on a programmer.

Regarding the usability of the system, several teachers expressed that they were very willing to use the proposed QR-ULMPS in their other courses; they were enthusiastic to understand and learn how to build u-learning activities through the use of our system. Moreover, the participating teachers also revealed that they believed the use of our u-learning system was helpful in motivating students' learning. Additional comments from the teachers are presented below:

"This u-learning system increases the students' motivation and attention to the instructional materials. If possible, I would like to apply QR-ULMPS to my other curricula."

"This u-learning system can provide supplementary information for students, and I am able to use multimedia materials to attract their attention. Thus, I am willing to use QR-ULMPS as a teaching tool in my courses."

"In my opinion, this u-learning system can provide an excellent opportunity to help students to engage in independent learning after school."

"This u-learning system allows my students to engage in relevant learning activities independently without my assistance. This method is very convenient when applied to outdoor teaching."

"This u-learning system provides an interesting learning method for students. I believe that students will enjoy using the u-learning system very much."

During the authoring process, some teachers encountered technical problems while using the editing system to generate multimedia material packages. They sometimes would forget how to encapsulate their multimedia objects into the packages, or some would ignore this step altogether. Furthermore, teachers who had less experience in designing multimedia objects could not create multimedia objects without the support of assistants. These teachers facing difficulties with the technology thought that our editing system was a complicated tool and suggested that we should add extra technical advancements and/or revise the GUI in order to enhance its usefulness. The negative opinions of participating teachers are presented below:

"If possible, the editing tool must be revised to include a sequential step-by-step explanation. I would like to refer to this sequence to create and design u-learning materials."

"It was not an easy job for me to design the instructional materials starting from scratch. I think that the editing tool needs to provide a more intuitive GUI that can assist teachers in creating content in a more structured manner."

"I suggest that the researchers should provide a more simple and primitive editing tool for teachers to design u-learning materials. This tool is a powerful system, but has too many unnecessary input fields within the GUI. It makes me so confused when I attempted to design u-learning materials."

"If possible, the editing tool should provide an image editor. I would like to use the editing tool to create/edit images directly, rather than manipulate them using another unrelated program."

"I recommend providing an ISO-based version of the u-learning system for Apple mobile devices, because not everyone uses Android-based mobile devices."

According of the above opinions from the interviews, we found that teachers generally approved the QR-ULMPS. The positive opinions revealed that the editing system was regarded as a useful tool to help teachers create an ideal context-aware u-learning environment. It is interesting to note that a majority of the teachers agreed that the proposed u-learning system could really help to focus students' attention on the instructional materials and teaching content. However, the negative opinions also showed that not all teachers agreed that the editing system was very easy to use, and this was particularly apparent for teachers who have had little exposure or experience in designing multimedia materials from scratch. Some teachers suggested that QR-ULMPS needs additional improvements and they were hopeful that the subsequently updated versions would contain technical advancements to enhance overall satisfaction and acceptability.

5.2 Results of Student Survey

Forty-eight first-year college students participated in this research study. The experimental results showed that the proposed context-aware u-learning system could have a considerable impact on student's motivation and learning.

5.2.1 Research Objective 1

The minimum and maximum scores of the IMMS were 36 and 180, respectively, as the response scale ranges from 1 to 5. The response scores collected from the experimental group ranged from a minimum of 125 to a maximum of 160, whereas the response scores from the control group ranged from a minimum of 112 to a maximum of 137. These results indicated that both teaching models can moderately motivate students and pique their learning interest.

The Shapiro-Wilk test is a test of normality and evaluates the distribution of groups in statistics. In this study, the test was used to examine the difference between the motivation of participants in the control and experimental groups, evaluating two different teaching models. The result of the Shapiro-Wilk test found that no significant departure from normality was present ($W = 0.957$, p-value $= 0.304$), indicating that the difference in students' motivation may come from a normally distributed population [33]. Therefore, it was determined that parametric tests could be used for the evaluating the remainder of the analyses.

The independent samples t-test was conducted to compare students' motivation between the experimental and control groups. The result indicated that there was a statistically significant difference between the experimental group ($M = 3.809$, $SD = 0.251$) and the control group ($M = 3.532$, $SD = 0.193$), $t(46) = 3.233$, $p = 0.003$.

A total of 10 questions in the midterm exam of the course were relevant to our instructional content. Specifically, these questions were comprised of five multiple-choice questions (four points each) and five question-response problems (five points each). The maximum possible score was 45 points. In this study, we utilized the mid-term exam score from these 10 questions to evaluate the difference between the learning effectiveness of participants in the control and experimental groups.

