Developing recommendations for designing smart and ubiquitous learning environments to be used at outdoors cultural heritage

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Abstract. Cultural heritage carries the historical values from the past, cultural heritage therefore, reflects the identity of societies. Thus, it is important to support people learn from these sites, which could be achieved by introducing new tools to assist in this aspect. Designing such tools could be challenging, as they need to enhance visitors' engagement as well as enable them to explore sites smartly to well-invested their time with the rapid pace of life. This paper presents the development of recommendations for designing smart and ubiquitous learning environments for outdoor cultural heritage. A novel list of design recommendations is introduced as a result, which was shaped throughout a research project carried out to develop a theoretical framework for designing such services, FoSLE. A user-centred design approach was used in this research adopting the socio-cognitive engineering methodology. Three field studies were conducted to gather user requirements, which led to introduce the FoSLE framework. A set of general requirements was devised from the framework to guide the design of a proof-of-concept smart and ubiquitous learning environment, SmartC. SmartC was evaluated in the field by potential end-users in terms of usability, usefulness and acceptance; suitability for learning was also investigated. The results enabled us to draw the list of design recommendations presented in this paper. This list consists of three parts: content provision, learning experience design and interaction with context design.

Keywords: Design recommendations; wearable computing; augmented reality; mobile application design; usability evaluation

1 Introduction

The cultural heritage concept refers to passing cultural traditions and physical artefacts from the past generation to the present [1]. Nuryanti [2] points out that it is considered as cultural tradition of society, as it carries the historical values from the past. Cultural heritage, therefore, reflects the identity of societies [3] and it is considered the gateway people use to discover history. It forms a significant part of the tourism industry as it contributes to a country's income [4], [5]. Some people visit sites to learn about the history of the place or to enjoy themselves, while others want to feel the place and be emotionally connected with it [6], [7]. Promoting heritage tourism would be powerful by evoking visitors' emotions and offering them the feeling of sites back in time [8].

Experience is defined by the Oxford English dictionary as "something felt or learnt by personal contact" [9]. That therefore emphasises how important is to enhance the visitors' experience at sites by helping them feel places and hold the sensation of these places. That would help the experiences to stay for a long time in learners' memory, which consequently enhances learning from these sites, as heritage tourism is considered a form of informal learning. In addition, it helps enhances sites' interpretation as well as raise awareness of heritage places as it encourages more visitors to visit.

The interpretation of sites is a key element in this learning process as it helps visitors of sites (learners) to travel through time to visit the past [2]; in other words it brings the past to the present world. The interpretation of sites has witnessed a significant revolution as visitors constantly look for some sort of guidance when visiting sites to help them in understanding history better [10]. Human guides used to be the only known means in this context until technology started to take over [11]. Technology would be an excellent means for enhancing sites' interpretation as well as visitors' experience [12], [13]. However, technology could be frustrating for visitors sometimes if it could not meet the visitors' needs [14]. In order to lessen any frustration new technologies might cause and enhance visitors' engagements, technology needs to be developed based on visitors' requirements. This could be achieved by introducing tools based on visitors' requirements to help in designing such technologies (i.e. models, frameworks and guidelines). The review presented in the next section suggests that there are some tools that were introduced for designing such technologies, but very few of them were considered in the context of cultural heritage.

An important aspect about the cultural heritage context is the necessity of enhancing visitors' engagement with this experience, as well as enhance the interpretation of sites. Interpretation is not only about presenting factual information, but more importantly about evoking the emotional and intellectual connection between visitors and attractions [15]. That in turn, would promote the sense of loyalty and belonging to the community, as well as increase awareness of cultural heritage places, which consequently would encourage the conservation of sites. In addition, due to the fact that visitors need to go back home or return to other activities after the visit, investing the time smartly during the visits is crucial. Given that, technologies for cultural heritage contexts need some other aspects to be considered, which were not considered in previous models/ frameworks and guidelines, such as: (a) the content that learners consume to perceive history; and (b) interaction with the contexts, which could involve some important aspects, such as: activities that learners perform to take learning opportunities, resources and tools that mediate the performance, information format, and, the interface design that learners use to access services and activities. More importantly, visiting cultural heritage sites involves a lot of movements between artefacts and attractions in order to acquire information, which could be supported by providing information regarding attractions while moving, which we refer to as 'learning on-the-move'. This has not been given a great attention in previous studies, and needed to be explored further. Learning on-the move refers to acquiring information through ubiquitous devices automatically and intelligently and while people are moving without any intervention from the users, but automatically based on the context. The value of learning on-the-move is to support people receive information they are interested in on-the-move, which helps in saving their time and effort searching

for information. Additionally, the rapid pace of life nowadays leaves no much room for learning, so, learning on-the-move would be a good support for learners in this aspect. For the context of cultural heritage, learning on-the-move would be an excellent choice as visiting sites involves changing context and location, moving from one attraction to another.

According to the review conducted as part of this research (details in the next section), most of the tools using new technologies for cultural heritage sites considered only indoors settings. However, outdoors cultural heritage is as important as indoors, and it might need extra attention, as usually attractions are distributed around cities with no members of staff available, but with labels and sometimes limited audio devices [16]. Additionally, the context of outdoors sites is different than indoors, where variables such as weather and level of brightness (i.e. sun light), are easy to control. Thus, there is a need to explore further and deeper to better understand how variables of outdoor settings would affect the experience, and how visitors will deal with them; this would help researchers address challenges that might arise.

Tools such as models/frameworks and guidelines/recommendations that are designed with respect to outdoor cultural heritage sites are required to meet the particular needs of the outdoors cultural heritage in order to offer a pleasurable, informative and effective experience for visitors. Some aspects that could be essential for making the experience informative, pleasurable and effective, are: (a) supporting informal learning at outdoors cultural heritage sites; (b) supporting visitors/learners to learn on-the-move; (c) considering visitors' requirements; (d) considering the surrounding environment. These aspects would increase visitors' engagement, which is an essential element in such a context, as visitors perceive visiting sites as a form of entertainment. That in turn would enhance the experience, as well as learning from sites. Given that, this paper presents the development of recommendations for designing smart and ubiquitous learning environments to support informal learning at outdoor cultural heritage. A list of recommendations is introduced as a result. The list was formulated based on a research project that was carried out to develop a theoretical framework for designing such services. This research adopted the socio-cognitive engineering (SCE) methodology within the user-centred design approach [17]. A theoretical framework, *F*ramework f*o*r *S*mart and ubiquitous *L*earning *E*nvironments (FoSLE), resulted from three previous field studies [14], [16], [18], which were carried out to gather user requirements (more details in Section 3). A list of general requirements was devised from the framework, which informed the design of a proof-of-concept mobile application prototype, SmartC. SmartC was evaluated in the field to gain users perspective regarding using such services, which helped to shape the list of recommendations to assist designers in designing such services. The focus of the evaluation study was mainly on the interaction between users and the app as it is considered a key factor of the user satisfaction that would significantly enhance their engagement [19], [20]; it was evaluated in terms of usability, usefulness and acceptance; suitability for learning was also investigated in the evaluation study; the full details of the evaluation study is presented in this paper. An overview of the FoSLE framework and the adopted methodology are presented in this paper (see section 3 & 4). Some research studies were carried out with respect to outdoor cultural heritage, which conducted studies to evaluate similar technologies in the field, such as in [21], [22], [23], but no recommendations were pulled out for designing such services. This

research makes a contribution to knowledge by providing tools, i.e. a framework and design recommendations, for assisting in designing informal learning environments to be used at outdoor cultural heritage sites utilising mobile and wearable computing.

The rest of this paper is structured as follows: Section 2 provides an overview of the related work; Section 3 outlines the adopted methodology; Section 4 presents the framework; Section 5 presents the design of the prototype; Section 6 presents the evaluation study; Section 7 discusses the results; Section 8 presents the list of design recommendations; and Section 9 concludes the paper. The next section provides an overview of models/ frameworks and guidelines/ recommendations from previous research for designing ubiquitous learning services.

2 Related Work

Several researchers looked into the development of services that support learning at cultural heritage sites for both formal/non-formal [24], [25], [26], [27] and informal learning [28], [29], [30], [31]. These were developed for particular goals, e.g. formal learning for field trips [25] or a particular site [32], [33]. These works, however, did not focus on the development of a framework or model. Some models/frameworks were introduced to support designing new technologies [34-40], however, none of them was introduced for outdoor cultural heritage sites, where visitors are continually changing context for acquiring information regarding attractions. None of them considered supporting visitors to learn on-the-move nor enhancing visitors' engagements.

A few guidelines were designed with respect to ubiquitous learning such as for different context such as for teaching and learning e.g. [41], [42]. [43], [44]. Another context is cultural heritage such as in [45], [46]. In addition, Binsaleh and Binsaleh [47] introduced a set of guidelines for implementing mobile learning in the conflict area of the four southernmost provinces of Thailand. Another guidelines are introduced by Saleem et al.[48] but they were rather technical and could be used in several contexts such as: social networks, healthcare, and banking. However, they are not about learning, nor for outdoor cultural heritage.

