SafarNama: Mobile Augmented Reality Application for Gamified Educational Virtual Tours for Pakistan

SafarNama: Gamified Educational Virtual Touring Application for Pakistan

Making historical and cultural tours more accessible for Pakistan through a gamified and virtual educational touring application using Augmented Reality.

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Given the traditional teaching methods and lack of educational physical trips amid the COVID-19 pandemic, technology in education can be used as a solution to influence and motivate students to learn actively. For this purpose, after a thorough user research and design prototyping process, we present SafarNama: a mobile Augmented Reality application with a novel approach to learning history and culture for Pakistan through gamified virtual trips using historically relevant 3D exhibits and an event-based dialogue system. With its unique design, the application aims to promote story-based, interactive and spatial learning as well as parental and teacher involvement and physical activity for children as they engage on virtual tours. We further analyze and review our design solution through an extensive user evaluation phase to determine its impact and implications for future research.

CCS CONCEPTS • Human-centered computing • Human computer interaction (HCI) • Interaction paradigms • Mixed / augmented reality

Additional Keywords and Phrases: Education, Mobile, Augmented Reality, User Study, Design, Evaluation, Gamification, Children

1 INTRODUCTION

Pakistan is a country with diverse cultures and traditions. Its population consists of multiple ethnicities including Punjabis, Sindhis, Kashimirs, Siraikis, etc. with each having its own culture. Before its independence in 1947, Pakistan was part of the Indian Subcontinent, so its culture has also been influenced by other civilizations and empires, including the British, Mughals, Sikhs, Hindus, Afghans and Persians. We see their influences throughout Pakistan, in the form of museum artifacts or historical monuments like the Badshahi Mosque, Lahore Fort, etc. Given these vast resources for culture and influence, it would intrigue the curious minds to study about them. Yet, the current generation shows a lack of interest in studying about the history and culture of Pakistan. Possible reasons for this could include the lack of promotion of the country's heritage or the history topics being taught to students through textbooks in a boring or non-engaging way. To grasp the importance of these historical resources, it is vital that students experience these instead of just reading about them. Not only will experiencing these, in museums or landmarks, lead to better engagement of the students, but it will also instill an interest in exploring these topics further. Furthermore, owing to the current situation, school trips to historical landmarks, museums, etc. have been completely stopped which will only aid in reducing this interest. Given this issue of the lack of interest and learning of history, a different method to teach it should be approached. Active learning may prove to be useful for this subject. Active learning involves engaging the student to the course content, having students actively participate in activities and collaborate with peers rather than just listening to the instructor. Not only does this improve learning, but it also helps the student build up their analytical and critical skills. A study also showed that active learning leads to students learning more and scoring higher [21]. A research paper involved testing the use of active learning for a history course [16]. The results showed that the groups involved with active learning performed better than the control group and scored higher. Conclusively, this showed that active learning could have a positive impact. Advancements in knowledge have also led to the progression in how individuals attain this knowledge. The emphasis has shifted towards creative and critical thinking. The modern approach is more learner-centered and consists of activity-based learning to promote critical thinking. This can be done by taking children on educational field trips.

Through extensive user research we identified that children are not going or being taken on educational trips enough by schools and parents. They are confined at home due to the COVID-19 situation. Moreover, there is a lack of awareness of digital mediums which provide these opportunities virtually even though they have technological devices available at their home and are regular users of it. Children are interested in history and culture and have a spark to learn more about it but the teaching methods are lackluster. Students are not provided with real life experiences for the respective subject and educational field trips usually occur when children are too young to understand the context and do not retain anything. These trips should be arranged at an age when they can understand and interact with the environment. Parents are usually too busy to take their children on educational trips and even when they do, the trips aren't engaging and interactive.

As a result, after a thorough low and high-fidelity prototyping process, we present our custom design solution called SafarNama - a mobile Augmented Reality application with a novel approach to learning history and culture actively and specifically in the context of Pakistan through gamified virtual trips using historically relevant 3D exhibits and an event-based dialogue system. With its unique design, the application aims to promote story-based, interactive and spatial learning as well as parental and teacher involvement and physical activity for children as they engage on virtual tours. We further analyze and review our design solution by conducting usability testing on the final application prototype to determine its impact and implications for future research.

2 RELATED WORKS

The related works section is divided into two sub-sections. The first sub-section consists of existing products that aim to tackle the specified problem area or solve problems related to the problem area. The second sub-section consists of existing literature that examines four major components of the problem area consisting of Active learning, Educational technology, Augmented Reality-based learning, and Virtual tours.

In recent years, there have been various products that have aimed to improve the interest in History and Culture. One of these is the Google Arts and Culture platform which provides its users with access to high-resolution images and videos of historical and cultural artwork from various parts of the world [11]. It also includes interactive features such as Art Filter, Art Transfer, Art Selfie, Art Projector, Pocket Gallery and Color Palette. Another interactive approach is LIT's Pehchaan [14] which is a personalized AR storybook that takes children on a tour through Pakistan, showcasing its famous monuments as high-quality 3D models in an AR environment. A similar application by the BBC team, called Civilizations AR [12], provides an even more interactive approach by allowing the user to interact with the 3D-models in AR, but in much more detail such as inspecting the contents of a coffin. Moreover, it also allows the user to read or listen to information related to the 3D model. In terms of a cultural context within Pakistan, Heritage360 provides a viable solution [17]. It provides digital access to the heritage of Pakistan through 3D models, 360 videos, and Virtual Reality. It contains a multitude of content for each exhibit in the form of images from various angles, panorama shots, as well as floor plans. A similar approach to the problem is the Colonial Williamsburg virtual tour [16] which allows its users to explore various historical landmarks within the museum in Virtual Reality. The user is able to walk throughout the museum and look at the various items and landmarks. An interesting application which involves the use of AR as well as gamification elements to keep the user engaged is called Metaverse AR [13]. It does not provide any historical context, however. A different type of application that aims to induce interest in history is the Discovering Egypt web-application which allows its users to experience the history of Egypt through minigames [15].

