

Integrating User-Centered Design with the Agile Software Development Methodology for a Cultural Heritage Information System

Nurfarahani Norman Anuar¹, *Mohd Kamal Othman²

^{1,2} Faculty of Cognitive Sciences and Human Development, Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, Malaysia

* Corresponding Author. Tel.: +6082-584501; Fax: +6082-581567. E-mail

Address: omkamal@unimas.my

ORCID ID [0000-0001-5401-2515](https://orcid.org/0000-0001-5401-2515)

Abstract. This paper reports on the findings of a user study on the design ideas for the Sarawak Digital Cultural Heritage Progressive Web App (PWA). The study elucidates the integration of User-Centered Design (UCD) in the Agile software development methodology. Five users were instructed to map their ideas on how they envisioned the application and the features it would have based on a brief description of the system as a one-stop center cultural heritage information for the general public in Sarawak while encouraging conservation and preservation of material culture. The study found that users prefer a simple and pleasing design with an emphasis on visual representation, and a straight forward and intuitive navigation to minimize cognitive load. Further study should explore the effectiveness of the integration of UCD for the Cultural Heritage Information System from the design stage to the evaluation stage.

Keywords: User-Centered Design, Digital cultural heritage, progressive web app (PWA), Agile methodology

1 Introduction

Cultural heritage is subject to the risk of irreversible loss and damage. As a result, over the years, efforts to digitize cultural heritage have become rigorous as a method of preservation and conservation. Heritage is created by collecting and preserving the activities of the Gallery, Library, Archives, and Museum (GLAM) institutions through collective memory processes that focused on memory stores and historical materials [1]. With an aim to ensuring long-term storage of information, digitization could be translated as a means of enabling physical attributes to be transformed into digital resources to be stored in a management system and repositories [2]. Realizing the risks to cultural heritage and the solution of digitization, we aim to develop an information system for the cultural heritage of Sarawak.

Sarawak is Malaysia's largest and most diverse state made up of more than 40 ethnic groups. The Sarawak Government has supported a number of efforts to adopt digitalization for economic growth and, to a large extent, cultural heritage. In an article by Borneo Post Online, the Digital Economy project manager has revealed that as of

May 2019, 54 out of 140 initiatives have been implemented under the digital economy initiatives, [1]. These projects include the construction of state-wide digital infrastructures with 50 percent of the 600 towers completed, a Memorandum of Understanding (MoU) with Huawei Malaysia to support the development of digital talent and technological innovation, a smart traffic light system as part of the smart city sector, the development of Sarawak's first e-wallet called *Sarawak Pay*, the implementation of the Internet of Things (IoT) for the cultivation of smart farming, and many more. With all of these initiatives focusing on sectors such as agriculture, e-commerce, and smart cities, we believe that more efforts should be made in the field of cultural heritage. This is where the Sarawak Cultural Heritage Information System plays an important role in supporting cultural digitization efforts as a means of protecting and storing cultural assets over the long term and at the same time, providing better access to cultural contents.

Several studies have been carried out to digitize Sarawak's cultural heritage. This includes the works of Hashim and Jehom [2], who worked on the photographic documentation of Sarawak's Pua Kumbu textile, the development of the Bario Langkuh Digital Library (BLDL) which stores the personal and definitive songs of Kelabit women [3], and the Sarawak Language Technology (SaLT) to revitalize and maintain Sarawak ethnic language using technology [4]. However, despite the wide variety of heritages this one State offers, there has yet to be a single well-established and fully digital accessible information system that actually serves that purpose. The system could potentially benefit researchers, tourists, and the general public as a one-stop cultural heritage information centre for Sarawak while encouraging the conservation and preservation of those tangible and intangible elements.

In order to reach the audience that this system is intended for, this study proposed the use of the Progressive Web Application (PWA), a reliable and engaging service that allows users to quickly launch a web application from their own mobile home screen. The reason is to implement PWA in this system to allow users to access the features of a website with the additional benefits of a native app without any drawbacks. Although the native app is more interactive and intuitive in terms of user engagement, it is not appropriate for this particular research. This is mainly due to the effect it would have on development costs and the fact that native apps are better suited to a system that requires complex interactions, more processing power and access to user device hardware instead of relatively simple applications [5].

Throughout the software development process, the Agile methodology was adapted with the integration of the User-Centered Design (UCD) element. The integration of UCD allows the allocation of effort to user research and analysis before the Agile, short time-frame iteration [6]. This study was built around the UCD framework proposed by Anwar et al., [7] as illustrated in Fig. 1. The aim of this paper is to elucidate the findings of the user study, the first step in the design and development of the information system which will then be informative when developing the Product Backlog.

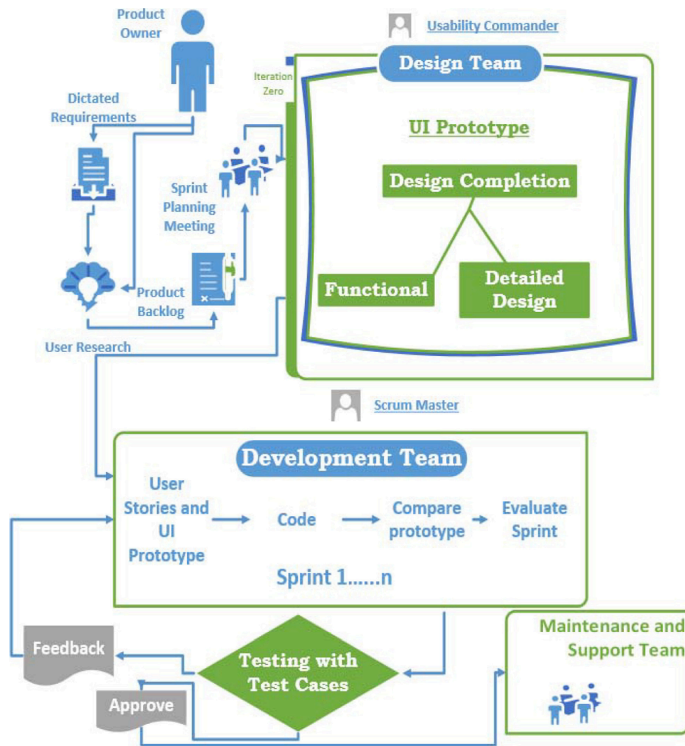


Fig. 1. Integration of UCD into Agile framework proposed by Anwar et al. [7].