From the guidelines presented so far, two guidelines were suggested for cultural heritage contexts, which are the guidelines introduced by Candello [45] and Winter [46] guidelines. The remainder were proposed for different contexts and different learning scenarios, which are not necessarily for designing technology, but rather to implement the learning environment by using mediating technology. Candello's research is mainly for interaction design, and more specifically interface design and content presentation. Winter's one is for museums settings, which are different from the outdoors settings as there is no weather effect and also artefacts are close to each other, unlike in outdoor settings. Nonetheless, it is clear that there are no specific guidelines or recommendations for designing smart and ubiquitous learning environments to support visitors learn at outdoors cultural heritage sites on the move. Thus, we introduce a list of design recommendations for designing smart and ubiquitous learning environments with respect to outdoor cultural heritage; the list was formulated based a framework and an empirical study that are presented in this paper. The next section presents a framework for designing such services.

3 Methodology

A mixed methods approach was used in this research within the SCE methodology [17]. SCE, is a user-centred design methodology, consists of two parts; analysis and design as shown in Figure 1. The analysis part concerns investigating how people perform their activities on one hand and studying theories that related to these activities on the other hand. In this research, we conducted a series of field studies adopting mixed methods using focus group, questionnaire and interview. The field studies were carried out to investigate how people use or may use mobile technology for learning purposes with respect to cultural heritage contexts. A task model in the form of theoretical framework, FoSLE, resulted from the field studies which acts as a base for designing new mobile-based technologies. General requirements were pulled out from the framework to inform the design of new technologies. The design stage of the SCE methodology involved the design space of a smart and ubiquitous learning environment, describing the requirements for the services, which were then translated into a prototype called SmartC. A brief overview of the field studies is given in Table 1.

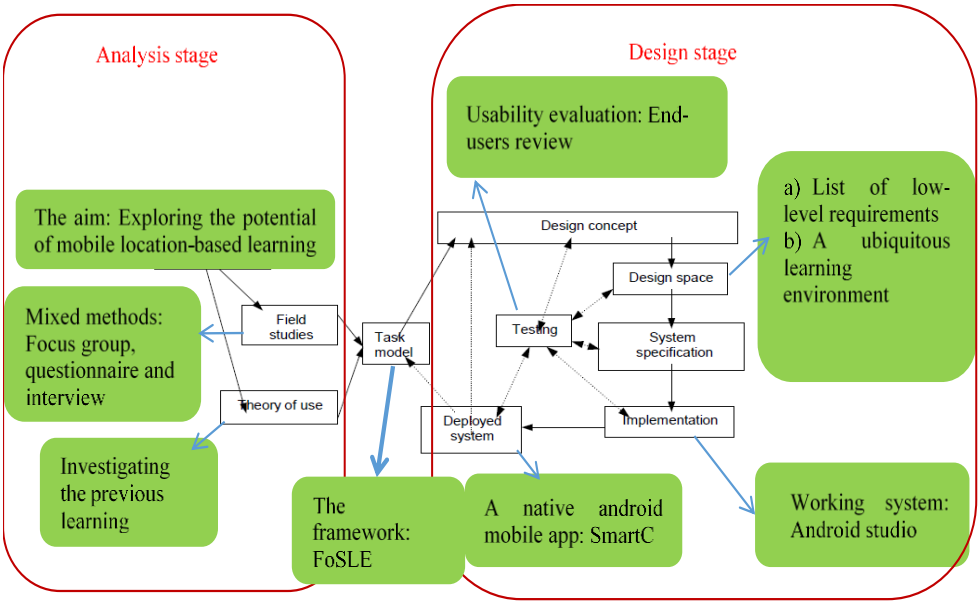


Fig. 1. Research methodology with the adopted methods and

Table 1. Illustrating the field studies that were conducted to formulate the FoSLE framework

Field studies	Participants	Methods and techniques
Focus group	Three males and three females from different background.; their age ranged from 28 to 50; all of them are familiar with mobile technology	Focus group discussion. Convenience sampling method. The thematic analysis method was used to analyse the qualitative data.
Questionnaire	189 from different background. Age ranged from 18 to 70+ years. 47% of participants were male and 52%; 1% skipped the gender question.	Self-administer questionnaire. Convenience sampling method. Simple statistical analysis method to analyse the nominal data.
Interview	Ten participants; two were cultural heritage staff who worked in the Historic Dockyard/ Portsmouth. Eight were potential end-users: age ranged between 28 and 70 years; two males and six females; one was polish and the remainder were British.	Semi-structured interview Convenience sampling method. The thematic analysis method was used to analyse the qualitative data.

4 The Framework

A theoretical framework for designing smart and ubiquitous learning environments based on mobile and wearable technologies was formulated based on three previous field studies – focus group, questionnaire survey study and interview [14], [16], [18]. Learning theories also contributed to this framework as they served as strength evidence to the framework, which will be mentioned where appropriate. The framework consists of six broad themes: learner, content, learning design, interaction design, context and challenges and obstacles. How we came up with each theme is illustrated in Table 2 with examples from each study as well as learning theories.

Table 2. The FoSLE's themes with examples from the field studies

Themes		Justification	Examples of extracted information from the field studies and theory of use
Learner		The learner is the core element in the informal learning process which is the person who is performing the learning. People visit cultural heritage sites individually, and in different types of groups (e.g. friends, family). Additionally, there are different types of people in terms of age, such as children, adults and elderly. Each type has different needs and different characteristics which need to be considered in designing new technologies for learning. The results of the survey show that learners would like to customise the app based on their interests to make it more personal; 62% of respondents ticked 'Yes' for customising their app. Six interviewees out of 8 preferred personalising their apps as they want to make sure they would have access to something they prefer rather than being bothered by something that they are not interested in.	'*…different people has different preference' (Focus Group, FG).* '*if you had like a particular interest in certain aspects of the site you can may be tailored to that, you can select what things are more interesting to you'* (Interview study (IS)) *'...perhaps that could be special apps for adults and children, students perhaps that can you trying to get more younger people interested in history because I think a lot of children when they go to historical sites they think it's boring so may be using this technology involves them more, engages them…' (IS)* 'in addition to the constructs of intelligence, and personality, there is also cognitive style as a distinct construct, and that style is different in nature and in the way it affects behaviour' [49] (theory of use (ToU))
Content		The results of the survey indicate learners like getting historical information while they are walking around, and finding out extra information about sites (e.g. public	*'... you can make [quizzes] in different levels…*' (FG) *'for learning from history, I think just giving me just sufficient information to understand the*
Learning material	Useful informatio		

Themes			Justification	Examples of extracted information from the field studies and theory of use
			services or opening times) as it gained 53% of responses. All interviewees agreed that the content is very important as it is the material that they use to learn. Six out of 8 interviewees wanted to know how we ended up having what we have in terms of cultural heritage.	*historical context of the social context of where I am, not too much information, I don't want it to be like a lecture, but just enough to understand this is would've been like at this period of time of history, this is why the building is here, this is would've happened in this building, this is what happened as a result'* (IS) *'I like to see pictures of the place as it used to look in the past'* (questionnaire study (QS)). '…*it can give you information like taxis, buses, it could be helpful or how far from the bus station*…' (FG).
Learning design			Learning is the main reason that drives people to visit cultural heritage site as 86% of the questionnaire respondents stated that. The other reason is curiosity as 70% of respondents stated that they like to investigate the culture of other countries. Another mentioned reason is envisaging the stories behind these sites (58%). All these reasons could be categorised under the learning theme. Thus, it is important to assist learners in designing their learning journey in terms of organising the visit and provide services to be used prior, during and after the visit It is important to provide different learning types such as: experiential, social, collaborative, situated and conversational learning	*'I would like to take my children to historical site to help them learn from them…' (FG)* *'...going around place with other people does mean there will be a conversation, conversation tends to improve memory so it gets you thinking more or probably remember more about the site because I've been talking with my friends and I might not remember that room very well but I will remember the conversation we had in that room about that statue or that painting or those artefacts…' (IS)* '…*is like a trigger that makes somebody who never use that kind of things go and use it…' (FG)* 'conversational systems which allow mental activities to be described in terms of dialogue and behaviour' [50] (ToU)
	Motivations	Types of learning learning preferences		