There have been multiple studies conducted on the various areas of the problem being solved. The literature review presented different ideas on how to tackle the problem area. Four areas were explored which included: Active learning, Education technology, Augmented Reality-based learning, and virtual tours. The research looked for different types of applications that were developed for these areas and the evaluation of those applications. The applications involved a variety of techniques such as making use of active learning methods, gamification elements, Augmented Reality (AR) and Virtual Reality (VR) [1, 3, 5, 6, 8, 19, 20, 21, 22, 25]. Different kinds of systems were tried as well which evaluated the use of the internet, online courses, live online teacher, storytelling videos for teaching, using clickers for MCQs, and virtual currency for encouraging students [18, 20, 31, 32, 36, 37, 42]. Example applications from these include a game called "Ori-Gami" which used Spatial learning, a museum guide system, a tour guide robot, and using AR for lab experiments [5]. The results showed that digital game-based learning was effective in various topics such as arts, storytelling, mathematics, and problem solving. The products and systems led to improvements in creativity, learning performance, engagement, collaboration amongst peers, content understanding, motivation and satisfaction. Memory retention and visual recognition was also boosted through the use of gamification and AR / VR. The use of technology also allowed students to work from home and at their own times. An interesting finding was that the use of AR encouraged the user to develop more interest in the field. However, there were some limitations to these approaches as well. A major limitation was that the degree of learning depended on the pedagogy model being used and the use of a weak model led to users not being engaged and learning passively. Overuse of technology led to attention tunneling, usability difficulties, and ineffective classroom integration.

The current solution was inspired from a combination of these products. The product makes use of active learning, keeping in mind a proper pedagogy model to keep the user engaged and motivated, while also leading to improved

learning. The focus is on the history and culture of Pakistan and makes use of AR, storytelling and gamification elements.

3 Methodology

Keeping in mind the target audience, an extensive user research was conducted involving online surveys for children and parents, individual interviews (semi-structured and unstructured with probing) of parents and teachers inclusive of expert reviews from the teachers and a focus group for children in our target user group. The online surveys provided us with quantitative data from primary users. 450 responses were recorded for the children survey, while the parent's survey received 62 responses.

Three in-person teacher interviews were conducted at a local school in Lahore, called Standard Model School, to receive expert opinion on the problem area. The format of the interviews was semi-structured so that the interviewer could probe the interviewee to attain more specific details. Additionally, all interviews were conducted after receiving consent from the interviewee. The interview questions focused on the reasons for the lack of interest in History and Culture by children as well as the usefulness of potential solutions and how different learning methods could be used. All other interviews were conducted virtually via Zoom and phone calls. Once the consent form was filled, interviewees were asked the interview questions, mentioned in the appendix.

A focus group was also conducted at the same school to get direct contextual responses from children to understand the problems they faced as well as the viability of potential solutions. Students from classes 6 and 7 were split and randomly sampled into two equal-sized groups for two separate activities. These two groups would act as control and test groups for a controlled experiment. This focus group involved testing the concept of virtual trips using a basic prototype for the test group against textual learning from books for the control group. In the first activity, the students were given a video tour of Lahore Museum along with a museum guide like explanation. In the second activity, the students were given a write-up on Lahore Museum which they were instructed to read. The students, in each group, were given a short quiz that was based on their activity and the results of both activities were evaluated.

After the user research, the focus was on the design phase to come up with a viable solution. This started with a brainstorming process where we attempted to move towards the design of the solution, utilizing findings from our user study and assessing needs and desires of users in our target group. Following brainstorming, various alternative design solutions were considered from which the final design solution was derived.

After extracting out the features and functionality, initial sketches, scenarios and storyboards were designed so that the team could visualize the application as well as the various use-cases and limitations. Next, the lo-fidelity paper prototype was created for evaluation on a small user group of 4 participants from the target audience. The paper prototype testing was conducted in-person on the four users. User 1 was a Computer Science Sophomore at LUMS. User 2 was a child in grade 2. Users 3 and 4 were both Computer Science Seniors at LUMS.

For the paper prototypes, 13x7 cm screens representing a large Android phone were drawn on paper and a large wooden frame was created to be handled by the user. The horizontal flow was used to show the process flow through the main user interface, and how it would be used and explored. The complete vertical flow for the entire tour experience was implemented for a single tour of The Lahore Museum. The complete tutorial was also included along with the main dialogues, but the tour was kept short (2 exhibits) as it was just for testing the user experience. Screens consisted of only English Language and were thus only tested on users who were comfortable with the language. The complete Augmented Reality experience was simulated by having the user cut the AR marker sheet themselves, place it around them, and then pick up the mobile frame as instructed by the facilitator when their

camera turned on so they could inspect these markers and have upright hovering models (paper cutouts) pop out in real. Video recording was done to capture the complete user experience and to locate issues later. A member of the team also took live notes about the issues that the users faced during testing.

All issues from the paper prototyping were noted and rectified in the first draft of hi-fidelity prototype, which was designed in Figma. This was used to design an interface that would later be replicated in the final application. The final application prototype was developed using Unity along with the EasyAR SDK for Android as it was necessary to test out the AR experience of the application. Images of the exhibits from the Lahore Museum tour were used in the creation of their 3D models using Smoothie-3D. The application prototype's language was also restricted to English due to time constraints. The final design included UI animations and visual design principles were followed. The design was made to be simple so that it is easier for the target audience to pick up at first glance. It was made approachable and recognizable by following Android Material Design guidelines making use of the standard menu, cards and dialog layouts. Contrast was ensured between background and text colors to make it easier to read. White space was used throughout the screens to make the content easily scannable and increase comprehension for the user. All elements followed a grid-like structure such as the side menu, which followed proper alignment for graphics and text. To ensure consistency, the design of the application was standard and consistent throughout all of the screens.

