A framework for evaluating the mobile augmented reality systems for ubiquitous and interactive cultural learning

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Abstract: Mobile augmented reality (MAR) is an increasingly popular technology for enhancing how students interact with and learn about the cultural environment and cultural objects in the physical world. In order to ensure successful launch the mobile augment reality of cultural interactive learning tool, it is extremely important to predict the delighted value of design alternatives systematically based on the common language understood by both students and designers. However, the framework for communicating and evaluating such value from interested perspective is not available in the literature. Therefore, the objective of this research is to extract key frameworks of delighted value from interested perspective and develop an effective algorithm to evaluate MAR cultural learning system. These frameworks, name as CARE framework in brief, included communication, association, reflection, and engagement. The perception differences of MAR cultural learning paper prototypes were conducted to verify the validity of CARE framework for comparative studied. The findings of this study demonstrated that CARE framework was effective for solution designing in MAR cultural interactive learning tool.

Keywords: mobile augmented reality design; frameworks of delighted value; cultural learning; multimedia information systems.

Reference to this paper should be made as follows: Chiang, C-W., Cheng, L-C., Liu, J-W. and Lin, C-K. (2017) 'A framework for evaluating the mobile augmented reality systems for ubiquitous and interactive cultural learning', *Int. J. Applied Systemic Studies*, Vol. 7, Nos. 1/2/3, pp.154–173.

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This paper is a revised and expanded version of a paper entitled 'Developing the framework for evaluating the interaction design of mobile augmented reality systems for cultural learning' presented at The 5th International Conference on Frontier Computing, Toyko, Japan, 13–15 July 2016.

1 Introduction

Today, more than a third of all adults and more than 50% of all college students in the USA have smart phone. Commercially available smart phones have enough processor and graphic engine power to run augment reality (AR) applications, and network connectivity fast enough to download high resolution videos. Because many students carry mobile devices everywhere they go, providing educational material through devices strikes us as a prime opportunity to reach the aspirational goal of 'learning anytime, anywhere', which expands vision (Weiser, 1991) of ubiquitous computing (ubicomp) to everyday educational contexts.

Mobile augmented reality (MAR) which involves the dynamic overlay of digital information in the user's view through mobile device is an increasingly popular technology for enhancing how people interact with and learn about the environment and objects in the physical world (Bier et al., 1993). Using MAR on smart phones, it explore ways to draw students' attention and delighted value to the physical environment they are immersed. Moreover, delighted value is related to the cultural learning interesting on cultural emotional ground (Cristian, 2011). Delighted value has been described as a relatively enduring predisposition to attend to certain objects and events and to engage in certain activities (e.g., Krapp et al., 1992; Renninger and Wozniak, 1985). The psychological state of delighted value can also be generated by specific environmental stimuli and is referred to as situational interest (Hidi and Baird, 1988). Sometime, students pay attention to learning culture was influenced by their delighted value and environments. However, interactive learning design practitioners often misunderstand what students really need. That is, they often encounter the problems of not being able to know students' preference and reactions. This is a barrier that every cultural education seeks to overcome during the process of cultural interactive learning development. If a common language between designers and students could be found, such as the interests of culture frameworks of the MAR of cultural interactive learning tool, the interesting gap between the two could be effectively narrowed.

To address this issue, the objectives of this research include identifying the elements of cultural environmental learning dimensions that influence MAR learning delighted value, extracting the cultural interactive learning frameworks, constructing an evaluation method for applying the cultural learning frameworks, and examining the validity of the cultural element dimension frameworks and evaluation method through case studies.

2 Building on previous work

In this section, we review the types of MAR technology in physical environment and mobile learning for the cultural learning of our framework of evaluating the interaction design.

Technological advances revolutionised people's way of learning, working, and entertainment and lifestyle. MAR's extended mobility enables digital information to be displayed in more places away from the desktop, in the users' physical and personal world. This has opened up environmental opportunities for mobile learning (Gleue and Dähne, 2001). In MAR systems, augmentable targets can be streets, buildings, natural areas and objects, even people and other moving targets. MAR enables the physical environment to be directly annotated and described in situ, guiding users to pay attention

and get more interests to particular parts of objects in their environment (Höllerer and Feiner, 2004; Wellner et al., 1993). Thus, other than individual, environment situations, and topics, cultural learning environmental factors should be considered when developing new interactive learning tools and the influence of cultural environmental learning value factors on learning should not be overlooked. Therefore, designers not only need to gain a deeper insight to students' needs from environmental perspective, but also have to think in a whole new design paradigm (Sharp et al., 2007). If designers have an effective evaluation method to estimate the extent of perception of students, then this would be a great benefit to the improvement of design process and design quality.

In this paper, there were two parts of literature review relevant to this research topic. The first part summarised experts' view points on factors that influence cultural environmental learning design and compiled students' cultural environmental learning concerns for MAR of cultural interactive learning tool design. The second part explored the current application of using quantitative analysis in the domain of cultural learning to evaluate design strategies and alternatives.

2.1 MAR

Recently the technological properties of mobile devices have been harnessed in a combined way to employ a technique that has not been seen before on mobile devices: AR. It however remains unclear why augmented reality applications and mobile devices are such a good match and in what context it might be useful. To answer these questions, MAR extends the AR paradigm which is to display digital information in the user's view via head mounted displays or other displays, so that objects in the physical world and digital world appear to spatially co-exist (Milgram and Kishino, 1994). AR is often understood as part of the mixed reality continuum focusing on augmenting the real worlds (Azuma, 1993). In the following section, we discuss aspects of MAR that can contribute uniquely to students learning about objects or cultural environment.