Themes			Justification	Examples of extracted information from the field studies and theory of use
Interaction design			Interaction design is considered a key aspect in drawing the users' attention to new technologies. As users deal with services via interfaces, it becomes essential taking good care in designing such services. Providing interesting information in multiple modalities for delivering historical information and also making it easy to use would help in motivating people to use this service. Also, learners use different resources and devices at sites. Learners would like to interact with the contexts using different services. Learners like to receive historical information in different formats and styles as the results indicate. The results of the survey suggested that images and texts are the most popular amongst respondents as 74% of respondents reported that they prefer images, 70% of respondents prefer texts, whereas 49% of respondents preferred video and 47% preferred audio. The results of the survey show that 72% of respondents prefer to receive formal information, 59% prefer to receive information as stories, 15% of respondents like quizzes and 13% like solving riddles that describes historical information.	,'*…[if the app is] more complicated, more interaction and more question you will lose number of users… ' (FG).* *'…they can listen to a story while they are visiting the site…" or utilise a quiz information style, "…quizzes for example…', (FG)* *'…probably want an app that connected to audio tours not visual, something that I can listen to [on] iPhone for example could track where I am then I would automatically know where I was and be able to give me the correct information based on where I'm standing' (IS).* (Seeing sites how looked in the past)*'…It's interesting because sometimes is difficult to visualise something when you can't [imagine] how would've been, so for me that's interesting especially may be somewhere is ruined…' (IS).* *'…I think the information that you receive and platform which presented to you or directly affect how enjoyable the experience was but also the amount of information you take back from it…' (IS).* *'[would like to have] Guidance about cost/walks & routes/family activities and "exterior" facilities would be useful.', 'Device needs to be flexible as user may not want it on all the time' (*QS*)*
Usability aspects	Adaptation	Interacting with the contexts		

Themes				Justification	Examples of extracted information from the field studies and theory of use
Contexts				Learning takes place at any time and in any context as there is no restriction of time and place for learning. The results confirmed that people use mobile devices for learning whenever they need regardless of time and place. Visitors experience sites differently such as individually or in a group, and within the groups also people come with friends, family or a guided group. All these aspects need different contexts for learning. Hence, considering different contexts could have a significant impact on the learning experience in which adaptation mechanisms can be considered to effectively respond to different surrounding environments and contexts of use.	'*…I might go to visit cultural heritage or historical sites if I am on holiday in another country*' , *'I would discover society's cultures, so the best way is to visit cultural heritage and historical sites…* ' (FG). *'…there is sort of dream like quality to going to older building and filling in the gaps for yourself and imagining and creating how it might have been, and imagining yourself may be with a princess walking down the amazing steps, you with a grand lady having tea in this room…'.(IS).* *'…I can remember that feel it is very personal, personal experience, when you with somebody else may be you talk about, oh its Jasmin that's interesting it feels beautiful, but may be you don't hold this sensation [of the place]' (IS).*
	in terms of time	in terms of places and settings	in terms of types of visit	in terms of learners' physical **state**		
Challenges and obstacles				Although learning in outdoors settings has its own benefits, it might raise some challenges with using mobile services such as weather issues. In addition, using mobile technology at sites might raise some issues as the results highlight such as finance.	*'…I think it [technology] takes [away] some of the dream and the fantasy…', '…I don't think and I don't think I would [use technology at sites], I know personally I would get frustrated with technology instead of enjoying being in historical place, that for me is the extreme opposite*

Themes					Justification	Examples of extracted information from the field studies and theory of use
Confidentiality issues	Financial issues	Tools and devices related	Surroundings related **issues**	Learners related issues	23% of participants noted they do not use mobile devices at cultural heritage sites for several reasons: (1) 57% of them stated that the mobile device distracts them during the tour, (2) 20% of them do not use mobile devices due to the poor network quality, (3) 13% of them reported that it is not easy to follow the instruction, (4) 11% of respondents said that the available applications do not meet their needs.	*of the experience that I want to have, I want to get lost in the history and in the time before technology'(IS).* '… *[people] may not feel comfortable with something knows where they are…*' (FG)

The FoSLE framework was designed for assisting researchers and designers who are working in the field of technology enhanced learning with respect to cultural heritage. FoSLE is for designing smart and ubiquitous learning environments for outdoor cultural heritage. It supports informal learning on-the-move at sites with the aim of enhancing sites interpretation as well as visitors' engagement, which consequently enhances their experience. The framework consists of six broad themes that act as resources of information to feed into system design (see Figure 2). The general scenario for using the framework could be summarised as follows:

Scenario: The framework provides information for developing such services to be implemented in a smart and ubiquitous learning environment (S-ULE) system, which the learner/visitor will use to interact with the real-world (i.e. outdoors cultural heritage contexts). The use of the framework will be through a set of general requirements, which then should be translated into features and service in a working system. Figure 2 illustrates the scenario.

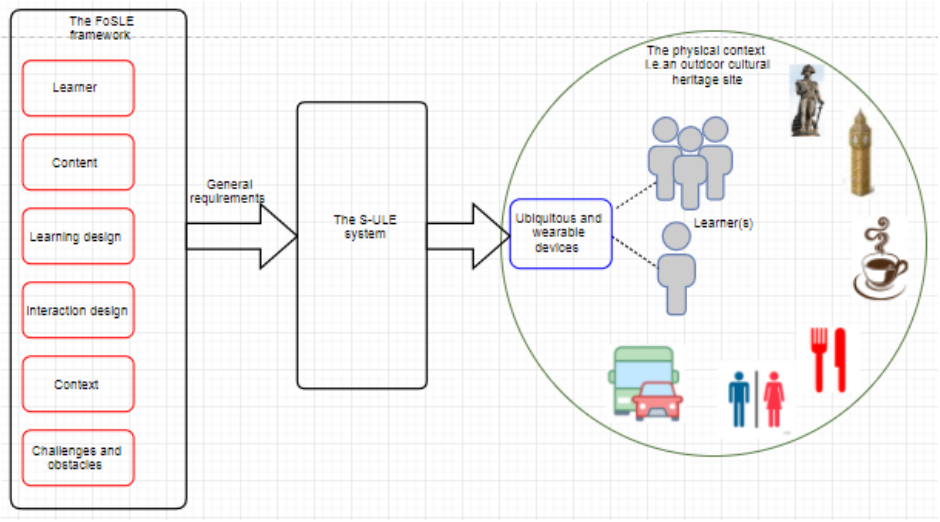


Fig.2. The general scenario of using the framework

The information provided by the framework are listed below:

1) The learner theme provides information regarding learners, such as learner characteristics, in order to provide a better experience for learners based on their profile.
2) The learning design theme offers aspects that are related to the learning journey including learning preferences and motivations for visiting sites.
3) The Interaction design theme offers aspects, such as services and devices that will be used by learners to access contents whether it is learning materials or other information to assist learners taking the learning opportunity effectively.
4) The content theme provides information regarding content to be included in such services, which will be accessed using the aspects provided by the interaction design theme.
5) The contexts theme provides insights of the potential contexts of use that learners perform whether is the surrounding environments or the context learners use to learn at sites.
6) The challenges and obstacles theme provide insights of the potential challenges that learners might encounter while using such services at outdoors cultural heritage sites. These insights need to be considered in all the above themes to provide a worthy learning tool that makes the learning process even smoother instead of adding more pressure on users when using technology at outdoors setting of sites.

To use this framework efficiently, researchers and designers are advised to choose the part that better serves their design or use the whole framework to fulfil their work as there is no restriction for that. The main concept of it, is to make the design serve the learner in the best way to obtain a better learning experience at sites with the minimum challenges as possible. The next section presents a mobile application prototype that was developed based on the FoSLE framework and the general requirements that were extracted from it

5 Designing a Prototype

A mobile application prototype, SmartC, was design based on a subset of general requirements (GRs) that were extracted from the FoSLE framework. The general requirements along with framework's themes are presented in Table 3.

Table 3. General requirements and the framework themes they are belong to

Framework's theme	General (GRs) Requirements
Learner	GR1: The service should maintain a learner model
Content	GR2: The service should maintain a content object
Learning design	GR3: The service should help to generate learners' interest:
Learning design	GR4: The service should support different learning types and preferences

Framework's theme	General (GRs) Requirements
Learning design	GR5: The service should support learning on- the- move
Learning design	GR6: The service should support learners to communicate with each other
Interaction design	GR7: The service should support learners interact with context easily and efficiently
Context	GR8: The service should support learners to take a learning opportunity in different contexts
Challenges and obstacles	GR9: The service should consider the challenges that might arise in using mobile devices in outdoor settings.

The given general requirements were further analysed to draw out more detailed requirements (low-level requirements (LRs)) and consequently translated into features and services into a working system. Table 4 illustrate the features involved in designing the prototype alongside the GRS and LRs.