After the application prototype was complete, the evaluation phase followed. The purpose for this phase was to employ usability test planning to evaluate and assess the application design. It would also allow us to compare our perceived ideas of user experience against how the user actually experienced the application. This would help us locate any inconsistencies and issues within our design which need to be fixed. Using usability testing would also help us understand what areas of the problem our solution successfully tackles and what areas have still not been resolved. Our testing primarily consisted of evaluating how the user would play through a particular tour. This is because the tour is the main element of our application which provides the solution to the problem of children not being interested in history and culture. This involved testing gameplay elements such as dialogues, quizzes and interactions with the models. A secondary target of testing was the main user interface such as the main menu and the settings. This also involved testing how the user understood and set up the magic sheets which were the most vital parts of our application.

Our objective in usability testing was not only to locate any usability flaws within the application but also to locate interface flaws along with the acceptability of the solution. Specifically, our focus was to evaluate the following:

- How will the user interact with and respond to Augmented Reality?
- Can the user locate the required functions naturally?
- Does the user understand how to set up the magical sheet?
- Does the user understand how to play the game?
- Is the user satisfied with the implementation of the quizzes and dialog as a solution to the problem?
- Can the primary user (children) successfully complete a tour without guidance?
- Will the user be able to follow the story and retain the information presented by the various exhibits?

Both, process and bottom-line data, were collected not just from questionnaire responses but also during the evaluation process. For process data, participants were asked to share their screens to capture where they were tapping, what specific errors they were making and screens that they were accidentally landing on as well as their process of recovery from accidental touches. Secondly, they were also asked to think out loud about their actions and permitted to ask for help. Expressions during the process were also captured for most users that gave consent and enabled live video feeds during the evaluation. The bottom-line data included task times including recovery time upon making any mistakes through those specific tasks and also final tour scores obtained after completion of the main tour task.

Most of our usability measures have been drawn from a systematic review done for such measures specifically for mobile-based augmented reality (MAR) learning applications [28], the slides and other literature comprising usability tests for prototypes created. Moreover, some inspiration was drawn from Ko et al.'s MAR usability principles (five usability principles for AR) [27] consisting of user-information, user-usage, user-cognitive, user-interaction and user-support were used to center our preliminary and post-testing questions around with consideration for each factor partially to the context of the application. The usability measures are mentioned along with the referenced literature from where it was drawn categorized into performance and preference measures individually for bottom-line and process data respectively. Note that most of the preference measures are exclusive of Nielsen's ten usability heuristics which we also utilized for the design of some of our questions through our evaluation questionnaires.

Performance measures:

- **Time-based Efficiency (Time taken to complete tasks including recovery time):** Using times from recorded videos (in seconds because of their relative significance) from the initiation of the tasks to the achievement of the task goal as soon as the users started interacting with the screen. This time includes recovery time as well in case the users make any error during the process such as tapping on the wrong button, going back or starting the tour without setting it up etc.
- **Final tour score:** A self-developed metric to test the user's knowledge and understanding of the story content involved in the application and also its retainment and recall from memory, after they complete the application tour and get tested based on the information they have learned about the exhibits and their history.
- **Number of uses of help:** Any intermediate questions or calls for support from users were counted during tasks. This was to gauge how well they understood the task, whether they became confused in the process and judge how effective the tutorials and integrated in the application were in addressing these issues.

Preference measures:

- **Learnability [2]:** To measure the learnability of the interface generally, whether the users were able to recall the gestures to interact with the 3D exhibits, how to tap on the dialogues to proceed and access the menu again from the home screen.
- **Ease of Use [29]:** Measured comfort with the interface, navigation to perform certain tasks through the main user interface, hold the device with correct orientation, navigate through the AR tour dialogues and complete the story.
- **Perceived usefulness [1]:** Degree of perceived usefulness and potential of the application for showcasing the heritage and culture of the tour played and as an educational source for gaining historical knowledge.
- **Precision of 3-Dimensional images [24]:** Perceived accuracy of the 3D model to actual historical depictions of the characters or their exhibit counterparts present at the location of the virtual tour
- **Object manipulation [24]:** Ease of manipulation of the 3D objects augmented from exhibits using specific finger gestures for interaction and adaptability of these controls.
- **Degree of interest for the content [19]:** To measure the degree of interest they developed for the storyline, its historical context, the characters and the AR experience.
- **Facial expressions and body movements (Frowning, Smiling, Surprise, Concentration/Focus, Leaning close to screen) [7]:** All facial expressions were captured for the users that gave consent and permitted sharing of their video, and their expressions were generally measured under these specified categories to evaluate their emotional responses.
- **Interest (would use again) [38]:** Gauge the reaction and interest of users as they were to inquire whether the degree of preference to which they would actually use the application again and also visit the tour for that specified location in real life themselves.

Our participants for usability testing consisted of three primary categories: children, parents / legal guardians, and siblings. Children, from grade 5 to grade 8, were the primary test group. Some tests were conducted with slightly older children as well to verify if that age group would be interested as well. Of the 17 participants, of the first survey, 9 were female and 8 were male. Thus, the sample responses were almost equally divided amongst both genders. The respondents belonged to five age groups: 5-10 years, 11-13 years, 14-17 years, 18-24 years and 25+ years old. Demographics of our participants and other associated details (obtained from our consent forms and pre-questionnaire) are as follows. Please note that names have been anonymized to ensure confidentiality and privacy of user information.