The Shapiro-Wilk test was used to evaluate the distribution of the midterm exam scores for any differences between the two teaching models. The Shapiro-Wilk test showed that no significant departure from normality was found ($W = 0.957$, p-value $= 0.079$). This means that the difference in students' learning likely comes from a normally distributed population.

The independent samples t-test was conducted to compare students' learning and acquired knowledge between the experimental and control groups. The results show that the midterm examination performance of the experimental group improved significantly ($t(46) = 2.107$, $p = 0.041$). In addition, the midterm exam scores showed that the experimental group ($M = 31.20$, $SD = 8.073$) outperformed the control group ($M = 26.30$, $SD = 8.008$). Since the experimental group scored higher than the control group, it demonstrated that there was a significant change in learning effectiveness from using our proposed system.

In summary, the mean grades of the experimental group from the IMMS questionnaires and the scores from the midterm exam were higher than those of the control group. Such results signify that the proposed context-aware u-learning system effectively improved the students' motivation and learning.

5.2.2 Research Objective 2

Table 5 shows the descriptive statistics for the four factors of the ARCS model. For all factors, the mean scores corresponding to the responses provided by the experimental group were higher than those from the control group. The mean score of all responses from the experimental group were above 3.6, whereas the Attention, Confidence and Satisfaction factors of the control group were below 3.6. The greatest difference among the mean scores was derived from the Satisfaction factor ($M_2 = 3.94$, $M_1 = 3.53$, $M_2 - M_1 = 0.41$). The lowest overall difference was produced from the Attention factor ($M_2 = 3.67$, $M_1 = 3.56$, $M_2 - M_1 = 0.11$).

TABLE 5
Descriptive Statistics for Four Motivational Factors

Factor	Control group		Experimental group	
	M_1	SD_1	M_2	SD_2
Attention	3.56	0.16	3.67	0.45
Relevance	3.62	0.20	3.96	0.24
Confidence	3.41	0.31	3.76	0.32
Satisfaction	3.53	0.27	3.94	0.42

The Shapiro-Wilk test was performed to evaluate the distribution of the four factors for any differences between the two teaching models. We concluded that the difference between the Attention factor ($W = 0.934$, p-value $= 0.077$), the Relevance factor ($W = 0.968$, p-value $= 0.517$) and the Satisfaction factor ($W = 0.930$, p-value $= 0.062$) may come from a normal distribution, while the difference in the Confidence factor ($W = 0.917$, p-value $= 0.029$) may come from a non-normal distribution.

Therefore, the independent samples t-test was only conducted for the results obtained from the Attention, Relevance, and Satisfaction factors, while the Mann-Whitney U test was performed on the results of the Confidence factor. Results indicated that the difference between the two groups was statistically significant for the Relevance factor ($t(46) = 4.063$, $p = 0.000$), the Confidence factor (Mann-Whitney $U = 37.500$, $p = 0.005$, 2-tailed) and the Satisfaction factor ($t(46) = 3.074$, $p = 0.005$). Through the use of multiple statistical tests, the level of significance of the four factors was confirmed.

5.2.3 Research Objective 3

As found in Research objective 1, students were highly motivated when they used our u-learning system. Indeed, data collected from the IMMS revealed that the experimental group assigned a mean score of 137.13 to the context-aware u-learning system, in a scale ranging between 125 and 160.

Table 5 displays descriptive statistics for the four factors that described students' motivation as participants in the experimental group. The highest mean scores were achieved from the Relevance factor ($M = 3.96$) and the Satisfaction factor ($M = 3.94$). The lowest mean score was assigned to the Attention factor ($M = 3.67$).

Table 6 lists the 12 questions that the experimental group responded to, which served to measure the Attention factor of the ARCS model. The highest mean score corresponds to Question 8 ($M = 4.07$), which indicated that the proposed u-learning system was attention-grabbing for participants. More than 80 percent of the students specifically reported that the proposed u-learning system helped to maintain their attention during the learning activity. Twenty out of 25 students in the experimental group disagreed with the statement that using our u-learning system to learn content was irritating (Question 31, $M = 4.00$). Moreover, 18 out 25 of the respondents indicated that there was something interesting at the beginning of the u-learning system that immediately caught their attention (Question 2, $M = 3.93$).