Table 4. Linking the adopted features to their GRs and LRs

GRs	LRs	Features
5	Delivering instant information regarding historical places when passing by	Receiving notification on-the-move
2 & 7	Provide different information format to deliver historical information	Multi-mode information format (i.e. text, audio, video & images)
7	Adopt a feature that enables learners to immerse themselves in the experience and use their senses to experience the life back in time	Use augmented reality to show how sites appeared in the past
7	Allow learners to use wearable and immersive technologies at sites	Harnessing smart eye glasses
9	Handling the potential errors	Error and process messages

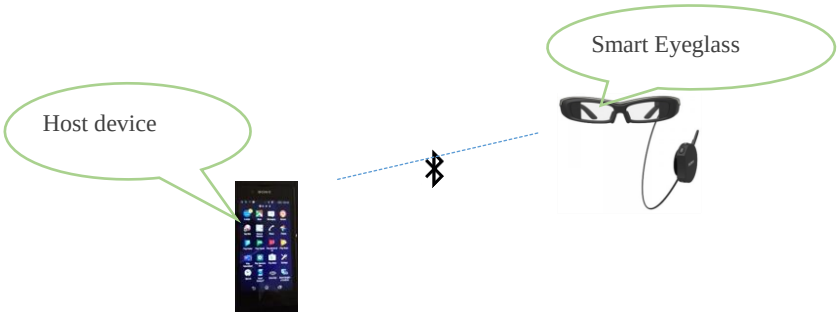
5.1 Architecture of SmartC

SmartC is a native android app, which was designed for smartphones and to be used in outdoor cultural heritage settings. A Sony XPERIA android device was used throughout the design and implementation stage. Sony android smart eye glasses were used in this research which helped investigate how learners react to such devices in the

field. The smart eye glasses device is connected to the mobile phone via a Bluetooth connection.

Android studio was used to develop this app. A database (SQLite) was utilised to store data and the Java programming language was used to handle retrieving information when requested by learners. The database is saved on the mobile device itself, thus, once the app is downloaded into the device, no internet connection is needed to retrieve content unless it is a video information format, in which case an internet connection is needed to retrieve it from the cloud (this was done due to the large size of video files).

This app uses geo-fence technology, which is placing a virtual boundary around a geographical area. It works when a user enters or leaves the area, which is identified by latitude and longitude of the area [51]. For this app, a circle shape of a radius of 100m was used to identify the geographical area of each involved attraction. The mobile device gets triggered when a learner enters that virtual zone, which is tracked using the global position system (GPS) of the device. The device pushes a notification to alert the learner when he/she gets close to an attraction. Notifications are pushed via the app through the mobile-based interface and the glasses-based interface simultaneously when the mobile device gets triggered (see Figure 3). It is important to clarify, setting a radius of 100m might sounds a big distance for attractions that are located in the one single site such as the Historic Dockyard in Portsmouth. However, it was used to overcome a technical issue that was captured during testing the app in the very early stages of the design. The issue was that the location of some attractions is quite deep inside the attraction yard, which is hard to be picked by the device unless learners get very close to the attraction, which they do not necessarily do (more details in Section 5). The next section describes the working system, SmartC.



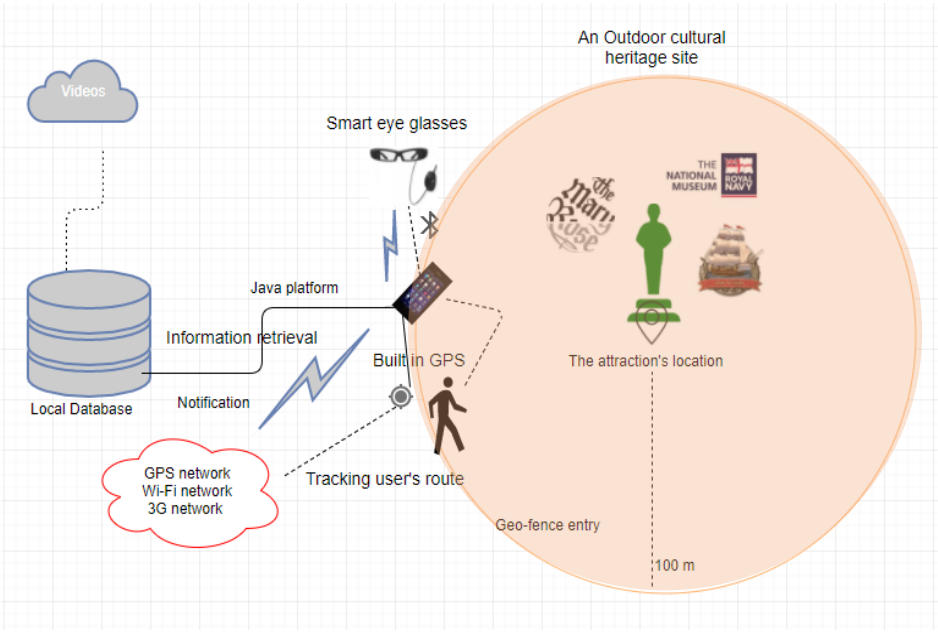


Fig. 3. The illustration of the architecture of SmartC

5.2 SmartC: The Working System

The previous section outlined the requirements that have been chosen to be fully implemented. The adopted requirements were translated into features and services in this version of SmartC, which responded to the most popular activities that resulted from the field studies, which are: (1) receiving notifications based on the location, (2) multimode information format and, (3) seeing sites in the past. SmartC utilises location-based services (LBS) to identify visitors' location, which in turn, allows the device to provide contextualised information about nearby cultural heritage sites. In addition, it utilises augmented reality (AR) technology to show attractions how they appeared in the past. AR is an excellent feature that would enhance learners' experience in outdoors settings of cultural heritage sites as it helps to enhance the real world instead of replacing it [29]. AR technology could satisfy learners' imagination of how sites appeared in the past and how people back in time used to live. Moreover, the wearable computing employed in this research could facilitate delivering information to learners in an unobtrusive manner through smart eye glasses, which would enhance learners' engagement. Smart eye glasses free learners' hands while walking in outdoors setting of sites. In addition, they would help engage learners' sight with the attractions they are looking at while simultaneously receiving information regarding these attractions; thus they do not need to move their sight back and forth between their mobile device and the attractions that might prevent them from being emotionally engaged with the attractions. SmartC provides different services and functionalities to assist learners in their learning journey at cultural heritage sites, which include:

1. Receiving notifications based on location: Learners get an alert when passing close to an attraction in the form of vibration and sound to inform them there is an attraction nearby which could be interesting. Notifications are delivered through mobile devices and smart eye glasses simultaneously. Learners have a choice to access information about that attraction or abort it if not interested.
2. Multimode information format: learners can receive historical information in different information formats (i.e. text, image, audio & video), which offer a wide range of choice to accommodate different preferences.
3. Seeing attractions how they looked in the past: this service gives an opportunity for learners to see how attractions used to look back in time, which helps to brings past to life. This service uses AR technology to attach an old image to a live camera view when the device is facing the attraction. In the other words, it is a location-based service.

Learners can access these features through the app' interface; details of the interface design are given in the next section.

As SmartC was designed for outdoor settings of cultural heritage, it was important to choose a site that contains several outdoors attractions. Thus, it was decided to choose a local and well-known site in Portsmouth, i.e. the Historic Dockyard, to conduct the evaluation study. The advantage of the chosen site is that it includes several attractions located in one large site and that they are relatively near to each other, which makes it easier for experts and users to walk around and take a quick tour in a small period of time (during the evaluation session).

5.3 The SmartC Interface Design

SmartC is a context-aware system to help learners of cultural heritage sites to comprehend the history of these sites on-the-move. Learners receive instant historical information while they are walking close to attractions in outdoor cultural heritage settings. SmartC is designed based on mobile and wearable technologies; details of the interface based on both technologies are given below.

Mobile-based interfaces. The mobile-based screen has five main interfaces that respond to the users' actions, which include (see Figure 4):

1. The main interface contains an image of the app's logo and two switches that enable users to switch the notification ON and OFF according to their need, and also a message area that changes based on the action. In addition, an overlay message appears on the screen to explain how the app works when users launch the app for the first time.
2. The notification message comes in a dialogue form and contains the name, image and two options, i.e. to view details or cancel, which enables users to choose what they want. The notification could be viewed through the mobile device and the glasses (see Figure 5). However, in this version of the app, the learner needs to use the mobile phone only to access the historical information.
3. When users choose to have more details, they will be directed to an attraction's page. The attraction's page contains the main navigation menu that leads to access functions and services (i.e. 'audio', 'see it in the past' and 'more which

contains ‘video’ and ‘camera’). In addition, a text area overlays the image of the corresponding attraction to display a description related to the attraction.

4. The ‘See it in the past’ page shows an old image of a certain attraction attached on a live camera view when facing the corresponding attraction.