2 Background & Literature

2.1 Digital Cultural Heritage

Digitization can be defined as the creation of digital artefacts from their physical attributes by representing their pictorial, graphical, or textual information through electronic devices [8]. The concept of digital cultural heritage has been widely known in the field of heritage studies and Gallery, Library, Archive, and Museum (GLAM) institutions. It became necessary for researchers and heritage institutions to recognise the fragility and vulnerability of cultural heritage that could pose the risk of destruction in wars [9], natural disasters [10], or pollution [11]. Various research has been carried out over the last decade with the aim of conserving, preserving and promoting cultural heritage, such as digitising libraries and archives [12], [13], [14], web and mobile applications [15], [16], [17], [18], game-based applications [19], [20], [21], [22], [23], the incorporation of Internet of Things (IoT) technology [24], [25], and the use of virtual reality (VR), augmented reality (AR) and mixed reality (MR) [26], [27], [28], [29].

Digital heritage is one of the areas that creative services and experiences Creative Computing has to offer. Creative computing or computational creativity is a field of study designed to generate machine creativity through imitation of human creativity [30].

A study by Hu [14] conducted a systematic evaluation of the perspectives of users through a set of usability tests in Dunhuang's digital library. Made public in 2016, the e-Dunhuang serves an important purpose in promoting the city's cultural and historical importance in the ancient silk road, mural and stone caves. The findings of this study can be used to improve the User Experience (UX) of the digital library. As digital libraries are considered to be an outdated way of digitizing heritage information, research and heritage institutions are introducing a web-based or mobile application to make cultural heritage more accessible. This effort has been demonstrated by Hausmann, Weuster, and Nouri-Fritsche [15] through MOSAICA, a web-based toolbox dedicated to the preservation of cultural heritage [16], the Digital Cultural Heritage Map (DCHM), an interactive application that allows users to discover 3D elements while answering questions related to culture [17], and a mobile application to promote Maltese Cultural Heritage on behalf of Malta Tourism Authority. The implementation of other aspects of digital heritage information has also been carried out. This includes the addition of gamification elements to the application [20], [21] where both applications allow users to actively engage in cultural-related contents while providing learning experience during their visits; and the integration of IoT architecture to support the smartness of cultural spaces with technological sensors and services to enhance users enjoyment in heritage spaces [24], [25]; and the implementation of VR, AR and MR technologies that can facilitate the experience of being in contact with art exhibitions [26], the immersive viewings of archeological sites [28], and even the modeling of intangible material culture [29].

Apart from acting as long-term storage of information, the aim of the digital cultural heritage is also to enable information to be more accessible to the public. The traditional method of storing sensitive heritage information in private archives of old manuscripts or limited locations such as museums and libraries restricts the general public's access to unique and valuable heritage information. In addition, efforts to digitize the cultural heritage of Sarawak's have also been made over the last few years through the initiatives of [2], [3], [4], [31], [32]. These efforts include the photographic documentation of Sarawak's Pua Kumbu textile, the development of a digital library that stores the personal and definitive songs of Kelabit women known as Bario Langkuh Digital Library (BLDL), the effort to revitalize and maintain the Sarawak ethnic language using technology through a project called Sarawak Language Technology (SaLT), and the exploration of the important indigenous knowledge embedded in the Bidayuh Bau-Jagoi community of paddy planting and head-hunting.

Thus, realizing the needs of cultural heritage digitization, this study intends to develop a comprehensive, one-stop digital information system in the form of a web application that stores and presents the diverse heritage information and material culture of Sarawak. The decision to develop a web-based application for Sarawak's Digital Cultural heritage is partly due to the fact that such a platform has been considered to be of interest to cultural tourism providers as it is capable of presenting a large amount of information in an easily understood manner, in addition to increasing the accessibility to cultural heritage [15]. In addition, in order to design this system, the

Netnography method will be implemented to crowdsource cultural heritage data from the public.

Digital crowd-outsourcing is based on the notion of gathering information from a large number of people through digital media [33]. The study by [34] found that by inviting the public to participate, users would devote their time to showcase their expertise by providing the information in that context. When asked about their motivation behind such commitment, the study found that self-satisfaction was apparently a sufficient incentive for their contribution. Digital crowdsourcing appears to serve as an advantage for cultural institutions to improve the quality of heritage data by utilizing the expertise and interests of the public [34], fostering public trusts and a sense of the importance of cultural heritage and its institution, and fostering a sense of public responsibility for the preservation of cultural heritage assets [35]. Recognizing the benefits of public participation, the study also intends to apply the same concept, and be able to replicate the success of the study by Pramatha, Davis, and Kuan [36], which invited contributions through an online digital portal to benefit the younger generations of the Balinese community.

2.2 Integrating UCD into Agile

The Agile software development method is based on the idea of continuous improvement and rapid delivery. Agile focuses on meeting the needs of its customers by adapting to changes. Agile has been a popular development and project management because of the values on which it is based. What differs Agile from other development methodologies is that the evolution of project requirements and solutions in Agile is expected throughout the development process [37]. Another uniqueness of Agile is the fact that the development tasks are broken down into small chunks and incremental improvements are made in different iterations.

At a glance, UCD seems to contradict with Agile, whereby it spends a significant effort on research and analysis before the development phase, while Agile aims to deliver as quickly as possible in short iterations [6]. However, the two approaches share one similarity: end-user and customer-focused approaches. According to the Interaction Design Foundation, UCD is essentially an iterative process that focuses on the needs of users at every phase of the design process [38]. The UCD process consists of two stages. The first step is to identify target users, their needs, and expectations. The few common methods for collecting this information are through surveys and focus groups [39]. The second step is to conduct formal user testing to validate the effectiveness of the system prototype. In the second step, users would be asked to perform a few tasks and the evaluator would observe the interactions of users during the process. Toh et al., [40] stated that there are two approaches to UCD, namely a product-oriented approach in which design requirements are determined prior to the product creation, and a process-oriented in which the designer sees the development process from a context of use perspective.