2.2 MAR design and cultural environmental learning dimensions

Many researchers had developed methods for enhancing positive responses of cultural environmental learning on mobile devices or AR. In addition to mobile devices and AR, user experiences on the usage and the personal identification caused by learning device ownership are also important. Design is in fact a kind of communication (Norman, 2004). Designer must have a deep understanding of users' environmental learning and communication with them. In fact, changing the user experiences and design content was the common approach in either design driven innovation or user-oriented design (Veryzer and de Mozota, 2005).

To accomplish successful communication, the first and the most important issue is how to correctly measure learners' environmental responses. In order to address this issue, some measurement scales had been developed and applied to the filed on marketing and behaviour analysis on the web, such as pleasure, arousal and dominance (PDA) scale (Mehrabian and Russell, 1974), different environment scale (DES) (Hidi and Baird, 1988), and self-assessment-manikin (SAM) scale (Lang, 1985). Although these scales were effective for marketing and online shopping (Huang, 2001), they were not developed specifically for the purpose of physical MAR cultural environmental learning

design and evaluation. In addition, they did not cover the issue of measuring environmental responses due to learner experiences on MAR usage.

On the other hand, although interest has a strong influence on individuals' cognitive and affective functioning to measure learners' feeling and impressions and then translates them into MAR parameters (Ainley et al., 1998; Renninger, 2000; Renninger and Wozniak, 1985; Schiefele, 1996; Schiefele et al., 1992), the measurement was mostly on different feeling at the same level of hierarchy. In fact, the issue of learner experiences on MAR usage always had several levels of hierarchy from environmental perspectives.

Based on presenting in MAR systems and build new and personal experience with cultural environmental learning, Olsson et al. (2012) described that MAR can effectively evoke such experiences because of its visual and immersive way of visualising information and by providing the user with a very immediate and intuitive way to interact with the information. In their study of people using MAR services in shopping centres, Olsson et al. (2012) found that people expect MAR services to be not just efficient, but also playful, inspiring, lively, and even provide positive surprises related to the current situation and location.

2.3 Access to new perspective

Technological advances in our ability to measure the physical world and in our computer modelling capabilities have led to the creation of an increasing number of high fidelity 3D models of cultural heritage objects and environments (Koller et al., 2009).

Various types of imaging techniques, generally targeted at other applications, have been developed and are becoming ever more popular among conservators. Clearly, digital camera images and 2D scans of historic photographs remain useful in documenting works. Beyond these basic tools, however, advanced imaging technologies such as X-rays, hyper- and multispectral imaging, 3D scanning, and computed tomography (CT) imaging are being used with increasing frequency (Kim et al., 2013).

Smartphone technology is being adopted by museums, cultural heritage sites and other informal learning organisations as a means to extend interaction with visitors often incorporating location sensing for content adaptation, for example, to automatically identify proximity of the visitor to specific exhibits and present relevant information (Moussourl and Roussos, 2014).

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It seems that people are willing to accept simulated views presented in MAR systems and build new and personal experience with it. Olsson et al. (2012) described that MAR can effectively evoke such experiences because of its visual and immersive way of visualising information and by providing the user with a very immediate and intuitive way to interact with the information. In their study of people using MAR services in

shopping centres, Olsson et al. (2012) found that people expect MAR services to be not just efficient, but also playful, inspiring, lively, and even provide positive surprises related to the current situation and location.

In summary, instead of being immersed in a virtual world, MAR enables people to remain connected with the physical environment they are in, and invites them to look at the world from new, alternative perspectives. Through rich multi sensory simulations, MAR can project past, future, or new and alternative views on the user's environment.

2.4 MAR and situated learning

MAR's ability to extend the interaction space to places beyond the desktop, and provide unique learning experiences that advantage of both digital and physical worlds is of particular and timely interest to the mobile leaning community. A number of studies have shown that mobile learning provides the opportunity to transform informal and semi-structured field experiences into meaningful learning opportunities that contribute to a student's overall education (Merdich et al., 1997; Sefton-Green, 2003; Yeh et al., 2006). Students with enriched informal learning environments have been shown to achieve improved scientific reasoning ability. Learning in context can improve student learning by allowing them to connect personal sensory experiences in the field to curricular materials. These out of classroom learning experiences can engage students in the synthesis of science and technology and help develop their inquiry skills through active location-sensitive discourse.

In contrast to traditional classroom learning, mobile learning has the opportunity to take the abstract and decontextualised knowledge (often offered in the classroom) and apply it back to the real world scenarios the students are immersed in. Mobile learning can help situate the learning in the learner's personal environment outside of the traditional classrooms. Situated cognition theory suggests that knowledge cannot be separated from the context in which it is embedded and learning results from students acting in apprentice like situations in interaction with experts (Lave and Wenger, 1991). One of the primary challenges in scaffolding novices to become experts is helping them first develop a 'professional vision' – being able to see the world from an expert's perspective (Goodwin, 1994).