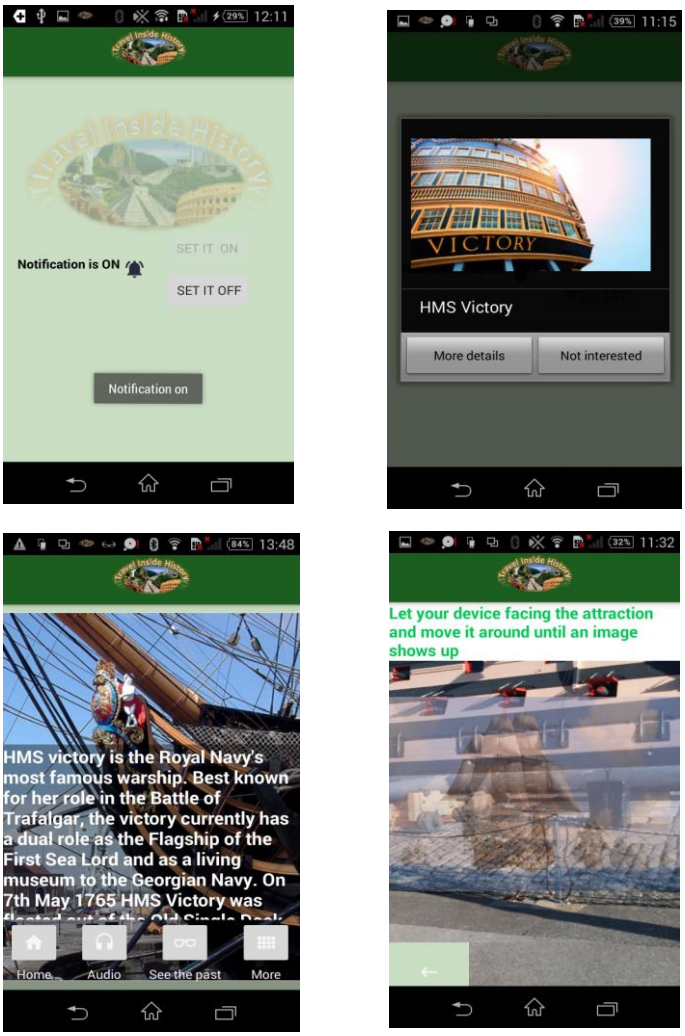


Fig. 4. The main screens of SmartC

Smart Eye Glasses-based interfaces. SmartC pushes notifications through smart eye glasses simultaneously with the mobile device. Different interfaces were designed to display a notification through the glasses (see Figure 5):

1. The name and the logo of the app appear on the glasses when no notifications were pushed.
2. The notification comes up on the desktop interface of the glasses in the form of sounds and a flashing icon, to inform the learner there is an attraction nearby.
3. The notifications' interface with the name of the attraction can be viewed, which gives learners an opportunity to see if the attraction is of interest before taking their mobile phone out of their pocket to access more details.

Fig. 5. Illustrating the notification of SmartC in the Smart Eye Glass

6 Evaluation of the Prototype – User Study

A user study was conducted to evaluate the SmarC app that was designed to be used at outdoor cultural heritage sites. This study was carried out in order to obtain users' feedback regarding their experience in using the app, which, in turn, helps to capture usability issues.

6.1 Methods

This study used potential end-users to evaluate the app. A combination of three methods was used which includes: questionnaire, observation and a brief group interview. The convenience sampling method was used to recruit participants via emails and social media. A permission to use the Historic Dockyard in Portsmouth, UK, as a proof-of-concept was obtained from the authorities of the site. Participants were given android devices with the application and a sheet contains a description of how the app works. They were asked to use the app while they were walking at the site.

Study design. The study was carried out in four sessions which took place at the Historic Dockyard between 10th and 12th October 2016; each session lasted around 2 hours; the tour and the discussion took around one hour each. This study used a combination of three techniques: questionnaire, observation and group interview. The questionnaire technique involves different types of questions: scale of five, closed questions of two choices (yes/no) and open-ended questions. The questionnaire consists of three sections: usability evaluation, features rating, and overall acceptance.

Fig. 6. The user study

The usability section consists of six categories that were adopted from ISO metric questionnaire [52]. The categories are: suitability for learning, self-descriptiveness, controllability, conformity with user expectations, error tolerance, and learnability [53]. The category 'suitability of individualization' was omitted as the related features to this category were not included in this version of the app for pragmatic reasons. Each included category involves a set of statements that participants were asked to state to what extent they agree or disagree with. A Likert scale of five was used, where 1= predominantly disagree and 5= predominantly agree. Moreover, participants were given an opportunity to indicate 'No opinion' to prevent a random selection.

This study also gathered users' feedback regarding the app's features in order to find out how useful these features were to users in their learning journey. Participants were asked to rate a number of features of the app on a scale of five giving that 1 = useless and 5 = useful. Furthermore, participants were asked regarding their overall attitude towards this app.

A brief group interview was held with participants after filling the questionnaire to obtain in-depth opinions regarding their experience in using the app in the field. Participants were asked about their experience using the app and also to point out any challenges that they had, if any. In addition, they were asked if there are any suggestions they would like to add to make the app better. Notes were taken by the researcher to document participants' answers.

An observational technique was used in order to capture any problems or difficulties users might experience when using the app. Notes were taking during the tour by the researcher as the authorities of the site did not allow filming the tour due to the naval-base security issues.

6.2 Participants

26 participants took part in this study; all of them were residents in the UK/Portsmouth; their age ranged between 20 and 71; they were 18 males and 8 females from different nationalities: Iraq, Britain, Germany, Iran, Sweden, Libya, Nigeria, Senegal, Jordan and Colombia. Their occupations were: 19 students (undergraduate, master and PhD), one engineer, one project manager, one unemployed, one teaching fellow and three retired.

6.3 Data analysis

SPSS was used to analyse the numeric data that was obtained from the user study; the cleaning data phase was carried out first as a preparation stage for the analysis phase. As it was mentioned earlier, participants were given an opportunity to state 'No opinion' in the usability section of the questionnaire. 'No opinion' answers were treated as a missing data, i.e. as 'No Answer'. A simple statistical analysis was carried out to obtain the mean for the data. Details of the results are given in the next section.

6.4 Results

A usability evaluation study with users was carried out in order to highlight the weak and strong points of the app from the user's perspective. Due to the nature of the informal learning as there is no standard scheme for the assessment of informal learning [54], it could be difficult to measure the effectiveness of learning and to assess how much information users take back from the visit. However, suitability for learning was assessed within the usability section. The main scope for this evaluation study was to assess the interaction design, which contributes to the field of mobile HCI. The results of the three techniques are given below.

The results of the usability questionnaire show that participants reacted positively regarding the usability aspects of the app. The average of each category ranged between 3.06 and 4.25, which indicates participants found it usable and easy to use (see Figure 7).

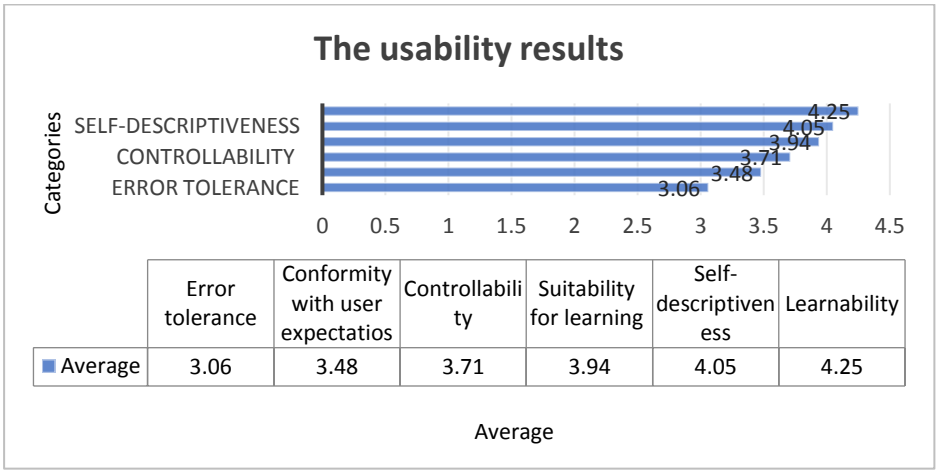


Fig. 7. The usability results

Alongside the evaluation of the interaction design, there was an assessment of how suitable the app was for learning. The results suggest the average of this category is 3.94 (see Figure 7). This indicates SmartC is suitable for learning, which would facilitate acquiring information at outdoors cultural heritage sites effectively. In this light, although the evaluation from a learning perspective was relatively in a small scale, SmartC would be considered as a useful tool for learning.

Regarding the usefulness, the results indicate that all features provided by the app are useful, as the mean ranges between 3.75 and 4.77. Participants liked receiving notifications based on location. Moreover, the results suggest that the audio explanation is the most popular information format amongst participants. Participants stressed that seeing attractions how they appeared in the past is very interesting and has a lot of potential. Four participants used the smart eye glasses during the evaluation study in the field. Three out of four liked receiving notifications through the glasses and found it useful as it freed their hands from carrying the mobile device during the tour. One participant did not like it as she likes to see the attractions with her own eyes; however, it is a personal preference; the device could be disabled if it is not needed (see Figure 8).