The implementation of UCD in the design of digital heritage can be thought of as the influence of one of the areas of creativity proposed by Margret Boden called “combinational creativity” [41]. This form of creativity is dedicated to facilitating a combination of people’s creativity. Instead of reinventing the wheel, people can focus more on how to maximize the use of available resources, technologies, and information

in society [30]. In the context of software development, what Creative Computing is essentially concerned with is to produce a better-quality product. Hence this is where UCD fits into the whole concept.

UCD is a well-established method used in software development for decades before the fame of the Agile framework took over. Although it is considered to have improved the usefulness and usability of the products, in exchange, there are cost-benefit trade-offs [42]. The Agile method, on the other hand, is based on the assumption that the development costs, time and product quality are fixed variables. Therefore, to reap the benefits of both methods, we are integrating the user-focused UCD element into the Agile framework.

Research on the implementation of UCD in the digital cultural heritage domain has been conducted in the past, including the domains of VR [43], AR [44], [45], [46], and digital libraries [47], [48]. In the case of Aytac [43], UCD methods have been applied holistically throughout the entire process of developing the VR application for the installation of Vrow Maria, with the aim of creating an engaging and rich user experience. By implementing the user-centric development of their AR tourism app, Williams et al. were able to acquire user requirements from their initial domain analysis, interviews, and observations in advance of the iterative design prototyping phase [44]. Despite previous UCD implementations across digital cultural heritage domains, no known UCD research on the design of PWA's digital cultural heritage has been identified. This would probably have been due to the lack of literature in the development of DCH-PWA itself.

3 Methods

3.1 Design

The study employs an observational research design that focuses on a focus group approach to gather user requirements and design ideas for the Sarawak Digital Cultural Heritage Progressive Web App (PWA). The focus group approach has some similarities with the Participatory Design (PD) approach. PD involves users in the design process [49], [50], [51], [52] but may also become non participatory in UCD [50]. The participation of users in this study only occurred during the requirement analysis and evaluation stages, but they did not become official members of the design team.

A focus group approach through an observation study allows researchers to gather insights from users without the practical difficulties of other research designs such as experimental (i.e. experimental conditions and procedure). The focus group has been widely used by psychologists and sociologists since the 1940s [53] and subsequently adopted to other research domains due to its effectiveness in gathering data through informal discussions among specific groups of users. Although there are different variations in the focus group used by researchers in different fields of research, it is important to follow the established guidelines for determining the focus group participants, such as homogenous "status" as suggested by Carrey [54]. In this study, the focus group is based on the homogenous "status" criteria, such as age, educational background, occupation, and cultural interest. This focus group observational approach

allows researchers to better understand the user study process by observing the interactions of the participants. The goal of using a focus group observation study was for researchers to act as a guide for the participants throughout the user study process to ensure that any deviations could be managed [55]. In addition, researchers act as moderators and note-takers to facilitate the discussion of the focus group. An observational study with a focus group approach is appropriate because of its flexibility and the fact that the study does not necessarily need to be structured around a hypothesis.

3.2 Participants

Although there is no such thing as one-size-fits-all in determining the optimal number of participants in a user study [56], Jakob Nielsen stated that five participants will be able to identify more than 80% of the problems [57]. The key to this is to run as many affordable small tests as possible with that small number of participants.

In this user study, five graduate students were recruited from Universiti Malaysia Sarawak (UNIMAS). Purposive sampling was utilized whereby all participants are selected because they fit a particular profile. In this study, the particular profile is an interest in cultural heritage. Purposive sampling is a technique that relies on the researcher's judgment in the choice of study participants and their knowledge of the study [58]. The reason this study chose this sampling method is that, unlike the random sampling method that would seem easy at a glance, this method requires a probable sample size. For example, if our target participants were a group of researchers, the outcome of the study would be overwhelmingly biased, as the participants consisted only of a small number of master's students who did not reflect the number of researchers in the sample frame or, to a certain extent, Sarawak researchers. In addition, the random sampling method would be neither time nor cost-effective. Both of which are against what Agile and UCD strive to be.

Our participants are all-female master's students with a mean age of 25 years old (SD: 0), 4 from the Faculty of Engineering, with no prior knowledge in Human-Computer Interaction (HCI) or Interactive Design Principle, and 1 from the Faculty of Computer Sciences and Information Technology, with a background in design and development of different types of system. The 4 participants were divided into groups of two to promote discussions among the members. The Computer Science participant, however, worked independently as she is quite familiar with the principles of mobile application design.

3.3 Focus Group Procedures

The user study was conducted in a workshop manner in order to optimize the participants' engagement and discussion. Since this study involved human participants, there were legal and ethical responsibilities to adhere. All participants were provided with an informed consent form and were asked to read and complete the informed consent form prior to the study. The informed consent form provided a summary of the evaluation plan, the evaluation protocol, the participants' involvement and rights, the data collection procedure and usage, and other relevant ethical considerations

The workshop began by informing the participants of the aim and general objectives of this research. Each group was given a piece of paper consisting of a mobile phone frame to help them visualize how their proposed screen-by-screen design might look like when it is displayed on a mobile device. The participants were then given the following instruction:

“Design a mobile application that stores and displays information on cultural heritage for public use. You can freely design the functionalities and features of the application without fixating on the technical development part, which requires the application to allow users to view the visual representation of cultural artefacts and to have textual information for users.”

As the design process took place, the participants were prompted with questions. Questions included, *“Do you think this system would be useful? Why?”* and *“Who do you think would benefit from this system?”*. They were also asked about the problem with the current or similar system which could possibly have an impact on user experience (UX), and how the proposed system will support potential users. Participants were asked to visualize the activities and interactivities of users with the proposed system. In addition, they were also told to be speculative in order to come up with innovative and useful design ideas for cultural heritage. They are free to discuss design ideas, such as better functionality or usability of the system. This kind of interaction with the participants will help them to conceptualize the system’s conceptual models from the user’s perspective. The conceptual model of the system details what the system looks like, what it can do, should do or behave based on the users’ ideas. The user conceptual model will help the development team to build the system’s image in the next phase of the Agile methodology. Feedbacks on these processes will help further justify our research objectives.