2.5 Virtual reconstruction, interactive design, and reflective design

In order to construct the framework of learner needs, a number of studies emphasized that the cultural environmental learning needs of MAR interactive design should include virtual reconstruction, interactive design, and reflective design. Similarly, Olsson et al. (2012) also proposed three-level concepts and described that MAR can effectively evoke such experiences because of its visual and immersive way of visualising information and by providing the user with a very immediate and intuitive way to interact with the information. In their study of people using MAR services in shopping centres, Olsson et al. (2012) found that people expect MAR services to be not just efficient, but also playful, inspiring, lively, and even provide positive surprises related to the current situation and location.

2.6 Summary of literature review

In absence of experts, can mobile technologies help scaffold novices by helping them see the world from experts' perspectives? If MAR can direct students more interest to explore the cultural environment by annotating the physical environment with digital information, can MAR direct students to discoveries the subject matter in certain ways that could be educational? Informed by the situated cognition theory, our goal is to explore MAR to simulate experts' perspectives and help designers engage in design process of frameworks.

Fulfilling the cultural environmental learning needs of students is becoming a critical issue in interactive learning design. Since it is difficult to express cultural environmental learning demands and calculate them using crisp values is an appropriate method.

Furthermore, to help designers make correct decisions, it is necessary to construct hierarchical frameworks that reflect the structure of cultural environmental learning needs from students. When such a framework is available, whether the evaluation method is robust enough to aggregate and convert vague expressions into quantitative values for comparing design alternatives becomes an important issue.

3 Development of the framework and the evaluation method

Knowledge and its management have been respectively accepted as a critical resource and a core business competency. Despite that literature proves the existence of a gap between the theoretical considerations of knowledge management (KM) and their efficient application. In an attempt to bridge this gap, an original, process-based holistic KM framework is proposed, aiming to address the problem of KM application and performance by utilising a set of well accepted enterprise modelling (EM) methods and tools (Stavros et al., 2007).

To provide a systematic method of estimate the perceived interaction of learning from cultural environmental learning perspectives, the research process was divided into three stages. In first stage, data about user experiences were gathered and organised through literature analysis and structured interviews, then a focus group encoded the interview content and defined elements. In the second stage, according to different age group and whether the participant has a design background, this study used a sample size over five times the elements size to conduct a larger scale questionnaire survey.

Then the authors used factor analysis to extract the cultural environmental learning dimension frameworks. In the third stage, three illustrative cases were used to test the sensitivity of the frameworks. The authors used Myers Briggs type indicator (MBTI) to classify participants' learning styles into thinking and feeling groups. Then, a pair wise comparison was used to collect their evaluation of different MAR interactive learning systems. At the end, statistical analysis was used to compare the performance of different MAR interactive learning systems in the CARE frameworks.

3.1 Exploring the elements of cultural environment learning dimension

To identify the elements that construct cultural environmental learning dimension, this study used literature analysis and structured interview with designers and students. The

results of interview then served as the data for a focus group to encode, select, and determine the elements.

As mentioned in previous, designers and students during the cultural environmental learning process usually do not have a common evaluation standard. To overcome this problem, this study first invited 12 participants with different levels of cultural interactive learning design or cultural working background. During the interview process, every participant needed to raise one to three related cases for explanation of their experiences of cultural environment learning and designing interactive with cultural environment. The content of the questionnaire included 12 open-end questions which worked from the cultural conservation and cultural images, and different levels of design and creation to encourage participants to deepen their thinking and investigate how to apply multimedia on cultural environment learning. By the end of this process, 12 cases with over 200 answered descriptions were collected.

These hundreds of descriptions were then discussed by a four group including scholars and experts with over 10 years of experience. The group used the factors from literature analysis as reference and the gathered cases during the focus group discussion. Through the process of encoding, similar cases were organised together and elements that could influence cultural environment learning value were drawn out.

Finally, the group classified the characteristics into 13 elements. They are cultural of conservation, cognitive geography, cultural visual imagery, knowledge of aesthetics, fusion design, elements transformation, creative opportunities, internal and art and external shape layers, special meaning, cultural story, cultural emotion, information services, and technology integration. These were used in the next stage when data reduction was used to extract the major factors of the cultural environmental learning dimension.

3.2 Extracting the major factors of CARE framework

Given the 13 elements obtained from the previous stage, the goal of this stage was to identify the structure among these elements through factor analysis. To help participant point out the factor that influences their cultural interactive learning efficiency. The elements of the factors were randomly permuted, with every element turned into a questionnaire. Participants selected from a nine-level liker scale to indicate the degree of possibility for cultural interactive learning efficiency based on the factor, with a range of 'not very possible' to 'highly possible', with scores from 1 to 9. Since the positive learning efficiency of every item gradually increases with a score, the scores could be added to facilitate subsequent analysis.

The result of the pre-test were analysed by factor analysis and the elements were analysed, deleted, merged or corrected, and at the same time common elements were found and give names to extract the key cultural environmental learning dimension frameworks.

This study at this stage gathered questionnaire surveys of 136 participants, which was compatible with the basic demand of the sample size of factor analysis. Among the 136 participants, 63 were male, 43 female; participants with no cultural learning background and those with cultural learning background were 50 and 56, respectively. There were 72 participants within the age range of 18–22 who are undergraduate students; 28 participants were within the age range of 22–24 who are graduate students.

After proceeding with the first factor analysis, according to the analysis result, the factor loading of 'cultural of conservation' and 'cognitive geography' did not exceed 0.50. Thus, these two relatively inconspicuous elements were deleted. The data then underwent the second factor analysis. The principle component analysis of factor analysis was used to extract common factors, and by choosing common factors with eigenvalue larger than 1 as the selection principle, four major factors were chosen, which explained 51.087% of total variance. By then using varimax method, the select factors were rotated, resulting in more significant and easily explainable factors. Detailed results are show in Table 1.