TABLE 6
Mean Scores and Standard Deviations of the Attention Factor from the Experimental Group

No.	Question	M	SD
2	The variety of interesting instructional materials presented at the start of the u-learning system immediately caught my attention.	3.93	0.46
8	The u-learning system is attention-grabbing.	4.07	0.59
11	The quality of the u-learning system helped to hold my attention.	3.80	0.56
12	The u-learning system makes the lesson so abstract that it was hard to pay attention to the lesson. (Reverse)	3.33	1.05
15	The teaching content and text that I discovered through the u-learning system looked unappealing. (Reverse)	3.47	0.83
17	The way the information is arranged using this u-learning system helped to maintain my attention.	3.73	0.59
20	Using the u-learning system for the learning activity to present information stimulated my curiosity.	3.87	0.74
22	The amount of repetition of the learning activity caused me to become bored. (Reverse)	3.20	1.01
24	I learned some things from the u-learning system that were surprising or unexpected.	3.73	0.46
28	The way the multimedia objects were arranged in the u-learning system helped to keep my attention.	3.20	1.21
29	The presentation of the u-learning system was boring. (Reverse)	3.67	0.62
31	The presentation of the u-learning system was irritating. (Reverse)	4.00	0.53

Table 7 showcases the mean scores and standard deviations of the nine questions employed in this study for measuring the ARCS Relevance factor of our proposed u-learning system. Five questions yielded mean scores higher than or equal to 4.0. Question 9 produced the highest mean score ($M = 4.47$), this indicated that more than 95 percent of the students were in agreement that the multimedia materials presented by our u-learning system conveyed to the participants that the content was important to know. Moreover, 23 out of the 25 participants in the experimental group indicated that it was important for them to complete the course successfully after using the proposed u-learning system (Question 10, $M = 4.33$). Finally, 21 out of 25 students answered that the content of the proposed learning system was relevant to their learning interests or objectives (Question 16, $M = 4.13$).

Table 8 summarizes the mean scores and standard deviations of the nine questions that were posed to the participants in the experimental group in our study, which focused on measuring the Confidence factor of the ARCS model. Question 1 yielded the highest mean score ($M = 4.27$), indicating that the teaching content presented by the proposed u-learning system gave participants the impression that the course would be easy. Twenty one out of 25 students indicated that they were confident that they could remember the course content after using the u-learning system (Question 13, $M = 4.13$). Twenty out of 25 students were in agreement that the organization of the content presented by the proposed system truly enhanced their confidence while learning about the instructional materials (Question 35, $M = 4.00$).

Table 9 shows the mean scores and standard deviations of the six questions targeted at measuring the Satisfaction factor of the ARCS model. The scores obtained for Question 32 resulted in the highest mean score ($M = 4.13$), indicating that more than 85 percent of the students felt positive and successful when learning instructional content through the use of the proposed u-learning system. Furthermore, 18 out 25 students reported that the proposed u-learning system assisted them in successfully completing the learning exercises, and they also enjoyed the learning process while using our proposed u-learning system (Questions 5, 21, 36, $M = 3.93$).

Regarding the questions with the lowest mean scores (Question 7, $M = 3.13$), we can assert that the use of the proposed u-learning system was not the main cause of the low score. Only seven out of 25 students indicated that they had a difficult time remembering the important points because the instructional materials presented too much additional information.

5.2.4 Research Objective 4

For this research objective in our study, we observed participants who were randomly assigned into the experimental group. Our objective was to determine whether the proposed

TABLE 7
Mean Scores and Standard Deviations of the Relevance Factor from the Experimental Group

No.	Question	M	SD
6	It was clear to me how the content presented by the u-learning system was related to my previous knowledge on the topic.	3.47	0.91
9	There was information that demonstrated how the u-learning system could be important to some people.	4.47	0.64
10	Completing this course successfully after using the u-learning system was important to me.	4.33	0.49
16	The content presented by the u-learning system was relevant to my interests and studies.	4.13	0.64
18	There are explanations or examples of how people used the knowledge or information in this course.	3.33	1.11
23	The content presented by the u-learning system conveyed the impression that the instructional content was worth learning.	3.93	0.73
26	This learning activity was not relevant to my needs because I already knew most of the information presented. (Reverse)	3.80	0.68
30	I could relate the content of this course to things I have seen, done, or thought about in my own life.	4.13	0.64
33	This learning activity will be useful to me for future applications.	4.00	0.38

TABLE 8
Mean Scores and Standard Deviations of the Confidence Factor from the Experimental Group