At the end of the workshop, three different designs of low-fidelity paper prototypes from conceived by each group. The outcome of this procedure identified the recurring features proposed by these users.

3.4 Data Analysis

The data collected from the focus group is the design artefacts in the form of low fidelity prototypes by the 3 groups. In addition, discussions that took place during the workshop were recorded to ensure that the researchers understood their rationale behind the design ideas.

Data were analyzed by identifying the recurring and unique features proposed by each group. The design ideas of the participants were then translated into personas and user scenarios to further visualize the system’s conceptual model and its functionalities. A user persona is a powerful tool for supporting design thinking. It is a representation of a person with specific characteristics based on contextual data collected from a segment of the target group, in this case, the focus group study, with a narration of their relevant story and character description, which includes their names, personalities, and backgrounds [62]. Creating a user persona helps to clarify the “Must and Should Have” functionality and features of the application. From the user persona, a user story and a scenario can be created for each persona. The user story is one of the Agile’s key

components. As the overall framework focuses on putting users at the center of the design, the user story helps to create a simplified description of the required software features while describing the value it would give to users [63]. The user story is formatted as such, “As a [persona]. I [want to], [so that].” This simple sentence identifies the persona, their goal, and the purpose behind it. A software called Trello was utilized as a Kanban board to present the stories. From the user stories, scenarios were created of how the users use our system, their motivations, the problems they faced that the system might be able to solve, and the possible ways to achieve users’ objectives [64]. These scenarios can be presented in a pictorial form or an illustration to make them more descriptive. A user scenario is an important tool in UX as it helps to nurture user empathy by not only understanding their goals, behaviors, motivations but also their pain points. The design ideas were also transformed into a use case before moving to the next phase. The use case diagram provided a general description of how users would interact with the system.

In addition, the participants' design ideas and core functionalities were compared with design principles to assess whether the product of the creative process not only met the users’ requirements but also adhered to design guidelines and principles. Subsequently, these design ideas were transformed into a wireframe design to further develop and evaluate the initial look and feel of the final product.

4 Results & Discussions

Fig. 2. – Fig. 4 shows the findings of the focus group procedures and Table 1 summarizes the features of the proposed design ideas.

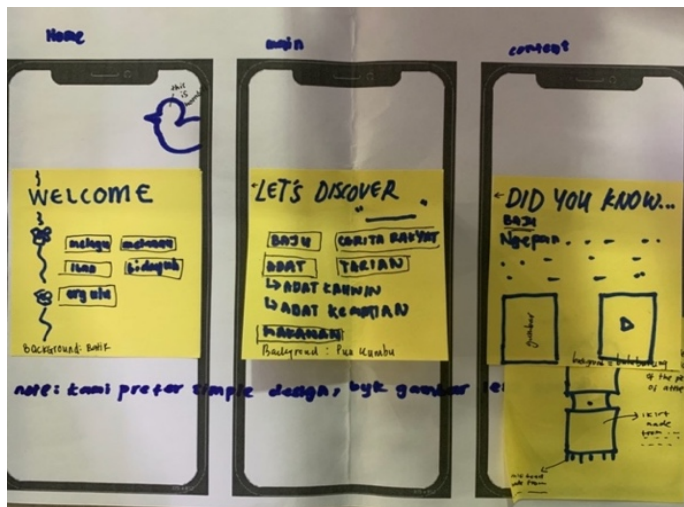


Fig. 2. Team 1 screen-by-screen design idea



Fig. 3. Team 2 screen-by-screen design idea

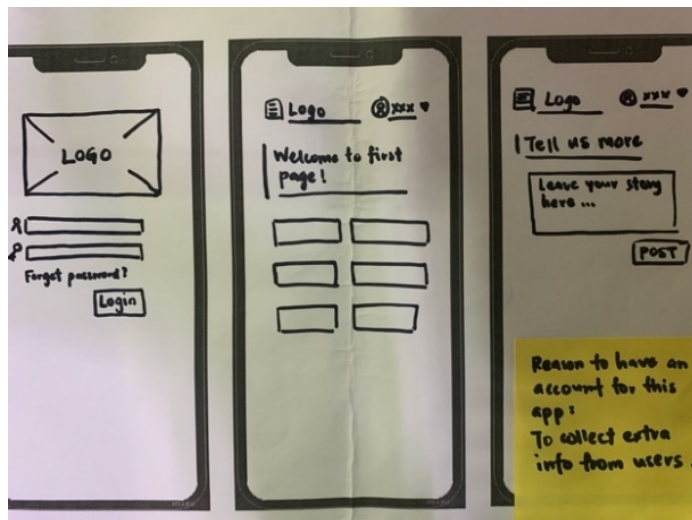


Fig. 4. Team 3 - the 5th participant's design idea.

The user study that incorporated potential end-users into the primary stage of software design is based on the intention to produce better-quality, customer-focused products. Tetteroo et al. proposed that end-users should be able to create and adapt system design to their preferences, or at the very least, be very closely involved throughout the design and development process so that the end product can satisfy their needs [59].

Based on the findings, there were recurring design ideas from the three Teams. All teams contend that the application must be straight forward and navigable. The teams

envisioned that heritage artefacts would be grouped together and viewed as a list. This is to make it easier for users to browse the data. The proposed lists reflect a mosaic, multilinear arrangements in which tiles can clearly represent collection categories without users having to contemplate on scrolling [60]. This proposed design is expected considering Campbell et al., [32] also states that the multilinear arrangement is considered to be the most renowned principle of spatial arrangement for object collections in digital collection interfaces.

Table 1. Summary of the design ideas.