Table 1 The result of factor analysis for the cultural environmental learning dimension

Elements	*Factor 1*	*Factor 2*	*Factor 3*	*Factor 4*
Cultural visual image	*0.628*	0.097	0.108	0.369
Shape and form characteristics	*0.617*	0.245	0.353	0.261
Aesthetic exploration	*0.501*	0.343	0.253	–0.199
Cultural story	0.217	*0.665*	0.016	–0.013
Cultural emotion	0.274	*0.715*	–0.072	–0.048
Heritage value	–0.225	*0.56*	–0.159	–0.477
Fusion of old and new elements	0.19	0.245	*0.555*	0.288
Cultural elements transformation	0.375	0.004	*0.702*	–0.404
Information service quality	–0.172	0.086	–0.053	*0.851*
Technology integration	0.163	–0.054	–0.013	*0.8*
Innovation	–0.156	0.109	–0.007	*0.757*
Variance (%)	18.196	14.152	12.727	10.915
Cumulative (%)	18.196	34.594	48.556	61.069

Note: Italic text indicates the absolute value of factor loading is > 0.5

Factor 1 consisted of three elements. They were cultural visual image, shape and form characteristics, and aesthetic exploration. These factor loadings were within the range of 0.501–0.628. The eigenvalue was 1.820, which explained 18.196% of total variance. Given the first four elements were related to characteristics directly expressed by cultural aesthetic shape and cultural image communication, factor 1 was thus named as 'communication'.

Factor 2 consisted of cultural story, cultural emotion, and heritage value, with factor loadings within the range of 0.56–0.715. The eigenvalue was 1.415, which explained 14.152% of total variance. Since these elements allowed learners to invoke wonderful feelings or touching stories, Factor 2 was thus named as 'association'.

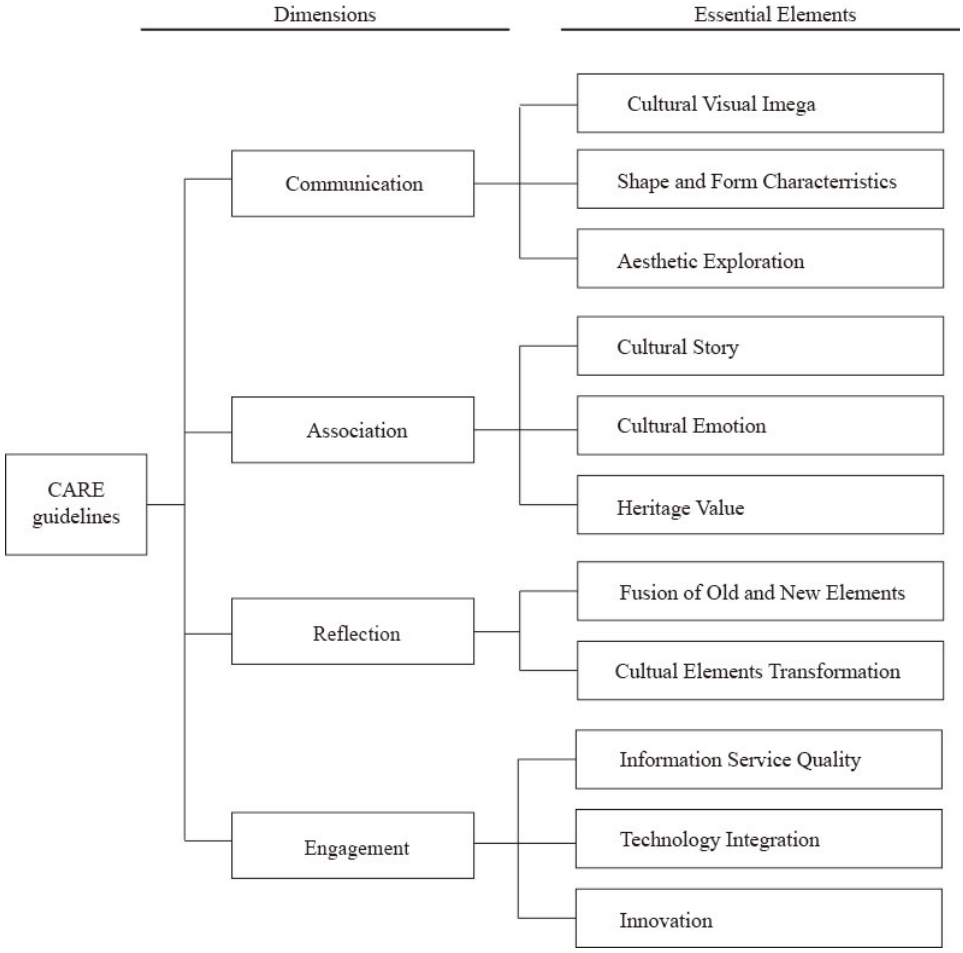
Factor 3 was main make up of Fusion of old and new elements and elements transformation, within the range 0.555–0.557. The eigenvalue was 1.092, which explained 10.915% of total variance. At the first glance, these two elements seemed unrelated, but in fact they had a common characteristic. That is, there were strong bond between learners' needs and design features. Learners benefited from these design

features and understood the knowledge of culture. In such a case, it is very difficult for the learners to stop thinking the culture. Thus, the authors borrowed a term from design connection and name the factor 'reflection'.