No.	Question	M	SD
1	When I first saw this u-learning system, I had the impression that this course would be easy for me.	4.27	0.46
3	The instructional materials and learning activity was more difficult to understand than I would have liked it to be. (Reverse)	3.53	0.83
4	After learning through the u-learning system, I felt confident that I had effectively learned the contents of this course.	3.87	0.52
7	The u-learning system presented so much additional information that it was hard to remember the important points from the instructional materials. (Reverse)	3.13	0.99
13	As I learned the information from the u-learning system, I was confident that I could remember the content.	4.13	0.52
19	It was difficult to understand the instructional materials in association with the real object. (Reverse)	3.60	1.12
25	After learning with the u-learning system for a while, I was confident that I would be able to pass a test on the course materials.	3.93	0.70
34	I could not really understand the instructional material that was presented by the u-learning system in this course. (Reverse)	3.40	1.06
35	The superior organization of the content presented by the u-learning system gave me confidence that I would be able to learn the instructional materials.	4.00	0.53

u-learning system could be suitable for liberal arts courses in a college level setting. We interviewed the experimental group using the u-learning system about their experience after the completion of the learning activity. The comments were all related to the proposed u-learning system, through which researchers collected information from participants regarding overall satisfaction and "learnability" from using the system throughout the learning process, as well as information about the difficulties faced while completing the learning tasks.

Regarding general system usage and overall satisfaction, the students in the experimental group were highly satisfied and enthusiastically engaged in their learning activities when using the proposed u-learning system. At the beginning of the activity, students first tried to use the u-learning system by themselves, and then they proceeded to help their peers operate the system once they were comfortable with the novel technology. Throughout the learning activities, we observed that the majority of the participants were eager to operate the u-learning system through the use of their mobile devices. The students had no problems at all in scanning QR codes and could easily navigate through the teaching materials presented by the u-learning system. Some of the comments stated by various participants revealed that they believed the use of the u-learning system was easy and enjoyable:

> *"I feel that the learning system made it easy for me to learn the related multimedia materials."*

> *"By using the learning system, I can learn multimedia materials without the teacher's assistance."*

> *"When I use the learning system to engage in learning, I am very excited to participate in the activities."*

> *"Audio and video files can make learning activities more fun."*

> *"Nice, its operating method is so easy. I can quickly learn how to use this learning system."*

Regarding the learnability of the u-learning system, several students in the experimental group willingly exerted high levels of concentration while engaging in the learning activities; they were enthusiastic to learn about the content presented by the proposed u-learning system. Furthermore, some students would go back to review teaching content they found particularly interesting. Upon completing the learning activities, we observed that close to one-third of the students formed independent, self-initiated discussion groups to discuss the features of the u-learning system. Some of the comments from participants are as follows:

> *"This system allows me to better focus on the teaching activities."*

> *"This system helps me to understand more about Dr. Mackay and Oxford College"*

> *"When I do not understand some information, I can watch or listen to the teaching content again. It helps me remember more information."*

TABLE 9
Mean Scores and Standard Deviations of the Satisfaction Factor from the Experimental Group

No.	Question	M	SD
5	Completing the exercises in this course gave me a satisfying feeling of accomplishment.	3.93	0.59
14	I enjoyed the u-learning system so much that I would like to continue to learn in this manner.	3.87	0.64
21	I really enjoyed studying with the u-learning system.	3.93	0.46
27	The feedback received after completing the exercises, or from other comments in this course, helped me feel rewarded for my efforts.	3.87	0.83
32	It felt good to successfully learn with the u-learning system.	4.13	0.35
36	It was a pleasure to learn from such a well-designed learning activity.	3.93	0.46

"This system provides clear explanations for me. I can quickly learn information and understand the legacy of Dr. Mackay."

"I can concentrate better through using this system versus reading books or attending class"

Moreover, participating students expressed their satisfaction with the learning experience, and they were very willing to use the proposed u-learning system in other courses via mobile devices. Students' comments are presented as follows:

"This learning activity was very entertaining. It is better than the conventional outdoor teaching method."

"I would be willing to take other courses that utilized this learning system."

"Is this a free application (APP)? May I install this APP in other mobile phones?"

During the course of the learning activities, some students encountered technical problems when attempting to access the wireless network. Sometimes, it was difficult to connect to our sharing server to download the relevant multimedia materials onto the students' mobile devices. Participants were able to solve the problem by waiting until after their peers were finished with the download(s), before proceeding with their own learning activity. We discovered that when many students accessed the system at the same time, the wireless network often became unstable. Moreover, participating students also gave other comments related to the problems that they faced:

"I suggest that the mobile devices should come equipped with headphones, because the volume accompanying the audio files was too quiet."

"If possible, the learning system should give a suggested timeline for each learning activity, so students do not spend too much time in one location."