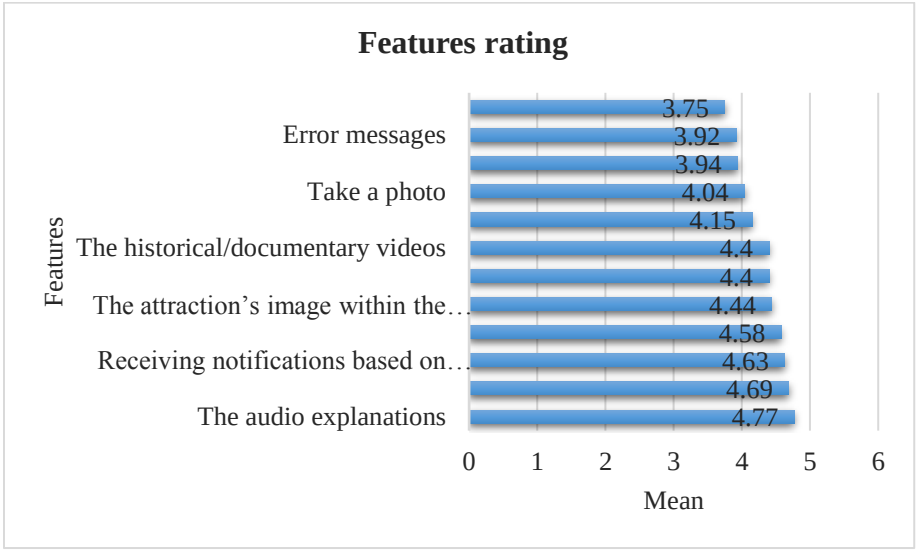


Fig. 8. The features rating results

Participants were asked to state up to three features that they liked or disliked; most participants made comments about features instead of stating which feature they liked or disliked especially for the category of the disliked features – they did not state any feature that they did not like. Table 5 illustrates the stated liked features.

Table 5. The liked features

No	Liked features	No	Liked features
1	Taking photo, audio explanation, photos of sites	5	See the past
2	Photos of attractions	6	The content in general (history description)
3	Audio explanation	7	Text explanation
4	Videos	8	Receiving notification

Participants added a few comments that highlighted some weaknesses in relation to the features of SmartC, which helped in designing the guidelines for developing such services. Some of these comments are given below:

> *'Lack of map, lack of direction, lack of [map] with direction of the attractions in historical time sequence'*
>
> *'Hard to receive notification, simple design'*
>
> *'Volume of audios not high enough, little bit fiddly to see photo in past, not able to see the video after [leaving] attraction'*

With respect to the overall acceptance, the vast majority of participants liked the app and stated they are happy to use it and recommend it to friends. Participants made some comments to illustrate their choice of why they would like to use the app. Some of these comments are given below:

> '*It provide flexibility of spreading knowledge, it is like you have one of those guidance in your pocket all the time*.'
>
> '*It is helpful, easier and lighter to use comparing to the old style ... guides for [sites]'*
>
> *It is a good idea especially if you don't know the site'*
>
> *'Idea of the app is quite interesting. It would be useful for open area like dockyard'*
>
> *'Having an app for android on my phone is more feasible when visiting such sites rather than using devices provided by the sites, which need a bit of time for learning how to use it.'*
>
> *'Because of the content and seeing it in the past gives a good [idea] to how it was'*
>
> *'It is very user friendly, you get interesting information that you would not get it just walking around, save spending on tourists audio devices'*

'I find it very useful and useful save a bit of time if you are in heritage'

One participant only mentioned that he would not use it because he likes to read every label attached to the attractions, however, he stated that he would recommend it to friends:

> '*No, because usually I walk around the attractions and read about the detailed information given and take my time to understand the writing'*

Participants were given an opportunity to add comments or suggestions to improve the app; Table 6 illustrates some of these suggestions and comments.

Table 6. Examples of comments and suggestions

Examples of comments and suggestions made by participants
'colors: choose colours that suits all, some people have a problem to see some colors (design the app for wide audience)'
'there isn't any backward if I want to repeat the previous place, I don't like glasses because I want to see the place naturally in a naked eye'
'It would be a good idea if we can re-call the notification again or select the attraction from the menu. giving a location tolerance to the " see the past" or other features to allow the user to see the past even from distance'
'I think that its accuracy should be improved. also, the user should be able recover an attraction after passing the attraction'
'I am not very good with android technology so feel perhaps I'm not the best judge of this application, found it interesting and helpful when going to attraction'
'It has many possibilities and developments. Maybe notification of facilities would also be good toilets, cafe etc.'

A brief group interview was held with participants after filling the questionnaire to obtain in-depth opinions regarding their experience in using the app in the field. Participants were very positive towards it and found it interesting and easy to use. However, they pointed out some challenges that they experienced during the tour, which include:

1) Receiving notifications for the same attraction a couple of times when passing near it.
2) Losing the current notification (i.e. when viewing a notification for a certain attraction and then move to another one, could not go back to the previous one).
3) Not very easy to see the old image in the 'see it in the past' feature constantly as it is based on the location and it disappears once the device moves slightly.
4) The video needs an internet connection which was not very good at the Historic Dockyard.

5) The audio did not stop when the participants used the back button of the device.

Participants suggested a number of aspects to be included with the app to make it better such as:

1) Adding directions to take you to the attractions.
2) Providing the distance to the attraction that users get notified about it from their current location.
3) Adding a map with all attractions to make it easier to see what is near.
4) Providing an option to download the video.
5) Giving users the opportunity to access the attraction's information they passed by whenever they want (i.e. saving their routes to see them off the site).
6) Adding notifications about public services like cafes or toilets.
7) Considering the day time (day or night) in the design as the sun spells make it harder to see the screen sometimes.
8) Making the audio louder as it was not easy to listen to in a group.
9) One participant suggested to have a list of the nearby attractions instead of receiving notifications based on the location. From her point of view users may not get close enough to an attraction to get a notification which may lead to missing an attraction. However, the main point of providing notifications based on the location is to support people to learn on-the-move while they are doing their daily activities.

The observational technique used to observe how participants interact with the app during the tour. Fortunately, the weather was nice most days, with only one session on a cold day, which was not expected and consequently participants were not very well-clothed. That affected the tour slightly as they were not very comfortable walking around in outdoor settings. Participants divided themselves spontaneously into groups. There were some participants who walked around individually listening to an audio explanation and finding out more about attractions on their own. Some others used the app in a group using one device, and also there were some participants who walked around as a group but using the app individually. All the groups were walking around, having conversation regarding attractions, helping each other with using the app and discussing some weaknesses and strengths of the app. Participants were comfortable in using the app and navigating through, and also managed to use almost all the features easily. It is also true that participants who were walking in groups collaborated to find attractions and helped each other use the app and overcome challenges, and also interacted with their surroundings more often than those who walked alone. Most participants liked receiving notifications based on their current location; also they liked the content especially in an audio format which they found very useful. The service of 'see it in the past' drew participants' attention and helped participants to engage with the attractions and to find out more information about them. Participants did not spend a considerable amount of time reading the texts on the screen, instead they play the

audio to listen and walk. It was noticed that participants did not manage to find some attraction easily, for instance, they received a notification regarding HMS M.33 while they were near Nelson's statue, which they could not see, as HMS victory was blocking the sight. However, they emphasised that providing the picture on the app that illustrates how the attraction looks like helped them to find it. It was also noticed that the app did not work properly through some participants own devices, which was due to the fact that some required resources on the device were not enabled, such as camera and location-based services. In addition, a number of challenges were noticed during the tour:

1) Due to many radars around, as it is a naval-base site, Wi-Fi, GPS and 3G did not work properly which affected the performance of the app slightly. Consequently, the notifications were sometimes hard to receive which needed to re-start the notification (switch it off and switch it on again).
2) For the same previous reason, video did not play for a couple of times at some points, which needed participants to move their location slightly to be able to obtain a good signal to play the video.
3) The surrounding environment included challenges such as: day time (day or night), weather (sunny or rainy), and noise. All these matters could also affect the users' experience, which are needed to be considered in designing such services.
4) Visitors' level of knowledge regarding technology could obstruct the experience. Some participants had problems in using mobile devices in general, which made the use of the app slightly harder.
5) The technical differences of the android devices in terms of operating system, as some devices show a good quality in picking locations more than others. In addition, some explanation messages did not appear on some devices which made it difficult for some participants to figure out how some services actually work.

Altogether, the results of the interview and the observation are consistent which give a level of confirmation of the findings.

In relation to assessing how learners react to the app, SmartC was shown to a participant who took part in the field studies (in both questionnaire and interview). It is important to mention, during the interview study, he did not show a great interest in using technology at cultural heritage sites. He commented that he would not use technology at sites unless it adds value to his visit. Interestingly, he showed a great interest to use SmartC at sites after it was shown to him in an informal environment, which could be interpreted that this app could add value to his visit.

7 Discussion

The user study was conducted to obtain users' perspective regarding SmartC in terms of usability, usefulness and acceptance. The results suggest that users' attitude was positive regarding the app and found it user-friendly.

Participants, in general, found the app useful and easy to use and with a lot of potential for facilitating acquiring historical information on-the-move. In addition, the results indicate the app is suitable for learning. The results suggest that learners/visitors of cultural heritage sites enjoy the visit and the learning experience in groups as they

can have a conversation regarding attractions and also enjoy being with friends and family that clearly support social and collaborative learning. The results of the user study suggest users seemed to be happy using the smart eye glasses in context. Three participants out four reacted positively towards using the glasses, which raises the potential of utilising smart eye glasses for informal learning in outdoor cultural heritage setting.