Factor 4 was mainly made up of information service quality, technology integration, and Innovation, with factor loading within the range of 0.757–0.815. The eigenvalue was 1.273, which explained 12.727% of total variance. Given that these elements were related cultural services and innovation complement, which were compatible with creations of need theory. Factor 3 was named as 'engagement'.

Based on the results of factor analysis, communication (C), association (A), reflection (R), engagement (E) were used construct the evaluation dimensions of CARE frameworks. This framework consisted of four dimensions and 11 evaluation criteria, as shown in Figure 1.

Figure 1 The four dimensions and 11 evaluation criteria of the CARE frameworks



4 Illustrative example and result

To test whether the CARE frameworks is able to distinguish the difference among MAR systems in cultural environmental learning dimensions, the authors collected data from 30 participants with different personalities, selected from different gender, age, and year from Taipei College of Maritime Technology. Those students are majoring in multimedia design, cultural creative design, and interactive design, and they will work on multimedia and cultural creative design spheres. It will help the research team to test the sensitivity CARE framework more accurately.

On the other hand, after studying design literature and interviewing the scholars of temples, the four person focus group with experts from academia research selected three well-known classic design mobile AR cultural learning system as experiment sample (Figure 2).

The MAR systems introducing the important cultural elements would show up to provide augmented information and 3D models on the mobile screen. In the MAR systems, animated characters and culture elements in the cultural objects were re-built to deliver the story of the ancient. These contents help students to understand the history and traditional cultural objects in the physical world.

Figure 2 Three famous and classical systems (see online version for colours)

Hybrid navigation system	Enjoyable informal learning system	M-learning platform system
		
Application: physical environment Devices: mobile Target: cultural environmental learning dimension	Application: physical environment Devices: mobile Target: cultural environmental learning dimension	Application: physical environment Devices: mobile Target: cultural environmental learning dimension

4.1 Illustrative case (1): hybrid navigation system

The subjects in the first illustrative case were hybrid navigation system which is a system that switches between the MAR and map views automatically. Technically, the system was designed to switch to the MAR view when the user enters inside of a specified radius of the location.

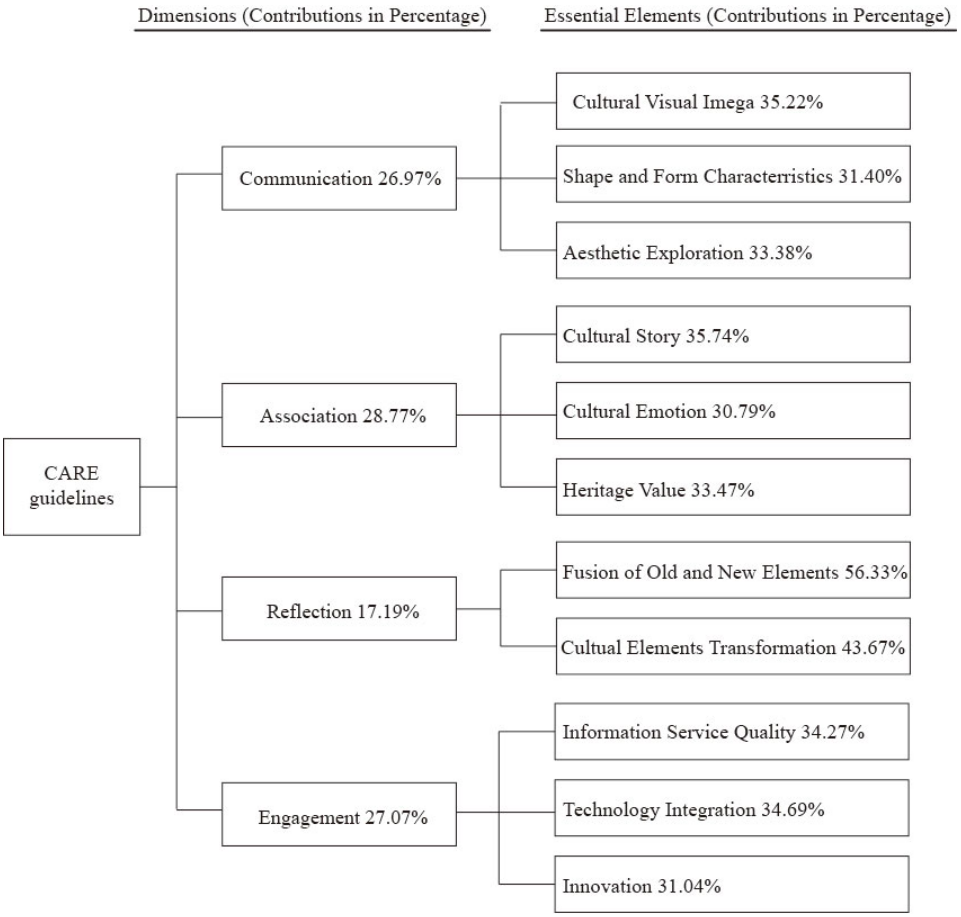
For example, at the Tamsui Fuyu temple, the system first shows the area on the digital map to guide on the regular temple path, but then it switches to the AR view so

that the system can show specifically which orientation the user should be facing and find the specific area (Figure 3).