"If possible, the teaching materials should contain more interesting stories about Dr. Mackay."

"I wish that the teaching content presented a deeper background on about Dr. Mackay and Oxford College."

Specifically, two students found that the teaching content and information presented contained a few mistakes. These students not only showed the identified errors to their peers, but also discussed the problems with their peers and subsequently provided the administrators with the correct answers.

6 Discussion

This study proposed that QR-ULMPS could encourage teachers interested in building a context-aware u-learning environment for their students to use QR codes that supports the delivery of course content via mobile devices. We wanted to see if the proposed u-learning system could serve as an instructional tool for motivating and engaging students in liberal arts courses, especially those conducted in an outdoor setting. The results were obtained by collecting and analyzing data from various sources, including questionnaire evaluations, midterm exam scores, direct observations and personal interviews. The following sections discuss the findings we uncovered in this study.

6.1 Feasibility of Instructors Using QR-ULMPS for Implementing Teaching Activities

From the results of the UTAUT-based survey, it can be concluded that QR-ULMPS was accepted as a useful tool for teachers in executing outdoor teaching activities. Based on the mean scores of each factor in the UTAUT model, the Performance Expectancy results revealed that teachers were in agreement that the QR-ULMPS can be helpful to their instructional work and enrich overall pedagogical value of their course. Regarding the evaluation of the Effort Expectancy factor, the results showed that teachers felt the QR-ULMPS was an easy tool to use and operate. In addition, the Social Influence factor indicated that the teachers believed that it was important how others encouraged them to use QR-ULMPS in the planning of their course content. In general, the Facilitating Conditions factor revealed that teachers were confident enough in their abilities and skills to be proficient in using the QR-ULMPS. From the above results, we can rationalize that the teachers are likely to accept and adopt QR-ULMPS into their courses.

The individual interviews were used to record the perceptions of the teachers and evaluate the acceptability of QR-ULMPS from the teaching perspective. In the study, the teachers responded positively to the use of QR-ULMPS in creating an ideal context-aware u-learning environment, and they also expressed interest in using this system in their other curricula. In addition, a majority of the teachers surveyed indicated that the proposed u-learning system could be helpful in motivating students' learning and attract students' attention. Therefore, these positive opinions and suggestions are in agreement with the results of the UTAUT questionnaire.

At the conclusion of the study, teachers provided suggestions of for how to enhance the overall usefulness of QR-ULMPS and improve the overall user experience. It was deemed necessary to debug various technical problems encountered and the teachers felt that the system required further advancements and upgrades. We also realized that it was crucial to instruct teachers on how to use the QR-ULMPS prior to the start of the course, and we must allow sufficient time for teachers to become familiar with the operation, configuration, and execution of the proposed system. There are also some limitations that must be addressed and explicitly identified to the instructors, so they may be better equipped to design course content that are conform to within the confines capabilities of the u-learning system. With sufficient practice and preparation, teachers can become confident in using QR-ULMPS as an effective course content delivery system that motivates students in the learning process.

6.2 Benefits of Using the Context-Aware u-Learning System for Students' Learning Motivation

We measured the impact of implementing the proposed u-learning system on student motivation by comparing the responses obtained from the IMMS, a survey that was administered to both the experimental and control groups.

The results revealed that the students in the control group were moderately motivated by the conventional teaching model, while the students in the experimental group were slightly more motivated to learn when the proposed u-learning system was used. This heightened motivational effect likely influences students' learning performance. The result of the midterm exam revealed that the students learning in the experimental group scored higher than the control group, demonstrating a significant improvement in learning effectiveness. This may be attributed to how the proposed u-learning system facilitated students' learning motivation and encouraged them to pay more attention in class.

From the results of the IMMS, the maximum difference of the mean scores from the control and experimental groups were obtained from for the Satisfaction factor. Thus, the positive impact of the u-learning technology on students' satisfaction provides a particularly encouraging result for future applications in the realm of education. Many studies have indicated that pursuing outdoor field trips through the specialized u-learning system can provide more interesting learning scenarios for students [4], [6], [7], [18]. Therefore, integrating such a learning application into the course curriculum can usually result in high levels of satisfaction after using this system.

The study also demonstrated that there was a large difference in the mean scores between the two groups when comparing the Relevance factor and the Confidence factor. Therefore, we believe that the learning content presented by the proposed u-learning system was crucial and relevant to students' learning interests and expectations. This novel learning method can give students confidence that allowed them to learn the required instructional content using the proposed u-learning system, and further encouraged participants to complete the learning tasks.