Although the results suggest that SmartC is easy to use, some challenges came up during the tours with users, which were addressed to enhance, in sequence, the framework, the general requirements and the app. Additionally, as a result, a list of recommendations for developing such services was developed. The challenges could be categorised into: (a) interaction design, (b) surrounding environment, (c) learners' knowledge and preferences, and (d) technical issues. Details are given below.

In terms of interaction design, some issues need to be taken into account to make the experience better.

1) The messages (error and feedback) need to be more obvious (e.g. keep it for longer, make it brighter, or make it in the middle of the screen);
2) The audio should stop when leaving the page using any means (the app standard button or the device standard button);
3) The volume of the audio and video need to be loud enough to be heard within a group; however, a headset splitter could be used to overcome this issue;
4) The image that illustrates how an attraction appeared in the past in the 'see it in the past' feature needs to be less faded and should be displayed for longer, even when changing the direction of the device slightly, to be easily seen.

The challenges of the surrounding environment include: day time (day or night), weather (sunny or rainy), and noisy or quiet. All these matters could also affect the experience which could be addressed by providing different themes (i.e. colours) for day and night.

Visitors' level of knowledge and preferences could obstruct the experience. Some participants had problems in using mobile devices in general which made the use of the app challenging. In addition, some participants' preferences did not meet the core features of the app (notification) as one participant reported. These aspects can be addressed by adding more messages that explain how each feature works. That might help to make it relatively easier for people who are not very confident in using mobile technology. Users were relatively tolerant and patient with errors and the surrounding environment when it comes to using mobile apps. They managed to use all features of the app and found the app useful and easy to use, and a useful tool for learning informally.

Some technical issues came up during the study, as it was mentioned earlier, which include: (a) receiving the same notification more than once, (b) poor network signal which makes it hard to play a video or even receiving a notification, (c) android devices differences in terms of operating system, as some devices showed good quality in receiving notifications, and others showed poor quality in displaying some messages. The evaluation study has led to introduce a list of design recommendation; a brief of these is given in the next section.

8 Design Recommendations

The results of the user study presented in this paper, helped enhance a list of recommendations identified in the field studies (see Section 3) [55] that was pulled out from the GRs to guide the design of SmartC. The previous list was re-design to introduce the current list of recommendations with more details.

The present set of recommendations considers different aspects within the app design that are related to the content and the interaction with the context at outdoor cultural heritage settings. The issues that have already been considered in the Android and iOS guidelines will not be mentioned to avoid redundancy (details about these issues are available in Appendix A). This research introduces a list of design recommendations, which consists of three main parts that cover different dimensions of designing smart and ubiquitous learning environments. These parts are: content provision, learning experience design and interaction with context design. Each part covers different aspects of the design which would make it easier for designers to choose the part that is more convenient to fulfil their artefacts design's requirements, or to choose the convenient elements from each part to accomplish the entire design. As was mentioned earlier, this version of the recommendations is the enhanced version that were identified in a previous study. The previous version was revised based on the current evaluation study and then re-designed to introduce a new version with three main parts and more details. The identified design recommendations are aimed to assist designers with such services by providing relatively high-level design recommendations while leaving room for creativity to designers to choose the feature(s) that would suit any specific recommendation for their design. The details of the recommendations are given below accompanied with the related GR they are belong to, and the source that each element was pulled from. The source is abbreviated as in the following table:

General requirements	GR
Source	SC
Focus Group	FG
Survey study	SS
Interview study	IS
Evaluation study	ES

8.1 Content provision

Content is an important element in designing learning services especially for cultural heritage sites as it provides details of events that happened at a particular site back in time. In addition, it enhances learners' engagement with the context, thus it is essential to take good care of the content deployment.

Table 7. Recommendations for content provisions

Content provision			
No.	Design Recommendation (DR)	GR	SC
Managing content			
1	Store historical information in a joint database that includes all attractions in which they are sectioned under cities and regions	2	IS
2	Use a sharable resources technology to make the historical information accessible to different stakeholders such as designers and curators		IS
Provision of historical information			
3	Provide information about human achievements related to a certain cultural heritage site that happened in a particular age	2	SS & IS
4	Provide information about events that these sites have had experienced back in time	2	SS & IS
5	Provide information about stories behind these sites	2	SS & IS
6	Provide information about life back in time and how people used to live in terms of clothes, food, housing and life style	2	IS
7	Provide information about how sites used to appear in the past	2	SS & IS
8	Provide information about development of the site over time	2	IS
9	Provide information about archaeology and excavation of these sites	2	IS
10	Provide information about interesting facts related to people and famous figures back in time	2	IS
11	Provide information about funny stories regarding famous figures	2	IS
Provision of useful information to assist learners in their learning journey and organise their visit			
12	Provide information about public services such as cafes and restaurants	2	FG, SS & IS
13	Provide information about transportation		
14	Provide information about ticket prices		
15	Provide information about the weather		
16	Provide information about the level of busyness of the site during a week and a day		

8.2 Learning experience design

Learning design could involve different stages, which help assist learners to take a new learning opportunity and make it an enjoyable process:

Table 8. Recommendations for learning experience design

Learning experience design

No.	Design Recommendation (DR)	GR	SC
Supporting people in taking learning experiences and motivate them to visit sites			
17	Provide activities that support learners to socialise while learning such as Geo-cashing games regarding historical events or characters.	4	IS
18	Provide activities that support learners to share experiences and knowledge such as a group quiz	4	SS & IS
19	Adopt functionalities that help motivate learners to visit cultural heritage sites and taking new learning opportunities such as providing a simulation of human achievements in a particular age	3	FG, SS & IS
20	Adopt functionalities to notify learners about cultural heritage sites when passing nearby (e.g. notification)	5	FG, SS, IS & ES
21	Adopt functionalities to deliver instant information about cultural heritage sites based on location (e.g. notification messages)		
22	Provide learning preferences that satisfy the sense of challenge such as riddles and quizzes	4	FG, SS & IS
23	Provide learning preferences that enhance learners' engagement such as stories		
24	Provide learning preferences that satisfy learners' curiosity such as conversational activities with actors dressed like figures back in time		IS

8.3 Interaction with the context design

Different elements could enhance learner's interaction with contexts, which consequently enhance learners' engagements as well as learning at sites. Maintaining learners' profiles, maintaining usable, accessible and easy to use features, designing an augmented reality view for attractions and using smart eye glasses could contribute positively to learners' experience at sites. Thus, these were embedded within the context interaction design guidelines as they are more relevant to this aspect when designing new artefacts in the form of software.

Table 9. Recommendations for interaction with the context design

Interacting with the context			
No.	Design recommendation (DR)	GR	SC
Maintain a learner's profile			
25	Allow learners to create their own account	1	FG, SS & IS
26	Collect information about learners' interests by tracking learners' route and save preferences.	1	FG, SS & IS

27	Allow learners to provide their preferences when first signing up, such as the favourite sites of cultural heritage	1	FG & IS
28	Give recommendations of cultural heritage sites based on learners profile	1	SS & IS
29	Allow learners to customise the app based on their interest	1	FG, SS &
30	Allow learners to save their favourite sites to re-view them whenever they want – even when they are off-site	1,7 & 8	FG, SS, IS & ES
31	Let the app save learners' route (attractions that learners passed by) and enable them to re-view the visited attractions whenever they want.	1, 7 & 8	SS, IS & ES
Maintaining usable, accessible and easy-to-use apps			
32	Provide an audio information format to present historical information	7	FG, SS & IS
33	Provide text information format for learners who prefer reading		
34	Provide images of attractions and life back in time for leaners who prefer this format		
35	Provide videos about events back in time related to a certain site		
36	Use an adaptation mechanism to adapt interfaces based on the level of brightness of the day time	7 & 8	SS, IS & ES
37	Use an adaptation mechanism to adapt sounds level based on the noise level at sites	7 & 8	ES
38	Allow learners to switch between different tour types easily such as group and individual's tour	7 & 8	FG, SS, IS & ES
38	Allow learners to switch services off when they are not needed	7	FG, SS & IS
39	Allow learners to navigate the visited sites and attractions' pages back and forth	7	ES
40	Provide in-app help in different forms such as: a) A separate page with a big library of instruction b) Popup contextual instruction for each service c) Description within first page explaining the overall functionality of the app	7 & 9	ES
41	Provide an image of an attraction with all pages related to this attraction to make it easier for learners to find it and engage with it	7 & 9	ES
42	Make the videos and audios stop when learners leave the page by any means (e.g. standard back buttons or the device's one)	7	ES