Table 3.1: Participants for User Evaluation

Alias	Gender	Age Range
P1	Male	18-24
P2	Male	14-17
P3	Male	18-24
P4	Female	14-17
P5	Female	14-17
P6	Female	14-17
P7	Female	11-13
P8	Female	11-13
P9	Female	11-13
P10	Female	18-24
P11	Male	18-24
P12	Male	18-24
P13	Male	5-10
P14	Male	11-13
P15	Male	25+
P16	Female	25+
P17	Female	25+

The method we deployed for conducting a usability test consisted of six parts. For the first test, a pilot study was conducted which involved all group members being part of the testing to observe how to conduct the test as well as locate any misunderstandings or errors that may occur in future tests. This was helpful in removing any bias from future tests as well as maintaining a consistent testing procedure. The first step in the testing involved asking the user for their consent to record the test. If the user was a minor / child, the consent was taken from their parents or legal guardian. The next step involved having the participant fill the pre-test questionnaire - a short survey which was used to get an idea of the demographic and basic information of the participant. This would be useful for the finding and analysis part as it would allow us to deduce factors that may have affected how the user experience changed with the demographic of the user. Following the pre-test questionnaire, the user was given an explanation of the SafarNama app such as its purpose and its goals. This would provide the user a basic understanding of the type of app they were dealing with as well as act similarly to the description section provided to users on the App Store before they can download a game.

Table 3.2 Tasks List

Task	Description
T1	Read FAQs and About Us
T2	Change Language After Initial Selection
T3	Select and Start Specific Tour
T4	Setup Tour using the Magic Sheet
T5	Find and Talk to an Exhibit
T6	Interact with the first 3D Model (Scale, Translate, Rotate)
T7	Find and Talk to the next Exhibit and take its Quiz
T8	Complete the Story
T9	Take the Final Quiz and Complete the Tour
T10	Inspect Tour History
T11	Attempt to Find and Unlock the Second Tour

The fourth step of the usability testing interview involved the user starting the app and performing the tasks (shown in Table 3.2) that they were assigned by the conductor. This was the crux of the usability testing as this is where the conductor could observe the problems in the application as well as collect the various testing measurements. The conductor acted mainly as a facilitator by providing the participant with the task that they were asked to perform. The tasks themselves were general tasks which provided no hints to the user such as "locate the first exhibit and interact with it". Moreover, the facilitator observed the participant and only guided them when they faced any issue with completing the task. Each time this happened, that event was recorded in the findings as a possible error that would need to be resolved. Time taken to complete each task was extracted from the time-frame present in the video recordings. The fifth step, after the completion of all tasks, was for the user to be given the post-test questionnaire. This would gauge the main items for analysis in the findings such as the ease of use, the consistency of the app, etc. It consisted of questions that were used to understand the overall experience that the user had with the app, any issues they faced and any suggestions they could provide for the app. The measurement factors were provided on a Likert scale which provided a quantitative measure of the measures. The issues and suggestions were filled in text boxes which could be used for qualitative measurement along with the conductor's observations of the participant. Finally, the conductor asked the user for verbal feedback as well so that the user was not limited to the questions on the post-questionnaire. This provided additional context as well as a view of the user's perspective to the conductor. An additional consideration while performing the tasks was friendliness and openness with the user. This would be beneficial so that the conductor could observe the user working naturally and without any pressure. This was especially considered in the case of children since they would be easily influenced by the nature of the test. Thus, the facilitator would be more helpful to children similar to how parents and siblings might help them. However, it was also made sure that not too much help was given so that the child's own decisions were not influenced.

4 USER RESEARCH

For the User Research, a focus group with activities and two online surveys, for kids and for parents, were conducted. The purpose of these activities was to get user feedback and response on the problem.

The focus group consisted of 2 activities, where students were divided into 2 groups. Each group participated in a single activity. The focus of the first activity was to see students' understanding of culture and history. A write up was provided to the children. The write up had a short text on Lahore Museum and pictures of some artifacts present in the Museum. The students were asked to read the write up and retain as much information that they can for a quiz based on the same write up. They were finding it difficult to understand the text in English. After they had read the write up, a quiz was conducted based on the content of the write up. The results show that the students found it difficult to read and retain the information and hence found it difficult to score a good score even when they were given a quiz immediately after reading the text. Overall, this focus group activity showed that there is a need and interest to use an app that can take them on virtual tours so this served as a great basic prototype. The activity also showed that there was a definite language barrier in schools. The students' responses showed that they had interest in culture and history.

In the second focus group activity, the majority of the students had gone on trips to historical places like Lahore Museum and Badshahi Masjid. We found out that these children had gone on recreational trips mostly, northern areas and shopping malls. The present children of this class had English as their favorite subject and not Social Studies or Science. When asked for preference over the latter two, they preferred Social Studies more, and specifically remembered incidents of warfare and emperors that fought in them in ancient history. For evaluation after the Lahore Museum virtual Google Earth Street View tour, every child remembered the name of the place, and when we asked what they remembered from the virtual tour they remembered everything. However, some of the children were repeating along with the others and on individual questioning forgot the names of the artifacts only a moment later. During the discussion they further confused names of some artifacts with those they had learned from textbooks. Some children only retained more information about the things they personally liked, for example, traditional weapons - swords and cannons. Conversely, when we gave them clues about an artifact using the direction, we turned in the tour and of other artifacts in the room, they were able to remember it. "What central object did you see when we turned left after the first artifact and saw between the cannon statue and weapon cases?" and their answer was "Queen Victoria" correctly. Moreover, they were able to recall the exact order of discovery of the artifacts upon asking.

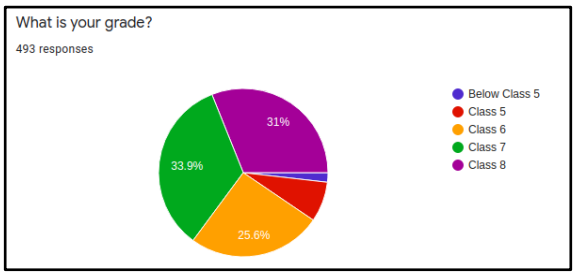

Figure 4.1 Children Grade distribution

Two surveys were conducted, one from students and another from parents. In the first survey, more than 450 students participated. The students belonged to five different classes: below class 5, class 5, class 6, class 7 and class 8 shown in Fig 4.1. There is an even split of respondents being from class 7 and class 8. The purpose of the survey was to find out whether the children had been or would like to go on trips. Out of them 72.4% of students have access to mobile phones, 50% successfully answered the quiz question. The survey conducted from

parents involved 62 parents, surveyed to evaluate their opinion of their children's trips. They were asked if they would allow their children to go on a school or an educational trip. 91.9% parents answered in "Yes" because they stated that it would increase confidence and interaction with other kids. However, 65% of the parents stated that it has been over a year that their children last went on such a school or educational trip. Moreover, findings showed that 88.7% parents would allow their kids to use mobile phones, however, 92% of parents also said that they would definitely allow the kids to use phones if they use educational applications.