Team 1	<ul style="list-style-type: none"> • The overall design of the application must reflect Sarawak's cultural aesthetics. • The design of the application must be simple and aesthetically pleasing. • The application must be straight forward and easily navigable. • The application must provide as many visual representations as possible in the form of images and videos.
Team 2	<ul style="list-style-type: none"> • The application must provide a bilingual option. • The application must allow users to request for feedback / allows user to interact with the system. • The overall design of the application must reflect Sarawak's cultural aesthetics. • The application must provide as many visual representations as possible in the form of images. • The team prefers pop-out information rather than a screen-to-screen display. • Includes a collapsing menu / hamburger menu icon that allows users to easily access menu items.
Team 3	<ul style="list-style-type: none"> • The application must support the contribution of users to cultural information. • The application must be straight forward and easily navigable • The application must allow the user to register in order to filter and authenticate the information provided. • The application must allow the user to interact with the system

In addition, Team 1 and Team 2 proposed the need for visual representations in the form of images or videos in the system. Visual representation is of equal importance in the relay and presentation of information on cultural heritage. Based on a survey conducted by Windhager et al., [61], most of the cultural heritage collections are represented as images. Both recommendations for listing objects in categories and images allow users to interact with digital collections by giving them the opportunity to view collections from a different perspective: collection overview, multi-object previews, and single-object previews [33]. The overview of the collection is not necessarily represented in graphical object representation, but instead, it can be a text that represents the high-level structure of the collection. Users would then encounter multi-object previews that would often display a group of objects in thumbnails in the form of lists, grids or mosaics. The specific visualization of the object would then be

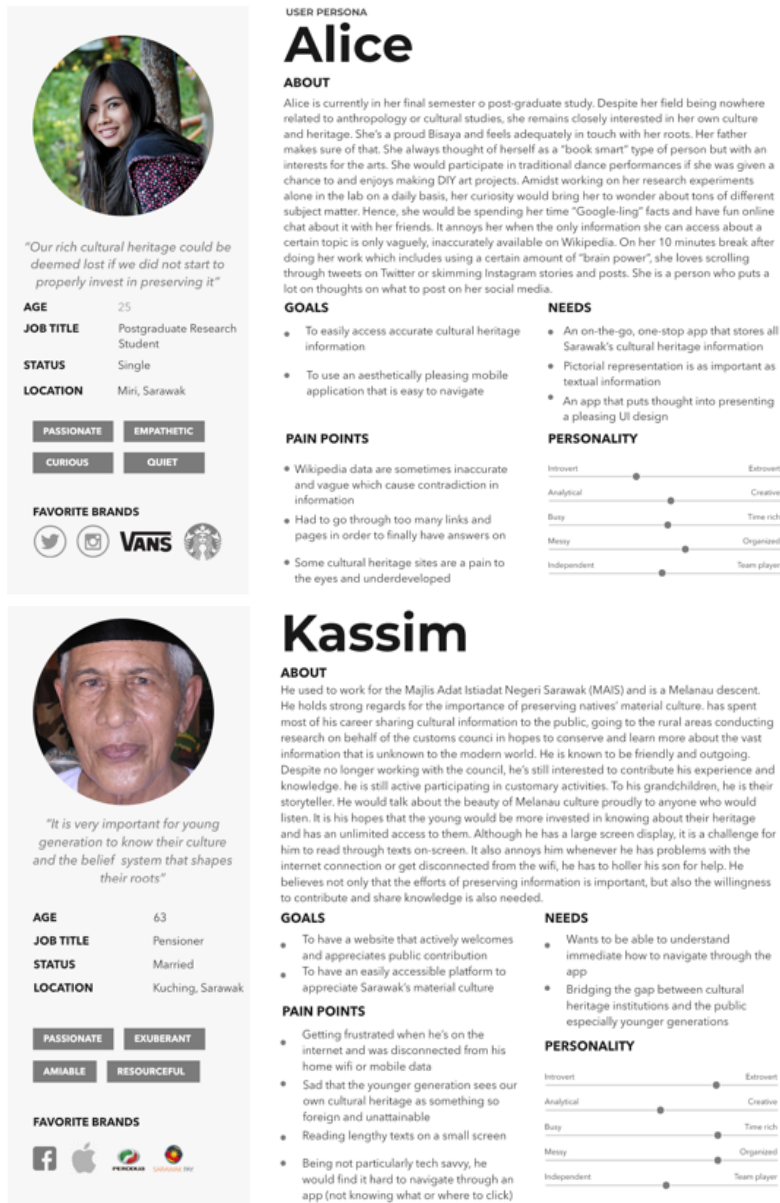


Fig. 5. The persona of a casual user (Alice) and a serious user (Kassim)

presented in a detailed preview of a single object. This detailed representation is usually accompanied by a textual description.

However, there were also important design ideas proposed by particular teams. Team 1 emphasized on having a simple and aesthetically pleasing design. This an important factor for a web application so as to not distract users from the important features of the application, namely the cultural heritage information. In terms of the aesthetics, Team 1 added that the aesthetics should reflect Sarawak's culture. This preference for Sarawak cultural aesthetics is also stated by Team 2.

Another important feature proposed by Team 2 is the bilingual option. Taking note of the fact that not all users may be proficient in the English language, Team 2 contends that users should be allowed language options when engaging with the application. This is an important design consideration to achieve the objective of a user-focused end product.

In addition, Team 3 put forward an interesting design idea that is the system should involve the users' engagement and participation in providing cultural heritage information. Team 3 proposed that the system should allow users to create an account with the application, which would then enable them to contribute their own cultural heritage data. When asked about the reliability issue that arises along with this function, the participant then referred to the role of the digital cultural heritage system in carrying out its own validation. The idea of inviting the public to participate in cultural heritage is not something foreign within the domain. In a sense, this proposed design would make it possible for the system to digitally crowdsource data from the public.

The similarities were used to construct user personas. Fig. 5 shows two primary user personas that were created based on the two identified types of users A casual user and a serious user.

Examples of the user stories based on the personas are as below:

"As a casual user, I want the app to be the ultimate one-stop cultural heritage information centre for Sarawak, so that people do not have to go through multiple sites painstakingly and search for comprehensive heritage information"

"As a <serious user>, I would like the heritage application to receive a public contribution so that the GLAM institution will no longer be limited to an only exclusive group of people"



Fig. 6. A scenario depicting how Alice (a casual user) is curious to find information about material culture and is frustrated that no links and pages on the internet are reliable enough for her to refer to it.

Fig. 6 is an example of a user scenario for our system.

Fig. 7. An example of a use case diagram on how users would interact with the system.