43	Make the notification message obvious and clearly indicate which attraction it is about (e.g. provide name and image of the attraction)	7	FG & ES
44	Allow learners to discard the notification if they are not interested	7	FG & ES
45	Allow learners to save the attraction they are being notified for a later time if they are not interested in the time being	7	FG & ES
46	Give an opportunity for learners to switch between services or abort them easily if they do not want to proceed	7	FG, SS, IS & ES
47	Allow learners to choose the level of information details such as brief or detailed	7 & 2	FG & IS
48	Provide different levels of learning materials to suit different learning ability such as: basic, medium and advance quizzes	7	FG & IS
49	Provide a location-based tour for nearby cultural heritage sites	5 & 7	SS, IS & ES
50	Provide a tour for individuals that allows learners to have a personal experience on their own	7 & 8	SS, IS & ES
51	Provide a group tour for families and friends that allows a group of learners to enjoy the experience together at a site	7	SS, IS & ES
52	Provide a map with nearby sites		
54	Provide directions to sites or attractions from the current location		
55	Adopt features that allow learners to experience life back in time based on location (e.g. employ wearable technology with AR to show life back in time and give learners an opportunity to touch, smell and see)	7, 5 & 2	SS & IS
56	Adopt features that allow learners to see attractions back in time from different angles based on location	7 , 5 & 2	SS & IS
57	Adopt features that satisfy learners' imagination such as adding their photos to a portrait of events back in time.	7 , 5 & 2	SS & IS
58	Provide a service that enables learners to look up useful information beforehand to organize their visit properly (e.g. the weather, tickets prices, and transportation)	7 & 2	FG, SS & IS
59	Provide a service to enable learners to interact with each other during the visit (e.g. chat service)	7 & 6	SS & IS
60	Provide a service that enables learners to find friends at a site	7 & 6	SS & IS

61	Provide a service that enables learners to share their experience when they are off the site after the visit (e.g. social media)	6, 7 & 8	SS & IS
62	Provide a service that enables learners, who are at the site, to create a network that enables video calls with friends and family who are not physically at the site to share with them the experience and get them to see the site live using the device's camera (distance visit).	6, 7 & 8	IS
63	Provide a service that allows learners to share personal stories related to sites or attractions that they have witnessed, if any.	4 & 7	IS
64	Provide a service that enables learners to generate a comment regarding the site they have visited.	4 & 7	SS & IS
65	Provide a choice for learners to immerse themselves in the experience by using immersive technologies at sites (e.g. AR technology).	5 & 7	IS & ES
66	Provide a second screen to deliver historical information to allow learners to choose what is suitable for them by using wearable devices such as smart eye glasses.		
67	Provide a choice for learners to receive information on the smart-eye-glasses' interface while looking at the artefact to free their hands and engage their sight with the artefacts.		
68	Allow learners to switch between devices smoothly.	7 & 8	FG, SS & IS
69	Provide an "Inside a site" location-based tour, which makes the app pick the attractions' location from a small distance based on the area size of the attraction.	7 & 9	ES
70	Provide an "Inside a city" location-based tour, which makes the app pick the attractions' location within a city or a big area from a wide distance to help learners to discover what is surrounding them if they are in a new place.	7 & 9	ES
Augmented reality element design			
71	Attach a view (e.g. old image) that shows how attractions appeared in the past in a live camera view	7	IS & ES
72	Let the augmented view appear when the device is facing the corresponding attraction.	7	ES
73	Make the view that augmented to the live camera view relatively transparent to easily see the corresponding attractions behind it.	7	ES
74	Make the transparency of the augmented image less than 40% to be easily seen on a bright day.	7	ES
75	Make the angle of the picking point (i.e. the attraction location within the augmented reality feature) relatively	7	ES

	wide to prevent losing the augmented view when moving the device slightly.		
76	Add the date of the augmented view with the live view	7	ES
77	Make the augmented view to show different angles of the corresponding attraction based on location	7	IS
Smart eye glasses			
78	Extend the notifications to the smart eye glasses device	7	IS
79	Extend description of attractions to appear in the glasses interface	7	IS
80	Add an image of an attraction with the name of the attraction on the glasses interface	7	ES
81	Add a brief description regarding the attraction that learners are being notified for on the glasses interface to help them decide if they are interested to go for further details using their mobile device	7	ES
82	Make the text very brief as the glasses' interface is very small	7	ES
83	Add only the important points regarding the attraction on the glasses' interface as learners do not prefer a lot of text on the glasses	7	ES
84	Extend the augmented reality element that shows how attractions appeared in the past to the smart eye glasses	7	ES

As it was mentioned earlier, designers could use the part or parts of the list that fulfil their design in both forms enhancing the existing one or designing a new one. For instance, if a designer wants to add a service to facilitate
communication between visitors to their existing app, they could choose some services that serve this goal such as design recommendations number 59 & 60, which are promoting the interaction and socialisation between visitors to interact at sites. The designer could (a) adopt the design example provided, if any, or (b) develop the feature that better suits the design; Table 10 illustrates how it could be used providing the two mentioned options.

Table 10. How to use the recommendations

DR-No	Design recommendations	Features	Feature description
59	Provide a service to enable learners to interact with each other during the visit (e.g. chat service)	Develop a chatting service	A chatting service enables a group of visitors (e.g. family or friends) to create a network between each other to communicate during a visit
60	Provide a service that enables learners to find friends at a site	Develop a service which could be called	This service enables a visitor to find friends (i.e. new or existing friends who has an account in the same app) who

		‘is any one nearby?’	are nearby to encourage socialising at sites

9 Conclusions

The development of recommendations for designing smart and ubiquitous learning environments was presented in this paper; a novel list of design recommendations was introduced as a result. The list was shaped throughout a research project that was carried out to develop a theoretical framework for designing smart and ubiquitous learning environments, FoSLE. FoSLE was formulated based on three field studies that were conducted to gather user requirements. The framework was further analysed to draw a set of general requirements, which guided the design of a proof-of-concept prototype, SmartC. SmartC was evaluated by potential end-users in the field, which served to finalise list of the design recommendations. The list consists of three main parts covering different dimensions of designing such services, which are content provision, learning experience design and interaction with context design.

The content provision part gives an overview about how the content of learning applications for cultural heritage contexts should be managed and maintained. Additionally, it suggests what types of information should be included regarding the sites’ history, and what type of information should be included that could be useful for learners in organising their visit. Content is an important element in designing such services, which could be a key for drawing learners’ attention and help them engage with the experience. Hence, it is essential to take good care of deploying the content.

The learning experience design part provides an overview of how the learning journey should be designed in terms of: (1) drawing learners’ attention to visit sites; (2) learning activities that help learners engage with the experience; (3) learning preferences of how learners prefer to learn; (4) supporting learners to learn while doing daily activities. These aspects help designers to have an overview of what they need to keep in mind when designing learning environments that would lead learners to learn about history at sites with more joy and engagement.

The interaction with the context design part provides an overview of how learning environments should be designed in terms of: (1) interaction design; (2) features and services; (3) augmented reality element design; (4) smart eye glasses. In addition, it deals with learners’ profiles as they could influence the interaction with the context in terms of learners’ preferences, which needs to embrace all aspects related to the interaction as the learner is the core element of the whole process of informal learning. This part provides a number of design recommendations that designers need to consider in terms of interaction, which would help in producing useful and easy-to-use apps.

The aforementioned parts would help to guide the design of smart and ubiquitous learning environments to be used in outdoor cultural heritage contexts. The three parts involve 84 design recommendations to cover different aspects to assist designers when introducing new learning environment in such contexts; an example of how the recommendation could be used was provided.

A number of areas we envision to carry out further work which include: (a) extend the evaluation study to include more sites; (b) conduct more evaluation studies in the field with experts of cultural heritage; (c) enhance the SmartC app based on the

evaluation study; (d) replicate the user study with more participants; (e) revise the list of recommendations based on results of these studies.

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APPENDIX A: the excluded recommendations from the list of recommendations because they have already considered in previous guidelines.

No.	Design Recommendation (DR)
Interface design	
1	Allow learners to go back always
2	Allow learners to go to the home page from any page
3	Provide feedback messages with each function to inform learners the request is being processed
4	Make the name and the logo of the app appear in the first page
5	Make the videos and audios to stop when learners leave the page
6	Keep the size videos and audios small as you can to reduce the amount of space the app takes in the device memory
7	Make the text in a dark colour if it is bright
8	Make the text in a bright colour if it is dark
9	Enable headset service for the noisy mode
10	Provide the notification message with vibration
11	Provide the notification message with sound
12	Put functions' buttons in one menu if five or less (or extended menu if more than five)
13	Make the menu obvious with a button clearly indicate it
14	Associate the functions' button with a name that clarify what they do
	Technical side's design
15	Let the app detect if internet connection is available
16	Let the device detect if the supporting resources is enabled such as camera, Wi-Fi and location services.
	Feedback and error messages' design
7	Make messages appear in the middle of the screen
18	Make messages in bright colours
19	Provide a title for the message to indicate what it is about (e.g. 'warning' or 'Error')
20	Provide a sound that indicates there is an error accrued
21	Provide error messages with the 'ok' button to make sure that it does not disappear before learners had read it
22	Let the feedback messages to stay for longer