Through our surveys, interviews, focus groups and expert reviews we were further able to analyze our problem domain and assess the corresponding needs and desires of our target audience. The parents from the user group emphasized the importance of trips for the children. One parent explains that trips help their kids in not only gaining the confidence but also in social and personal development,

> *"I believe kids should be well-equipped with how to develop relations with friends and human relations, to realize the other person's importance and care for them, to feel for them. It is a materialistic school system - you just come and study, they try to make it creative but there is no implementation. More importantly, there is a lack of social development." [Parent]*

In order to make the learning more effective and efficient, the parents and teachers want active learning to be implemented where children not only engage but experience the concepts directly.

> *"Students remember whatever they directly experience. As an example, since I'm a science teacher, we had a science-based activity in class where we had students taste various types of foods. The children still remember the details from that activity to this day." [Teacher]*

There was a consensus between parents and teachers for having a platform that could result in developing more interests of students in history and culture.

> *"History and Culture are usually very dry subjects and thus there are only a few students who develop interest in these. Therefore, if active learning or trips are used to teach these subjects, then they are able to learn more swiftly and are able to understand more as well." [Teacher]*

The user group consisted of students, parents and teachers. The students as well as their parents wanted learning to be story based to make the topic interesting so that the children could retain information too. In addition to the emphasis on learning the history, science and culture of Pakistan, the user group also needed the platform that could visualize the concepts which would help in better learning. Since the start of lockdown due to COVID-19, parents are worried about the quality of education of their children, they wanted to somehow merge education with technology which would definitely result in Active learning which would help children in problem solving and critical thinking skills. Due to the uncertain times of COVID-19 and to build a healthy relationship with the children, parents need a platform that could act as a bridge by involving them in the activity.

21st century school-going kids, growing up in the technology rich environment of today, wish to visualize the concepts they are learning about. They suggest that education through AR/VR is an advanced way to teach with added benefits. The use of music for focusing and animated characters could be a good way of incorporating learning into their daily lives as they will be able to relate with the content and actively partake in the process. In addition to a platform involving roleplay, our user would be fascinated by the 3D models of Pakistani Monuments and historical characters of it.

5 DESIGN

Realizing the lack of educational trips for kids in Pakistan, we devised ways, both physical and virtual, of making history and culture-based tours more accessible. Any possible solution would have to be bilingual (Urdu and English). In the case of a virtual solution, an immersive trip experience at home could be delivered by Virtual Reality / Augmented Reality including 3D Models, images and videos as well as other visual elements and sounds. Roleplay can stimulate learning by involving the user as a character of the story. Narration of text or voice dialogues would also be beneficial. Quizzes can be used to reinforce learning, but may make the experience complex or frustrating if not handled carefully. Gamification elements can further increase replay ability and a reward system can incentivize learning as well, using scores and leaderboards. A mascot would be really important in making the tour more engaging and would also be able to instruct and guide the player. Parent and teacher involvement were also deemed to be important. Finally, different types of learning methodologies were considered, consisting of interactive, auditory, verbal, spatial, social and interpersonal learning.

Our design alternatives consisted of a gamified quizzing application, VR-based touring application, historical and cultural interactive-storybook, physical touring agencies, and AR-based mobile touring. By taking key points from the various alternates and considering the limitations, the solution was finalized - a mobile application called SafarNama.

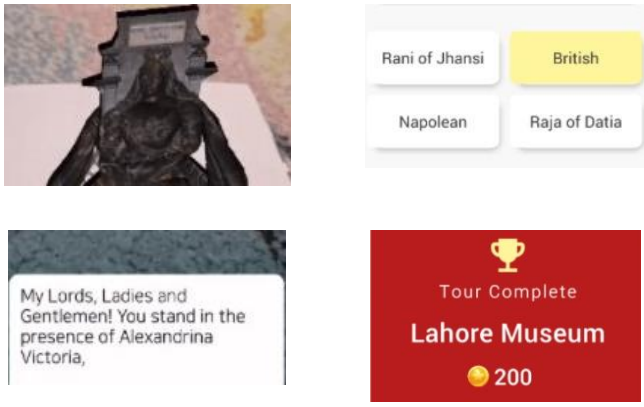

Figure 5.1: Designed application screen segments for SafarNama

SafarNama is an Augmented-Reality based mobile application utilizing gamification, story-telling elements, and focusing on the historical and cultural context of Pakistan. All these elements should keep children engaged, focused and incentivized to learn about the culture of Pakistan. A general flow of the design solution's features and functionalities is given below.

Storytelling of the History and Culture of Pakistan: A storytelling approach is adopted for this application. The user will be able to choose tours comprising stories of different topics related to the history and culture of Pakistan. For a single story, the user would go through multiple AR markers in a specified order. Each AR marker would either consist of a model of an historical figure, a landmark or an artifact (the first one called Queen Victoria is shown in Figure 5.1 image 1). Each model will share their tale with the user in an engaging manner through the use of dialogues (shown in Figure 5.1 image 3), in different dialects. This will make the experience more immersive for the user as well as keep them engaged. Additionally, dialogue will be bilingual (English or Urdu) so that it is easier to follow for different demographics. If the user visits a marker out of order, they would be asked to visit an earlier

marker before they can explore the current marker so that the story progresses in order. Each marker will build up the story until the final marker, which will conclude the story.