During the learning activities conducted within this study, the students who participated in the experimental group demonstrated high levels of engagement and enjoyment while using the proposed u-learning system to gain course related knowledge. These students expressed their satisfaction in terms of system usage, the possibility of receiving instructional content in different formats in the future, and the feeling of having control of the learning activity as they could explore certain topics further according to their own needs, or re-learn teaching materials as required.

Several students indicated that they achieved high levels of concentration when performing the learning tasks through the use of our u-learning system. They also claimed that this u-learning system could potentially support students in memorizing and understanding the necessary content required by the course objectives. Indeed, once the learning activities were completed, some students automatically formed discussion groups to discuss the features of the u-learning system, including some detailed analysis of the teaching material and any mistakes they discovered within the teaching content.

7 Conclusions and Future Work

This study proposes the use of a tool called the QR-ULMPS that truly helps teachers build a context-aware u-learning environment. In this new and technologically enhanced learning environment, students can interact with real-world problems, and further combine real-world resources with a wealth of digital world information to find knowledge appropriate to their needs. Therefore, QR-ULMPS was designed to resolve issues encountered when using conventional outdoor teaching approaches, which are often very time-consuming and labor-intensive. With a high level of technical support built into the QR-ULMPS, teachers can easily incorporate outdoor teaching activities into their domain knowledge, with demonstrable benefits in student learning and motivation.

In relation with the feasibility survey, the instructors participating in this study were able to learn about and use the QR-ULMPS to build a context-aware u-learning environment. The quantitative analysis proved that teachers were satisfied with the proposed QR-ULMPS. It is evident that teachers were also likely willing to continue using this technology and expressed interest in integrating the u-learning system into their other course curricula. These quantitative results reiterated the results obtained from the qualitative analysis that advocated the feasibility of instructors using QR-ULMPS. Therefore, although the QR-ULMPS is not yet mature enough to be used in a sundry of educational applications and domains, it can provide an opportunity for teachers to conduct classes that differs from, and quite possibly improves on, traditional teaching methods.

In reference to the benefits survey, the students participating in the experimental group indicated that they felt satisfied with the proposed u-learning system and achieved high levels of concentration while performing the necessary learning tasks. The quantitative analysis proved that students were moderately motivated by the use of our context-aware u-learning system. These quantitative results were complimented with the qualitative analysis and the midterm exam scores, which provided proof of the benefits of using this system in supporting the learning process. We believe that the proposed u-learning system not only results in positive effects on students' motivation, but our system can also promote better learning outcomes. Further studies should be conducted to validate this deduction.

Although this study provides persuasive results, it is advisable to conduct a similar research study that spans across an extended period of time to avoid the novelty effect, in which user performance typically improves when new technologies are introduced. It could be useful to determine what effect this system can have on student learning during a long-term study in which the proposed u-learning system can possibly result in greater benefits. Moreover, though our u-learning system seems to be innovative and interesting, a collaborative learning environment was not implemented for this study. It is expected that students who have the option to participate in collaborative learning through active discussions, knowledge sharing and problem solving are more likely to enjoy the learning process and solidify their knowledge acquisition [20], [21]. Thus, in our follow up study, we propose that a collaborative environment should be made available where students are encouraged to produce content, share u-learning materials, and learn collaboratively during outdoor activities. Furthermore, the parameters of this study only allowed for the recruitment of 48 student participants and we could not collect formal pre/post-test data to evaluate each individual's learning background and performance. Such limitations can result in imprecise experimental outcomes. Thus, the researchers aim to revise the experimental design to overcome these limitations, with efforts focused on recruiting participants and applying a formal evaluation process to provide more accurate experimental outcomes. Finally, we plan to implement standardized ethical consent policies in all of our follow up experiments because we believe that ethical approval must be obtained from legal institutions, and this action can ensure our evaluation process and study procedure is conducted with integrity and fairness towards all participants.

Based on the results of this study, we believe our work can encourage teachers to develop a context-aware u-learning environment, which supports students in obtaining adequate knowledge during outdoor teaching activities. We intend to provide engaging self-learning opportunities for students to review teaching content and brush up on related materials in a way that is suitable to their unique individual needs.

ACKNOWLEDGMENTS

This study was supported by the National Science Council of the Republic of China (Contract No. MOST 103-2221-E-156 -007 and MOST-103-2221-E-027 -061). Yen-Lin Chen is the corresponding author.

REFERENCES

[1] C.-M. Chen and Y.-N. Tsai, "Interactive augmented reality system for enhancing library instruction in elementary schools," *J. Comput. Educ.*, vol. 59, no. 2, pp. 638–652, 2012.