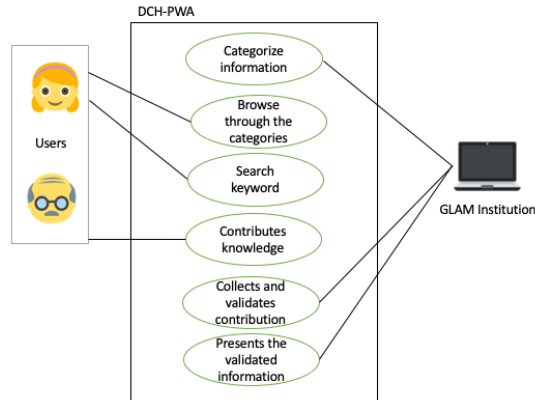


Fig. 7. The Use Case diagram of users' interaction with the system

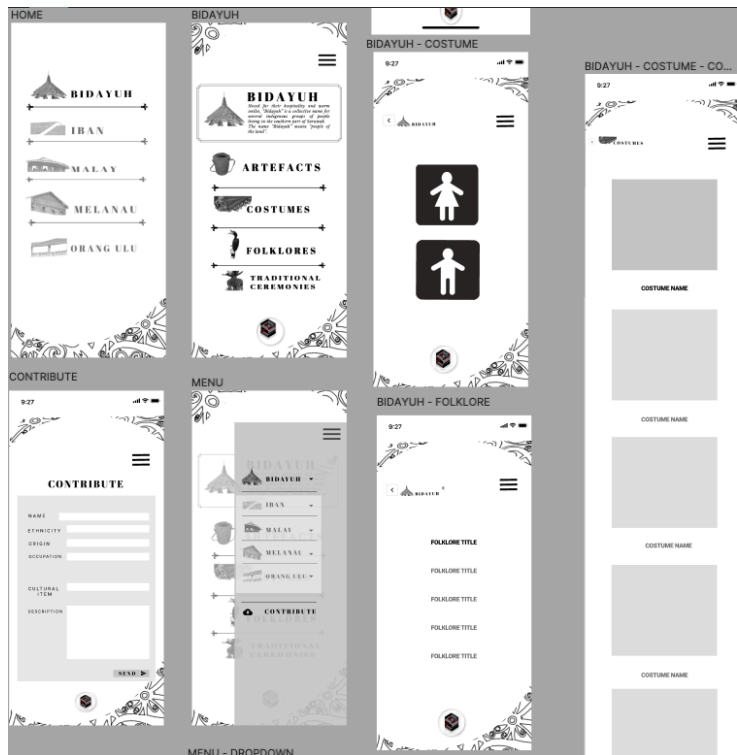


Fig. 8. High-fidelity wireframe for Sarawak Digital Cultural Heritage PWA

Data obtained were further conceptualized by designing the wireframe of the system (Fig. 8).

After conducting the user study, a number of key challenges in involving the end-user as participants were identified, in these substantive and observable processes. Firstly, support in the design of interactivity must be provided to the participants. Since a design guideline known to the participant was yet to be established in the creation of their own solutions [59], the process of finding solutions seemed to be unstructured, resulting in vague and less meaningful design ideas. The way in which to support this should be further investigated in order to continue with the involvement of end-users in the development process. Another challenge that needs to be addressed is the socio-technical approach to development for end-users mentioned in Tetteroo et al.'s study [59].

Since the concept of combining Agile with UCD is designed to cater to both users and developers at the same time in order to ensure that the end-product is user-focused through continuous improvements and rapid delivery by developers, users and developers should not be treated as two separate entities. Instead, in the UCD-Agile development spectrum, the developers and users should be able to switch between roles depending on the context. As one of the usability issues is the common gap between designers' and users' mental models, this could bridge the gap and create a system's model that results in an application that fits user needs and is easy to understand and use.

5 Conclusion

The aim of this study is to conduct a user study that will provide insight into how Sarawak's digital cultural heritage web-app would be designed by end-users. The study demonstrates the integration of the UCD element into the Agile development framework. In the study, users were asked to come up with a paper prototype design on the basic functionalities of the application and the overall design. Their designs will then become the basis for the design and development of the app in the next stage. The findings of this user study revealed a number of similarities in design ideas, namely the idea of an aesthetically pleasing and simple design to minimize the cognitive load on users, straight forward navigation to ensure that the app is intuitive and understandable, and the emphasis on visual representations. These similarities in design ideas act as a basis in the design of the Sarawak Digital Cultural Heritage Information System.

Acknowledgement. We gratefully acknowledge the grant from Universiti Malaysia Sarawak, (Petronas P- Ramlie Research Chair) F04/PRC/1933/2019.