Figure 3 Hybrid navigation system (see online version for colours)

Hybrid navigation system		
		
Hybrid navigation system detect the Tamsui Fuyu temple	The system first has the virtual world and the real world in the same time and same space.	The system switches to the AR view. User can be facing and find the specific area.

Figure 4 CARE Index test the perception of hybrid navigation system



The subjects from groups used the CARE index to test their perception of hybrid navigation system. During the questionnaire fill-in process, the research group first demonstrated the major characteristic function and encouraged the participants to personally operate and experience the products. After the participants completed the questionnaire, data were collected (Figure 4), and the detailed comments and evaluations of the prototypes were shown in Table 2.

Table 2 The advantages and disadvantages of hybrid navigation system

Styles	*Advantages*	*Disadvantages*
Hybrid navigation system	Using digital map to guide on the regular temple path, it's easy to fine the subject target.	The process is spend a lot of time on discover when the system switch to the AR view.
	The system automatic switches to the AR view. That makes more fun for students to discover the detail inside the temple.	The process makes users feel that there is no help when users have difficult time to use the AR view.
	Learn more knowledge about culture.	
	Using digital map, it is easy to navigate the temple tour and to find the whole subject targets inside the temple.	After the system switching to the AR view, the system lack for guiding or helping function. It make students more confusing when they try to detect more information.
	The system guide students to the subject target and automatic them to learn more cultural information by switching to the AR view.	
	After the system switching to the AR view, students can detect a few cultural elements in the specific area.	

Table 3 The advantages and disadvantages of enjoyable informal learning system

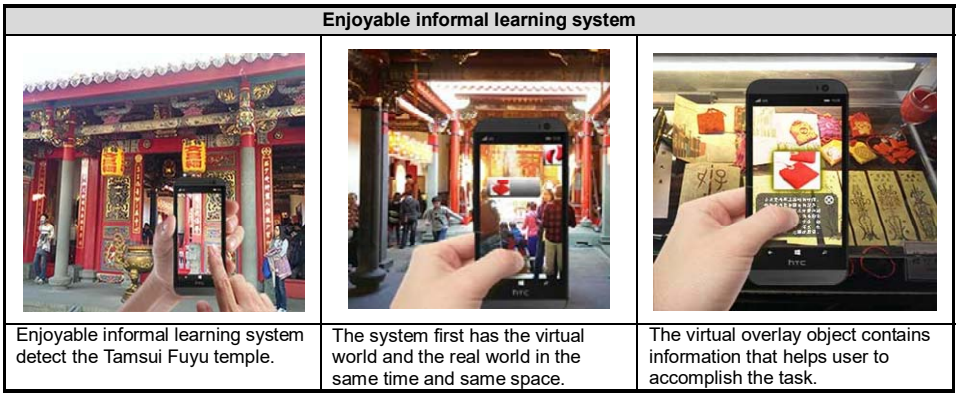
Styles	*Advantages*	*Disadvantages*
Enjoyable informal learning system	All digital contents display at the same time.	The process is lack of challenging for discover the major subject inside the temple.
	Full cover screen, it makes the important elements easy to control.	The process makes users feel that the system overlay too much information on mobile screen.
	Users could really pay attentions on the information and learning the knowledge. It is easy to find out the major subject elements.	
	Setup for the tasks, the system helps users to remember what they have saw.	
	It is save time for students to detect the important elements when all digital contents display at the same time.	Sometime, all digital contents displaying whole screen will make students more confusing to focuses on specific element to learn.
	The system can guide students to accomplish the task.	

4.2 Illustrative case (2): enjoyable informal learning MAR system

The subjects in the second illustrative case were enjoyable informal learning system which is a system that having the virtual world and the real world in the same time and same space. Technically, the system was helped user to perform their tasks by overlaying the virtual object that contains information that helps user to accomplish the task.

For example, at the Tamsui Fuyu temple, the system shows the area whole information, and enhances the visiting experiences. Then it switches to the challenges and activities tasks that embedded in the technology for users to feel enjoy. The activities should allow users to test their skills also makes users have the feel of control while doing the activities. Then, they can see the effect of their actions as a sense of personal power (Figure 5).

Figure 5 Enjoyable informal learning system (see online version for colours)



4.3 Illustrative case (3): m-learning platform system

The subjects in the final illustrative case were m-learning platform system which is a system that provides an AR-based m-learning platform for location aware learning. Technically, the system was contained context-aware ubiquitous learning, and augmented reality. In addition, the AR interface allows the teacher to coach students to recognise geographical location of each landscape.

For example, at the Tamsui Fuyu temple, the system can solve the problems of traditional field trip exploration. For the location-aware issue, GPS registers the student to the space of a landscape. It also allows students to immerse into the explored historical events of landscapes by using QR Code (Figure 7).

The subjects from groups used the CARE Index to test their perception of m-learning platform system. During the questionnaire fill-in process, the research group first demonstrated the major characteristic function and encouraged the participants to personally operate and experience the products. After the participants completed the questionnaire, data were collected (Figure 8) and the detailed comments and evaluations of the prototypes were shown in Table 4.