Tour Guide: Our mascot is Makhnu the Markhor, who will also be the tour guide and will guide the user during the stages. The tour guide will be explaining a particular tour to the user and will also provide valuable information and facts about the artifacts within the tour. In addition, the interaction and communication between the tour guide and the user will be part of the roleplay feature.

Gamification Elements (Quizzes, Tour History, Coins): There will be two forms of quizzes that take place during a story: progression quiz and final quiz. The quizzes will be in MCQ format and may be supported with images. A progression quiz occurs at every model, except for the first one, where the user will be required to answer a question related to the previous model. If the user is unable to answer this question correctly, they will have to revisit the previous model and then retake the quiz before they can proceed. If the user answers the progression quiz question correctly, they will be told the story of the current model and progress. After all the models have been visited, a final quiz will take place which will comprise all of the information of the various models (shown in Figure 5.1 image 2). Furthermore, the user will be able to win coins (in-game virtual currency) at the end of every tour based on their performance in the quizzes (Figure 5.1 image 4). These will be used to unlock new tours. Users will also face a competitive environment where they will have to work hard to answer the quizzes correctly and that too in a short time period to climb the leaderboards.

Marker-based AR: To stimulate parent/teacher involvement, they will be required to print a sheet consisting of AR markers for each exhibit/model/character on a specific stage. Placing these markers around the house/school will lead to a custom hide-and-seek game for the children/students. This will encourage physical activity for children as they look for these markers in a search for the unknown, driven by competitive and gamification incentives as well as a curiosity to find the next mystery artifact/character and uncover a new part of the story. Parents/teachers will also be able to view statistics of the tour when it ends.

AR-based Interactions: To improve active learning and deliver a more immersive experience, users will be able to perform various gestures to interact with the application: tapping to trigger animations and dialogues, twisting to rotate the projected 3D model and pinching to scale the model to different sizes.

During the Lo-Fi paper prototyping, various issues were noted. Most of the users were unable to recognize the mascot's origin/animal during the loading screen. Some users were unable to identify the swipe to see the next tour feature. Some users also identified the lack of instructions for scanning and using AR markers. Moreover, most of the users were unaware that they had to get the marker sheets, prior to starting the tour. In addition to this, some of the users tried placing the device exactly over the marker. One possible reason for this was the missing tutorial about how to use and scan the AR markers as well as the constraints caused by the paper prototype. The users did not understand what to do when they failed to answer a quiz correctly. Moreover, there was an issue with dialogues which, in addition to complex vocabulary, were too short and were not appealing. The controller of the wooden sticks, during paper prototyping, made the users unsure whether or not they could interact with the exhibit. They were unsure whether to interact with an exhibit during the tutorial or not.

6 Results

For our usability testing phase, each user testing the application was first asked to fill the pre-questionnaire and post-questionnaire online surveys. 17 responses were recorded from both the surveys. There was a differentiable split in the age groups, allowing a variable level of responses from children and parents/guardians. All of the respondents, aged between 5-20, had studied in or were studying in an English medium school which allowed them

to understand the English version of the app with comparatively low difficulty. Majority of the users did not have direct access to printers. Thus, it would seem that our application should put more emphasis on the ability to open up the marker sheet on a separate device and scan the marker from there. This was possible, but almost all of the users were unaware that they could scan the markers using another device. The respondents were then asked whether they have played or interacted with applications based on Augmented Reality. 12 people agreed while the remaining 5 had never used such an application. Thus, it was the first experience with AR technology for some of them. The tests showed that all of the participants were quickly able to pick up how to use the markers with their phones. Thus, it was a simple process to understand and follow for most users. Moreover, since most users had experience with AR technology, it would seem that the general public would have similar experiences as well and would thus be able to quickly understand our application. The users were also asked whether or not they have visited the Lahore Museum prior to using the app for the first time. 10 people said that they had never visited the Lahore Museum before. On the other hand, 7 of the respondents stated that they had visited the Museum at least once. Thus, for the 10 people who had not visited Lahore Museum previously, we could check if playing the app induced any more interest in visiting the Lahore Museum. The majority of the users who had not previously visited the Museum before displayed positive responses to visiting the Lahore Museum after playing our app.

The post-questionnaire consisted of two variants, one for the children and students and one for parents and guardians. Table 6.1 below shows the average score of questions asked from the children and students' variant of the second survey. The average score is that each question had for the corresponding preference metric or heuristic. The score is computed by averaging out the user responses given on Likert scale of 1 - 5. A score of 5 shows that a user strongly agreed with the statement of the question, on the other hand a score of 1 suggests that the respondent strongly disagreed with the statement of the question. A high average score means that the user agreed with the question statement strongly and vice versa.

Table 6.1 Preference Metrics, Questions and Average Likert Scale Scores

Preference Metric / Heuristic	Question	Average Score (out of 5)
Learnability	The application was easy to learn even after using it for the first time	4.31
Error recognition and recovery	Whenever I made a mistake using the application, I could recover quickly and easily	3.69
Ease of Use	I felt comfortable using the application	4.62
Recognition rather than recall	I can easily remember where everything is located after using the application once	4.23
Help and documentation	I was clearly informed about what to do and how to progress in the game	4.38
Degree of interest for the content	How interesting was the story to you?	4.46
Visual appeal	How much did you like the 3D models?	4.08
Precision of 3-Dimensional Images	How accurate (similar) do you think were the 3D models to their actual exhibits or characters? (Those models that you had seen prior to using this app.)	4.15

Interest (would use again)	After playing this tour, I am certain that I would like to visit the Lahore Museum and look at these exhibits myself in real life.	4.00

Figure 6.1 below shows the average score of questions asked from the children/students in the survey. The score is computed by averaging out the user responses given on Likert scale of 1 - 5, with 5 being the highest value and 1 being the lowest. A score of 5 shows that a user strongly agreed with the statement of the question, on the other hand a score of 1 suggests that the respondent strongly disagreed with the statement of the question. A high average score means that the user agreed with the question statement strongly and vice versa.