References

1. Kong., S.: "Sarawak's digital updates in 2019, <https://www.theborneopost.com/2019/05/12/sarawaks-digital-updates-in-2019/> (2019)
2. Hashim, K.H., Jehom, W.J.: Photography Documentation of Cultural Heritage; Pua Kumbu Textile of Sarawak, Borneo, Proc. 2014 Int. Conf. Virtual Syst. Multimedia, VSMM 2014, pp. 149–152, (2014)
3. Yeo, A.W., Yong, S.C., Songan, P., Ghaniah, J., Ab Hamid, K., Masli, A.B., Bala, P.: Lesson Learnt in the Development of Applications for Remote Communities, Localis. Focus - Int. J. Localis., vol. 5, no. 1, pp. 7--11 (2006)
4. Yeo, A. W., Saeed, S., Sarah, F., Jali, N., Suriati, K., Mit, E., Ting, S.H., Wilfred, J., Ng, G.W.: Preservation of Sarawak Ethnic Languages : The Sarawak Language Technology (SaL 1) Initiative, (2008)
5. Buettner, K., Simmons, A. M.: Mobile Web and Native Apps: How One team Found a Happy Medium, In: Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), vol. 6769 LNCS, no. 1, pp. 549-554 (2011)
6. Da Silva, T.S., Martin, A., Maurer, F., Silveira, M.: User-centered Design and Agile Methods: A Systematic Review, Proc. - 2011 Agil. Conf. Agil. 2011, no. September, pp. 77-86 (2011)
7. Anwar, S., Motla, Y. H., Siddiq, Y., Asghar, S., Hassan, M.S., Khan, Z.I.: User-centered Design Practices in Scrum Development Process: A Distinctive Advantage?, In: 17th IEEE Int. Multi Top. Conf. Collab. Sustain. Dev. Technol. IEEE INMIC 2014 - Proc., pp. 161--166 (2015)
8. Manžuch, Z.: Ethical Issues In Digitization Of Cultural Heritage, J. Contemp. Arch. Stud., vol. 4, (2017).
9. De Ruyter, M.: Under the Cruel Sea: Effects of Armed Conflict on Underwater Cultural Heritage, UNSW, (2014)
10. Nicu, I.C.: Tracking Natural and Anthropoc Risks from Historical Maps as a Tool for Cultural Heritage Assessment: A case study, Environ. Earth Sci., vol. 76, no. 9, (2017)
11. Di Turo, F., Proietti, C., Screpanti, A., Fornasier, M.F., Cionni, I., Favero, G., De Marco, A.: Impacts of Air Pollution on Cultural Heritage Corrosion at European Level: What has been Achieved and What are the Future Scenarios, Environ. Pollut., vol. 218, pp. 586–594, November (2016)
12. Lynch, C.: Digital Collections, Digital Libraries and the Digitization of Cultural Heritage Information, First Monday, vol. 7, no. 5, pp. 131--145 (2002)
13. Komlodi, A., Caidi, N., Wheeler, K.: Cross-Cultural Usability of Digital Libraries 2 Methodology : Evaluation of National DL User Interface, pp. 584–593 (2004)
14. Hu, X.: Usability Evaluation of E-Dunhuang Cultural Heritage Digital Library, Data Inf. Manag., vol. 1, no. 2, pp. 122--135 (2018)
15. Hausmann, A., Weuster, L., Nouri-Fritsche, N.: Making Heritage Accessible: Usage and Benefits of Web-based Applications in Cultural Tourism, Int J. Cult. Digit., vol. 2, no. 1, pp. 9--27 (2015)
16. Barak, M., Orit, H., Zvia, K., Dori, Y.J.: MOSAICA: A Web-2.0 Based System for the Preservation and Presentation of Cultural Heritage, Comput. Educ., vol. 53, no. 3, pp. 841--852 (2009)

17. Mousouris, S., Styliaras, G.: Implementing Digital Cultural Heritage Map, IISA 2014 - 5th Int. Conf. Information, Intell. Syst. Appl., pp. 3--8 (2014)
18. S. Boiano, J. Bowen, and G. Gaia, "Usability, Design and Content Issues of Mobile Apps for Cultural Heritage Promotion: The Malta Culture Guide Experience," pp. 66--73, 2012.
19. Bakar, N.A.A., Chepa, N.: Towards Engagement of Digital Malaysian Traditional Games: Usability Evaluation Experience, In: AIP Conference Proceedings, vol. 1761 (2016)
20. Coenen, T., Mostmans, L., Naessens, K.: MuseUs: Case Study of a Pervasive Cultural Heritage Serious Game, *J. Comput. Cult. Herit*, vol. 6, no. 2, (2013)
21. Vocaturo, E., Zumpano, E., Caroprese, L., Pagliuso, S.M., Lappano, D.: Educational Games for Cultural Heritage, In: Italian Research Conference on Digital Libraries (IRCDL) (2019)
22. Malegiannaki, I., Daradoumis.: Analyzing the Educational Design, Use and Effect of Spatial Games for Cultural Heritage: A Literature Review, *Comput. Educ.*, vol. 108, pp. 1--10 (2017)
23. Čosović, M., Brkić, B. R.: Game-Based Learning in Museums—Cultural Heritage Applications, *Information*, vol. 11, no. 1, p. 22, Decemeber (2019).
24. Piccialli, F., Chianese, A.: Designing a Smart Museum: When Cultural Heritage Joins IoT CHIS-Big Data for Semantic Social Business Intelligence View project Medical Image Analysis View project Designing a Smart Museum (2014)
25. Piccialli, F., Chianese, A.: The Internet of Things supporting the Cultural Heritage Domain: Analysis, Design and Implementation of a Smart Framework Enhancing the Smartness of Cultural Spaces (2015)
26. D'Agnano, F., Balletti, C., Guerra, F., Vernier, P.: Tooteko: A Case Study of Augmented Reality for an Accessible Cultural Heritage. Digitization, 3D Printing and Sensors for an Audio-Tactile Experience, *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch.*, vol. 40, no. 5W4, pp. 207--213 (2015)
27. Boskovic, D., Rizvic, S., Okanovic, V., Sljivo, S., Sinanovic, N.: Measuring Immersion and Edutainment in Multimedia Cultural Heritage Applications, *ICAT 2017 - 26th Int. Conf. Information, Commun. Autom. Technol. Proc.*, vol. 2017, December, pp. 1--6, (2017)
28. Calisi, D., Cottefogleia, F., D'Agostinia, L., Giannonea, F., Nencia, F., Saloniab, P., Zarattia, M., Ziparo, V.A.: Robotics and Virtual Reality for Cultural Heritage Digitization and Fruition, *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.*, (2017)
29. Doulamis, N., Doulamis, A., Inonnidis, C., Klein, M., Ionnides, M.: Modelling of Static and Moving Objects: Digitizing Tangible and Intangible Cultural Heritage, *Mix. Real. Gamification Cult. Herit.*, pp. 567--589 (2017)
30. Yang, H., Zhang, L.: Promoting Creative Computing: Origin, Scope, Research and Applications, *Digit. Commun. Networks*, vol. 2, no. 2, pp. 84--91, May (2016)
31. Zaman, T., Yeo, A.W., Jengan, G.: Designing Digital Solutions for Preserving Penan Sign Language: A Reflective Study, *Adv. Human-Computer Interact.*, vol. 2016, no. March (2016)
32. Campbell, Y. M., Ghazali, K., Sahuri, S.: Preserving Indigenous Knowledge Through Folk Narratives: Podi and Ngoyu, *J. Southeast Asian Stud.*, vol. 21, no. 1, pp. 203--219 (2016)
33. Seitsonen, O.: Crowdsourcing Cultural Heritage: Public Participation and Conflict Legacy in Finland," *J. Community Archaeol. Herit.*, vol. 4, no. 2, pp. 115--130, May (2017)
34. Oomen, J., Aroyo, L.: Crowdsourcing in the Cultural Heritage Domain: Opportunities and Challenges, In: C and T 2011 - 5th International Conference on Communities and Technologies Conference Proceedings, pp. 138--149 (2011)
35. Terras, M.: Crowdsourcing in the Digital Humanities, no. January (2015)
36. Pramatha, C., Davis, J.G., Kuan, K.K.: Digital Preservation of Cultural Heritage: An Ontology- Based Approach, In: The 28th Australasian Conference on Information Systems (2017)
37. Jönsson, E.: Agile Development and User-Centered Design - A Case Study at Sony Mobile Communications AB, Lund University (2013)
38. Interaction Design Foundation, <https://www.interaction-design.org/literature/topics/user-centered-design>