Figure 6 CARE index test the perception of enjoyable informal learning system

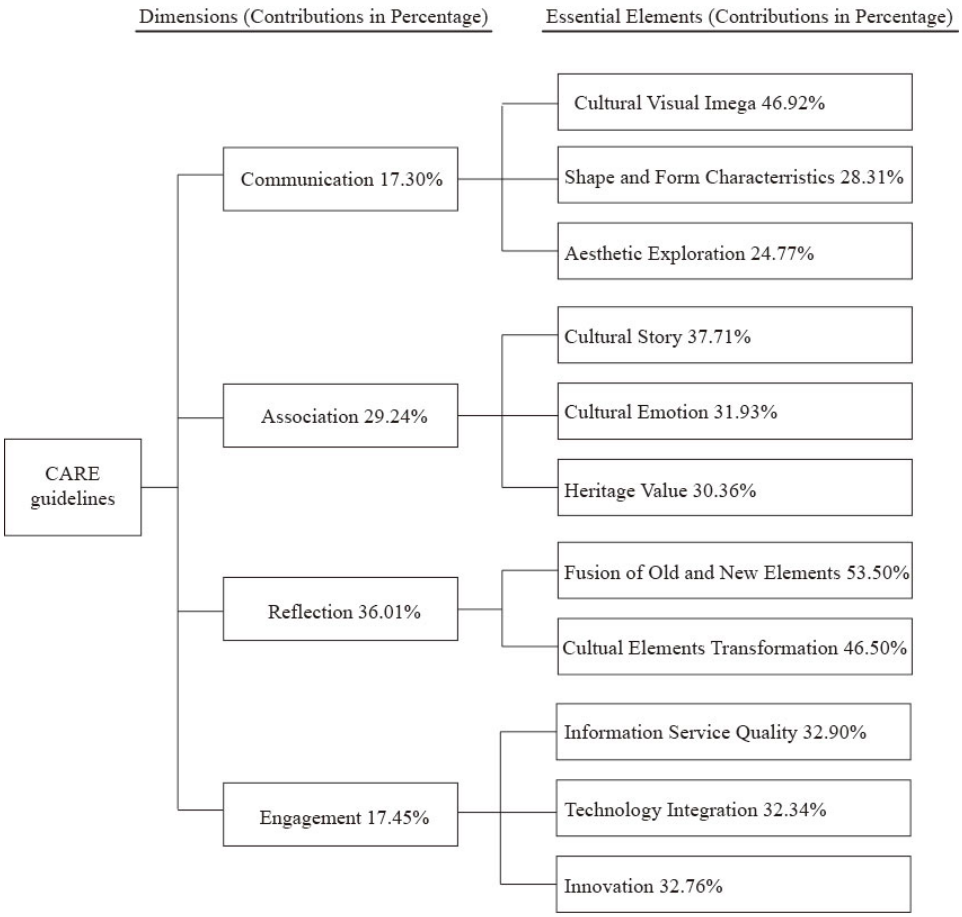


Figure 7 M-learning platform system (see online version for colours)

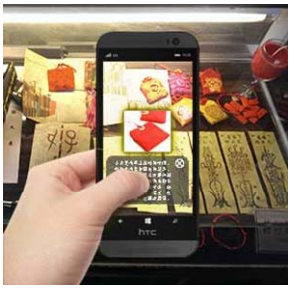
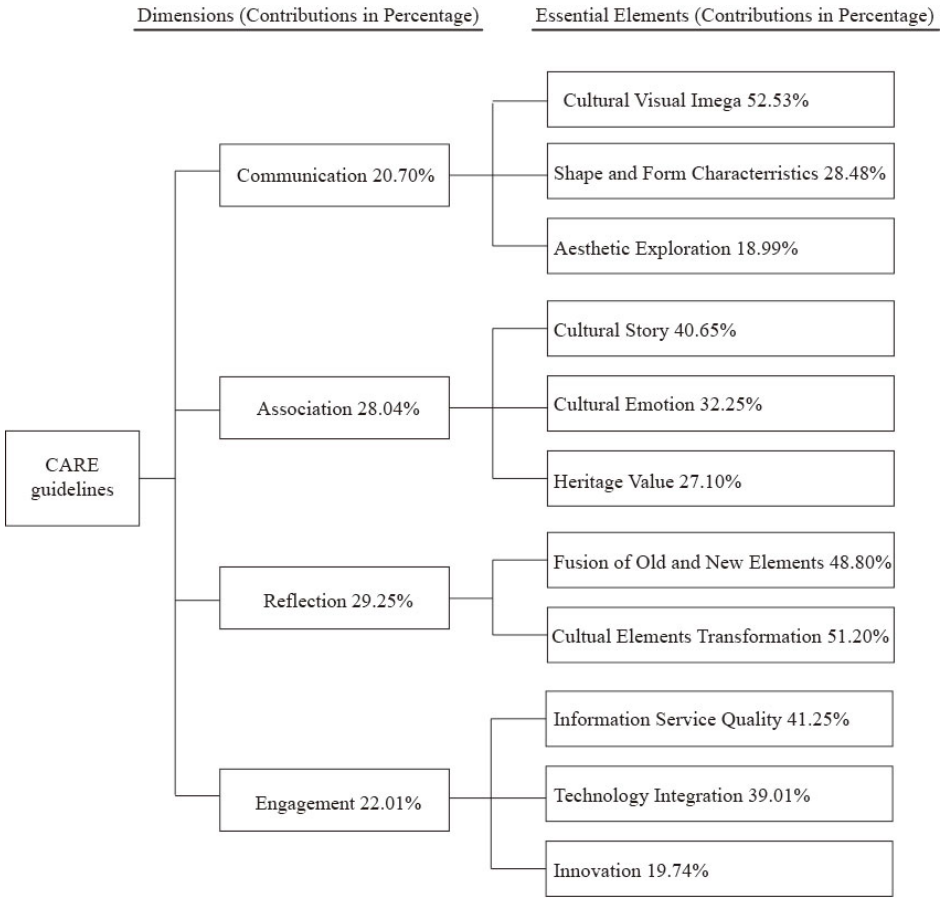
M-learning platform system		
		