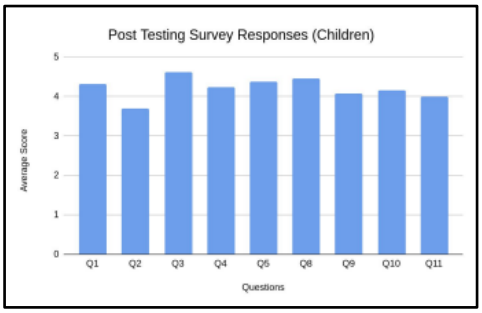

Figure 6.1 Average Post-Testing Questionnaire Likert Scores for Respondents

Variant 2 of the second survey focused on getting statistical feedback from the parents/guardians regarding the application. Their feedback is based on the interaction with the app until starting the tour for their children. A total of 4 parents filled this survey.

After testing the app, the parents were first asked, on a scale of 1-5, how easy was it to learn the application even after using it for the first time. These statistics showed that 3 of the users found the app to be easy to use. These results also support the performance measure, ease of use, discussed above. The parent respondents were asked whether they felt comfortable using the application. All of the parents agreed with the statement. This maps one of the usability measures: Degree of interest for the content. The users were very much interested in the content, leading up to the story and the application as a whole. The parents were also asked whether they could easily remember where certain features were located, within the app. All 4 respondents agreed with the statement. This shows that the features and content was correctly located and was easy to access and found by the parents. Finally, the parents were asked to rate the ease of starting the tour. The results showed variable responses. 2 out of 4 parents found the tour starting task to be very easy and doable. The other 2 parents found this task to be difficult. These results highlight one of the potential areas of improvement. The user experience was negatively affected by the difficulty present in starting a tour.

The post testing performance was measured based on the three performance measures of task-time efficiency (time taken to complete tasks including recovery time), final application tour scores and number of uses of help. The following graphs summarize the measurements and data that was used to measure the above-mentioned performance measures.

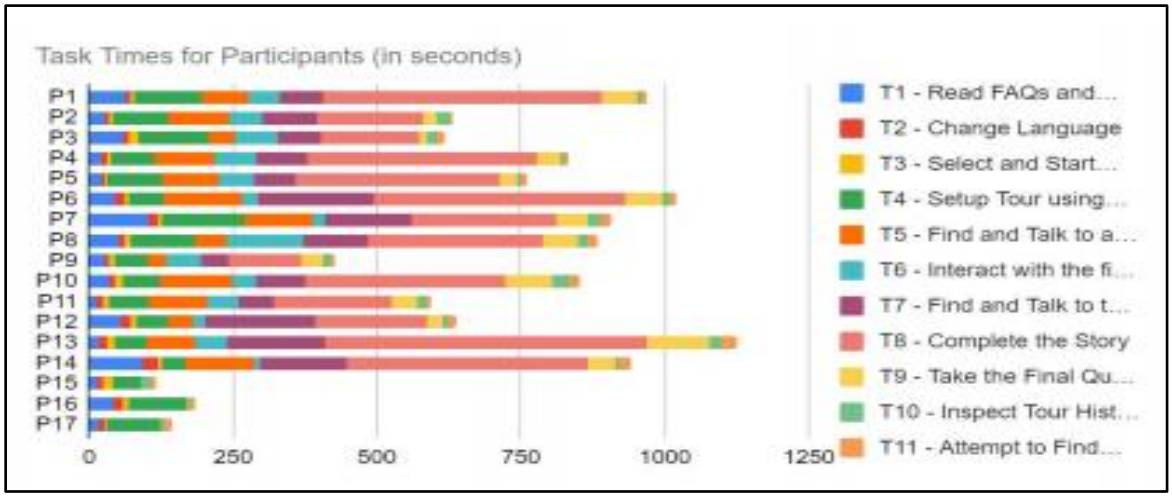

Figure 6.2 Task Time for Participants

Task-Time Efficiency: To measure our first usability metric, task time efficiency, for performance measurement analysis, times for all core application tasks were recorded in seconds from initiation of the task to the achievement of the task goal for all participants (depicted in Figure 6.2). Note that participants P15-P17 are parents and guardians and thus for them, only specific tasks associated with them were tested. The figure here displays the task times for each task for every participant that we obtained from our usability testing.

Task T3 took the shortest average time to execute (9s) while Task T8 took the longest time on average (317s) to execute. The average time taken for the tasks specific to parents and guardians (T1, T2, T3, T4, T10, T11) was approximately the same as it involved general navigation through the application interface. We noticed through our performance measure related to time-based efficiency, that generally the users took more time while setting up the exhibits and scanning them to find the models. One member also mentioned that the app should include a tutorial in order to explain more about the sheet printing, cutting, scanning and usage in order to interact with the models. They were confused after the first exhibit and didn't know that he had to drag the scanner to the second marker in order to proceed to the next model's story. One reason for this ambiguity was the online scanning process as a lot of users did not have printers at home, so images of the sheet had to be sent to them and they had to scan the pictures of the markers (in their laptops) through the app scanner in their phones.

Figure 6.3 Application Tour Scores for Participants

Final Tour Score: Figure 6.3 showcases the results obtained for the final tour scores or coins from the main Lahore Museum tour of the application which the users were required to play through the evaluation. This score was as a result completely dependent on the final quiz which tests their knowledge and memory of the historical facts covered throughout the virtual tour. The average tour score for our participants was estimated to be 260.71 which is relatively high and shows that they answered at least 2 out of 3 questions correctly in the final quiz. This verifies that the participants of our evaluation clearly understood the story content to some extent and retained most of the facts covered to succeed in this final quiz.