[2] M. M. Organero, P. J. M. Merino, and C. D. Kloos, "Adapting the speed of reproduction of audio content and using text reinforcement for maximizing the learning outcome though mobile phones," *IEEE Trans. Learning Technol.*, vol. 4, no. 3, pp. 233–238, Jul. 2011.

[3] V. Garaj, "m-learning in the education of multimedia technologists and designers at the university level: A user requirements study," *IEEE Trans. Learning Technol.*, vol. 3, no. 1, pp. 24–32, Jan. 2010.

[4] C.-C. Chen and T.-C. Huang, "Learning in a u-museum: developing a context-aware ubiquitous learning environment," *J. Comput. Educ.*, vol. 59, no. 3, pp. 873–883, 2012.

[5] C.-F. Lai, Y.-M. Huang, and S.-Y. Chen, "A M-learning content recommendation service by exploiting mobile social interactions," *IEEE Trans. Learning Technol.*, vol. 59, no. 3, pp. 873–883, Jul.–Sep. 2014.

[6] H. Peng, P.-Y. Chuang, G.-J. Hwang, H.-C. Chu, T.-T. Wu, and S.-X. Huang, "Ubiquitous performance-support system as mindtool: A case study of instructional decision making and learning assistant," *J. Educational Technol. Soc.*, vol. 12, no. 1, pp. 107–120, 2009.

[7] G.-J. Hwang, C.-C. Tsai, and S. J. H. Yang, "Criteria, strategies and research issues of context-aware ubiquitous learning," *J. Educational Technol. Soc.*, vol. 11, no. 2, pp. 81–91, 2008.

[8] Y.-M. Huang, P.-S. Chiu, T.-C. Liu, and T.-S. Chen, "The design and implementation of a meaningful learning-based evaluation method for ubiquitous learning," *J. Comput. Edu.*, vol. 57, no. 4, pp. 2291–2302, 2011.

[9] T.-Y. Liu and Y.-L. Chu, "Using ubiquitous games in an English listening and speaking course: Impact on learning outcomes and motivation," *J. Comput. Edu.*, vol. 55, no. 2, pp. 630–643, 2010.

[10] M. Virvou and E. Alepis, "Mobile educational features in authoring tools for personalized tutoring," *J. Comput. Edu.*, vol. 44, no. 1, pp. 53–68, 2005.

[11] E. Arendarenko, "A study of comparing RFID and 2D barcode tag technologies for pervasive mobile applications," Master's thesis, Dept. Comput. Sci. Statist., Univ. Joensuu, Joensuu, Finland, 2009.

[12] T. Lotlikar, R. Kankapurkar, A. Parekar, and A. Mohite, "Comparative study of barcode, QR-code and RFID system," *Int. J. Comput. Technol. Appl.*, vol. 4, no. 5, pp. 817–821, 2013.

[13] M. Virvou and E. Alepis, "Mobile educational features in authoring tools for personalized tutoring," *J. Comput. Educ.*, vol. 44, no. 1, pp. 53–68, 2005.

[14] W. Tsou, W. Wang, and H.-Y. Li, "How computers facilitate English foreign language learners acquire English abstract words," *J. Comput. Educ.*, vol. 39, no. 4, pp. 415–428, 2002.

[15] C. Y. Law and W. W. S. SO, "QR codes in education," *J. Educational Technol. Develop. Exchange*, vol. 3, no. 1, pp. 85–100, 2010.

[16] E. Ozcelik and C. Acarturk, "Reducing the spatial distance between printed and online information sources by means of mobile technology enhances learning: Using 2D barcodes," *J. Comput. Educ.*, vol. 57, no. 3, pp. 2077–2085, 2011.

[17] M. J. Weal, D. T. Michaelides, K. Page, D. C. D. Roure, E. Monger, and M. Gobbi, "Semantic annotation of ubiquitous learning environments," *IEEE Trans. Learning Technol.*, vol. 5, no. 2, pp. 143–156, Jan. 2012.

[18] Y.-M. Huang, Y.-T. Lin, and S.-C. Cheng, "Effectiveness of a mobile plant learning system in a science curriculum in Taiwanese elementary education," *J. Comput. Educ.*, vol. 54, no. 1, pp. 47–58, 2010.

[19] K. Verbert, N. Manouselis, X. Ochoa, M. Wolpers, H. Drachsler, I. Bosnic, and E. Duval, "Context-aware recommender systems for learning: a survey and future challenges," *IEEE Trans. Learning Technol.*, vol. 5, no. 4, pp. 318–335, Oct. 2012.