M-learning platform system detect the Tamsui Fuyu temple.	The system recognise geographical location of each landscape.	M-learning platform contain context aware ubiquitous learning

Table 4 The advantages and disadvantages of m-learning platform system

Styles	*Advantages*	*Disadvantages*
M-learning platform system	The system interface allows the teacher to coach students to recognise location of each landscape.	The process is lack of challenging for discover the major subject inside the temple.
	The location-aware allows students to immerse into the explored historical events.	The process makes users feel that the tasks separate from the system.
	The add QR code function. It is easy for students to get more cultural information	
	The system interface directly guides students to explore historical events and detect cultural elements.	The learning process is passive. Students directly follow the orders and directions, and they do not feel too much fun on interactive learning.
	The system, including the location aware, help students to save time on whole interactive learning process.	

Figure 8 CARE index test the perception of M-learning platform system



Based on the analysis of cases (1), (2), and (3), CARE index was sensible to those cultural learning systems. In order to study that CARE index was useful for discriminating cultural learning systems, the authors compared studies among three cultural learning systems with respect to individual CARE index. The results showed that there were essential thoughts among three systems for all CARE index. The association and engagement ranked first in feature. The communication and reflection were considered the worst in association. According to this result, we can learn that to ensure successful launch the MAR of cultural interactive learning tool. Interactive designers most significantly need to think the association about cultural story, culture emotion, and heritage value, especially cultural story. In the engagement, need to consider about information service quality, technology integration, and innovation. Information service quality will be the key to help the users to learn the culture. During the design process, designers can also add some elements about communication and reflection to enhance cultural learning systems.

5 Discussions and conclusions

5.1 Discussions

Determining appropriate terms that could be understood by both designers and customers was a difficult task. While collecting the user experience data from participants, the authors did encounter the problem of analysing qualitative descriptions in different levels of abstraction. For examples, participants with the education background in design school or engineering school tended to provide their experiences more precisely than those without such backgrounds. Since the precision differed in the terminology and the level of details for judging products and providing comments, the authors had to carefully consider both categorisation and hierarchy issues in taxonomy. In fact, it took several iterations in selecting and determining the words in CARE index. Based on the responses from the participants in the heterogeneous and homogeneous product evaluation cases, these terms were easy to communicate. The research team provides a good table that compare CARE index with previous schemes on the main characteristics and contributions.

Table 5 The comparison of CARE index with previous schemes

Schemes	*Elements of frameworks*	*Advantages*
Coordination mechanisms	Conventions and shared practices: conventions and shared practices refer to the shared social and cultural understandings and beliefs that provide a foundation for coordination.	The proposed framework resulted in an effective design management tool, allowing us to perform design activities in compliance with the goal of sustainability.
	Verbal and non-verbal communication: spoken and written language, and non-verbal gestures are often used as primary means of communication for the coordination of activities.	

Table 5 The Comparison of CARE index with previous schemes (continued)

Schemes	*Elements of frameworks*	*Advantages*
Design management for sustainability	Eco-design: allowing engineers to perform environmentally conscious design and development of a product.	The frameworks previously mentioned provide general descriptions of how human cognition works across all contexts.
	Ergonomics and safety issues: design for sustainability concept.	The research work is focused on the integration of technical and environmental issues, helping designers in understanding the potential benefits of improving a product's relationship with its users.
CARE index	Communication: cultural visual image, shape and form characteristics, and aesthetic exploration.	The frameworks will bridges the gap between designers and students and help multimedia designer to design the MAR systems in cultural environmental learning more accurately and usefully.
	Association: cultural story, cultural emotion, and heritage value.	The findings of this study demonstrated that CARE framework was effective for solution designing in MAR cultural interactive learning tool.
	Reflection: fusion of old and new elements and elements transformation.	It is extremely important to predict the delighted value of design alternatives systematically based on the common language understood by both students and designers.
	Engagement: information service quality, technology integration, and innovation.	

In addition, selecting an appropriate and intuitive way for untrained customers to compare different products was another challenge. In fact, only a small group of the participants were familiar with the pair-wise approach of evaluation at the beginning of experiments. Some participants even needed intensive practices in order to deliver consistent results. However, when they got used to this approach, all participants reported that it was more intuitive and systematic than other methods they used before, especially in the cases that the delighted value cannot be measured quantitatively with available instruments.

5.2 Conclusions

Based on in-depth studies of the results from several experiments, this research had the following conclusions:

1 most literature provided the concepts or case studies of delighted value design qualitatively. In this study, the four dimensions of CARE index were derived from a large-scale survey and factor analysis. Furthermore, quantitative methods for evaluating the perceived value of consumer cultural learning systems from delighted value perspectives were demonstrated through three cultural learning systems evaluation cases

2 in the past, delighted value relevant to user experiences on cultural learning systems were seldom studied and discovered. Moreover, This will bridges the gap between designers and students and help multimedia designer to design the MAR systems in cultural environmental learning more accurately and usefully. From the results of this research, three dimensions out of the CARE index.

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