39. Comeaux, D. J.: Usability studies and user-centered design in digital libraries, *J. Web Librariansh.*, vol. 2, no. 2–3, pp. 457–475 (2008)
40. Back, E., Cagiltay, K., Boling, E., Frick, T.: *Handbook of Research on Educational Communications and Technology User-Centered Design and Development Publication details User-Centered Design and Development, Handb. Res. Educ. Commun. Technol.*, no. 11237, pp. 660–668 (2019)
41. Boden, M.A.: *The Creative Mind: Myths and Mechanisms*, 2nd Edition. Routledge Taylor & Francis Group (2003)
42. Vredenburg, K., Mao, J.Y., Smith, P.W., Carey, T.: *A Survey of User-Centered Design Practice* (2002)
43. Reunanen, M., Díaz, L., Horttana, T.: A Holistic User-Centered Approach to Immersive Digital Cultural Heritage Installations: Case Vrouw Maria, *J. Comput. Cult. Herit.*, vol. 7, no. 4, pp. 1–16, Feb (2015)
44. Williams, M., Yao, K.K., Nurse, J.R.C.: *Developing an Augmented Reality Tourism App through User-Centred Design (Extended Version)*
45. Toh, Y.W., Jeung, J.H., Pan, Y.H.: A Combined User Research Process for Designing Mobile AR Guide in Cultural Heritage, In: 9th IEEE International Symposium on Mixed and Augmented Reality 2010: Arts, Media, and Humanities, ISMAR-AMH 2010 - Proceedings, pp. 71–72 (2010)
46. Darling, J.M., Vanoni, D.J., Levy, T.E., Kuester, F.: Enhancing the Digital Heritage Experience from Field to Museum: User-Centered System Design of an Augmented Reality Tablet Application for Cultural Heritage, In: Proceedings of the Digital Heritage 2013 - Federating the 19th Int'l VSMM, 10th Eurographics GCH, and 2nd UNESCO Memory of the World Conferences, vol. 1, p. 453 (2013)
47. T. Heuss, B. G. Humm, T. Deuschel, B. Humm, and T. Fröhlich, “Finding without Searching: A Serendipity-based Approach for Digital Cultural Heritage Finding without Searching-A Serendipity-based Approach for Digital Cultural Heritage.”
48. Aytac, S.: *Development of a User-Centered Digital Library for Ottoman Manuscripts* (2003)
49. Muller, M.J., Kuhn, S.: Participatory Design, *Commun. ACM*, vol. 36, no. 6, pp. 24–28, January (1993)
50. Carroll, J.M.: Encountering Others: Reciprocal Openings in Participatory Design and User-Centered Design, *Human-Computer Interact.*, vol. 11, no. 3, pp. 285–290 (1996)
51. Muller, M.J., Wildman, D.M., White, E.A.: Participatory Design through Games and Other Group Exercises, In: Conference on Human Factors in Computing Systems - Proceedings, vol. 1994, pp. 411–412, April (1994)
52. Spinuzzi, C.: The Methodology of Participatory Design,” *Tech. Commun.*, vol. 52, no. 2, May (2005)
53. Wilkinson, S.: Focus Group Methodology: A Review, *Int. J. Soc. Res. Methodol.*, vol. 1, no. 3, pp. 181–203 (1998)
54. Carey, M.A., Smith, M.W.: Capturing the Group Effect in Focus Groups: A Special Concern in Analysis, *Qual. Health Res.*, vol. 4, no. 1, pp. 123–127 (1994)
55. Carver, J., Shull, F., Basili, V.: Observational Studies to Accelerate Process Experience in Classroom Studies: An Evaluation, In: International Symposium on Empirical Software Engineering, pp. 72–79 (2003)
56. Six, J.M., Macefield, R.: How to Determine the Right Number of Participants for Usability Studies <https://www.uxmatters.com/mt/archives/2016/01/how-to-determine-the-right-number-of-participants-for-usability-studies.php> (2016)
57. Nielsen, J.: Why You Only Need to Test with 5 Users, <https://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/> (2000)
58. Glen, S.: Purposive Sampling (Deliberate Sampling) - Statistics How To, <https://www.statisticshowto.datasciencecentral.com/purposive-sampling/> (2015)

59. Tetteroo, D., Soute, I., Markopoulos, P.: Five Key Challenges in End-User Development for Tangible and Embodied Interaction, In: ICMI 2013 - Proceedings of the 2013 ACM International Conference on Multimodal Interaction, pp. 247--254 (2013)
60. Windhager, F., Federico, P., Mayr, E., Schreder, G., Smuc, M.: A Review of Information Visualization Approaches and Interfaces to Digital Cultural Heritage Collections, In: Proceedings of the 9th Forum Media Technology 2016, pp. 74--81 (2016)
61. F. Windhager, Faderico, P., Schreder, G., Glinka, K., Miksch, S., Mayr, S.: Visualization of Cultural Heritage Collection Data: State of the Art and Future Challenges, IEEE Trans. Vis. Comput. Graph., vol. 25, no. 6, pp. 2311--2330, (2019)
62. Hartson, R., Pyla, P.S.: The UX Book: Process and Guidelines for Ensuring a Quality User Experience, Elsevier Inc. (2012)
63. Rehkopf, M.: User Stories with Examples and Template. <https://www.atlassian.com/agile/project-management/user-stories>
64. Justinmind, User Personas, Scenarios, User Stories And Storyboards: What's the Difference?, Available: <https://uxplanet.org/user-personas-scenarios-user-stories-and-storyboards-whats-the-difference-cf00315f0799> (2017)