[20] G.-H. Hwang, H.-C. Chu, B. Chen, and Z. S. Cheng, "Development and evaluation of a web 2.0-Based ubiquitous learning platform for schoolyard plant identification," *Int. J. Distance Educ. Technol.*, vol. 12, no. 2, pp. 83–103, 2014.

[21] G.-H. Hwang, B. Chen, H.-C. Chu, and Z. S. Cheng, "Development of a web 2.0-based ubiquitous learning platform for schoolyard plant identification," in *Proc. IEEE 7th Int. Conf. Wireless, Mobile Ubiquitous Technol. Educ.*, pp. 259–263, 2012.

[22] X. Chen and J. H. Choi, "Designing online collaborative location-aware platform for history learning," *J. Educational Technol. Develop. Exchange*, vol. 3, no. 1, pp. 13–26, 2010.

[23] V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, "User acceptance of information technology: Toward a unified view," *MIS Quart.*, vol. 27, no. 3, pp. 425–478, 2003.

[24] C.-P. Lin and B. Anol, "Learning online social support: an investigation of network information technology based on UTAUT," *CyberPsychology Behavior*, vol. 11, no. 3, pp. 268–272, 2008

[25] E. M. van Raaij and J. J. L. Schepers, "The acceptance and use of a virtual learning environment in China," *J. Comput. Educ.*, vol. 50, no. 3, pp. 838–852, 2008.

[26] Y.-S. Wang, M.-C. Wu, and H.-Y. Wang, "Investigating the determinants and age and gender differences in the acceptance of mobile learning," *Brit. J. Educational Technol.*, vol. 40, no. 1, pp. 92–118, 2009.

[27] J. M. Keller and K. Suzuki, "Learner motivation and e-Learning design: A multinationally validated process," J. Educational Media, vol. 29, no. 3, pp. 229–239, 2004.

[28] J. M. Keller, "First principles of motivation to learn and e3-learning," *J. Distance Educ.*, vol. 29, no. 2, pp. 175–185, 2008.

[29] W.-H. Huang, W.-Y. Huang, and J. Tschopp, "Sustaining iterative game playing processes in DGBL: the relationship between motivational processing and outcome processing," *J. Comput. Educ.*, vol. 55, no. 2, pp. 789–797, 2010.

[30] K.-Y. Chin, Z.-W. Hong, and Y.-L. Chen, "Impact of using an educational robot-based learning system on students' motivation in elementary education," *IEEE Trans. Learning Technol.*, vol. 7, no. 4, pp. 789–797 , Oct. 2014.

[31] Á. Di Serio, M. B. Ibáñez, and C. D. Kloos, "Impact of an augmented reality system on students' motivation for a visual art course," *J. Comput. Educ.*, vol. 68, pp. 586–596, 2013.

[32] M. P. Fay and M. A. Proschan, "Wilcoxon-Mann-Whitney or t-test? on assumptions for hypothesis tests and multiple interpretations of decision rules," *Statist. Surveys*, vol. 4, pp. 1–39, 2010.

[33] S. S. Shapiro and M. B. Wilk, "An analysis of variance test for normality," *Biometrika Trust*, vol. 52, no. 3/4, pp. 591–611, 1965.

Kai-Yi Chin received the PhD degree in information engineering and computer science from the Feng Chia University, Taichung, Taiwan, in 2011. Currently, she is an assistant professor in the Department of Digital Humanities, Aletheia University, Taipei, Taiwan. Her research interests include computer-aided learning, multimedia applications, mobile technology, ubiquitous learning, and web technology.

Ko-Feng Lee received the BS and MS degrees in information engineering and computer science from the Taichung Feng Chia University, Taichung, Taiwan, from September 2007 to July 2014. Currently, he is working toward the PhD degree in information engineering and computer science from the Feng Chia University, Taichung, Taiwan. His research interests include computer-aided learning, multimedia applications, mobile technology, ubiquitous learning, and web technology.

Yen-Lin Chen (S'02-M'07-SM'12) received the PhD degree in electrical and control engineering from the National Chiao Tung University, Hsinchu, Taiwan, in 2006. From August 2009 to January 2012, he was an assistant professor in the Department of Computer Science and Information Engineering, National Taipei University of Technology, Taipei, Taiwan, where he has was an associate professor since February 2012. His research interests include image and video processing, embedded systems, pattern recognition, intelligent vehicles, and intelligent human-computer interactive systems. He is a senior member of the IEEE.