Number of uses of help: An average number of 3 calls for help or questions asked by each participant individually. This is still a relatively high value which shows that some of the instructions for the tasks and their execution were unclear to participants and hints towards lack of understanding for the instructions provided by the application. The exact correlations for the number of calls to age cannot be drawn because we are limited by our small sample size used for the evaluation.

The responses from the first survey, which was conducted before app testing, showed that the users took a keen interest in the stories of the ancient rulers of the Subcontinent and their lifestyles. This showed that generally, the respondents were interested in visiting a historical place. Respondents also stated that the presence of a tour guide, who would have provided insights on the description and historical backgrounds of the museum artifacts, is significant in enhancing the tour experience of the visitor.

> *"The dialogues were very interesting and the 3d models were very nice and they could be rotated in all directions" - P4*

> *"I liked the historical details, which makes this application very informative and intuitive." - P2*

After using the app, the participants liked the interaction with the 3d models of the various historical characters from the Lahore Museum and their unique dialogues were also very fun. They could also rotate the models to get a 360-degree view and compare it to the images that were displayed before each 3D model appeared and conversed with the users. The users also liked the historical details that were provided in the form of a story presented by the characters themselves and found them to be very informative. Another interesting feature of the app that many users loved was Makhnu the Markhor, who was the mascot of the app and also the tour guide who helps the user understand various steps and walks them through the entire journey.

> *"History is my favorite subject and I am especially interested in the Mughal Era. I even like to solve fun quizzes related to it online. I have never seen anything this fun and interesting to attract your interest to this subject. The 3D models were exactly that of paintings I have seen like that of Tipu Sultan. I would really like to play a similar tour for the Ottoman Empire so I definitely suggest making one." - P2*

Post testing interviews also provided some valuable responses and analysis. One of our participants (P2) was absolutely delighted to see our app and loved the whole tour of the Lahore Museum including the 3D models, their story related to the 1857 War of Independence and even the quizzes. His response especially validated our preferential measure on perceived usefulness as he foresaw and indicated great potential in the application. He very much liked the subject of History and also solved quizzes online, so this app provided him with a good combination of historical stories, artifacts and quizzes in a single platform. These are some of the features that will soon be added to the app to increase the overall experience through several models and exciting stories. Overall, the user believed that the user interface was simple, easy to use and the options were clearly visible. Furthermore,

he stated that the app's idea was really unique and interesting, and with a few improvements, the app could do really well as it has a lot of potential.

> *"The mascot was very cute. But the models did not look real which I did not like. The game was fun to play but some of the words were difficult to understand for me." - P6*

> *"I really like the concept of application, although I have learned this all during my O Levels but learning and experiencing through this way is quite interesting and engaging. I liked how the models interact with the user and the contextual words are really appealing like Afreen and Namaste." - P10*

According to some users the language used by the models while narrating the story included difficult vocabulary which made it difficult for them to understand what the models were saying and similarly, the quizzes were also very tough for them. The app's tour guide Makhnu was liked by almost all of the users and they thought he was very cute and adorable. As for the 3D models, the users had conflicting views - some though the animations were very well done and accurate in resemblance to the actual museum artifacts, while some users thought that the models needed some improvement in terms of their colors, texture etc. The users also related to the story, and thus, carefully read the dialogue for the purpose of learning. The models greeting the user by saying greetings like 'Salam' and 'Namaste' added extra value to the overall user experience.

7 Discussion

We primarily noticed that the application was given more preference by an audience slightly above the age group we had imagined because of the interest required for the story content and quizzes as well as the difficulty of language. Thus, in order to improve that we could include more imagery in the story telling part. While the models narrate the story, the user would be able to see images of the historical event in the form of an animated video or images. This way, users of all age groups would be able to understand the stories and would be able to solve the quizzes in a better way. Moreover, we could also include an option of 'level of difficulty/vocabulary' in the settings, which would show 'easy', 'medium', 'hard'. Then students in grade 5 or below could select the 'easy' or 'medium' option which would then show the same models and stories but the English would be easier, according to their level of understanding.

We also noticed a general lack of exposure and understanding to Augmented Reality. More suggestions asked for improvements to be made towards the interaction features as they were taken for granted due to this assumption. more tutorials should be based around the interaction part to improve usability. Similarly, the performance metrics validated the usability of the application in general but there is still room for improvement for some of the primary tasks by inclusion of more intermediate tutorials as even suggested by our participants themselves. Regarding our metric on realism and accuracy of the 3D models judging their aesthetics, there is also more room for improvement and they can be reconstructed in both structure and texture to increase the heuristic of visual appeal for children of our targeted age groups.

Even though all their queries were answered in the FAQ section, they still asked the interviewers for help. This showed that they quickly forgot that the settings included the FAQs option. So, for that, we could provide an 'info' option to the users for quick reference throughout the tour. This way if the users get stuck during any part of the tour, they would easily click the always available, 'For more info' option on the top right side of their screens and would be able to see the FAQs directly. We also found that some users had trouble with the sound/volume and were distracted by the typing sound when the models were narrating their story through the dialogue boxes. They had

to close the app and go to their phones' settings option in order to eliminate the keyboard sounds. In order to overcome this issue, we plan on adding a 'volume' option in the settings which would then allow the users to easily increase or decrease the app volume.

Another thing we found was that some of the users were very much interested in historical civilizations and empires and history in general. So, in order to enhance their overall experience with our app, we plan on introducing more tours related to other historical places like Badshahi Masjid, Sheesh Mahal, Lahore Army museum etc., where the uses will be able to interact with more models and listen to exciting new stories. Besides this, we also plan on introducing other empires and civilizations apart from those related to the Sub Continent (e.g., Ottoman Empire, Chinese Dynasties, ancient Egyptian civilizations, etc.). Each empire/ civilization will then have its own tours, models and stories. Thus, this evaluation has indicated that there is potential for expansion of the application both vertically and horizontally. Consequently, as a future implication, we believe that further consideration should be given to this domain of designing mobile augmented reality applications utilizing gamified stories for delivering historical and educational virtual experiences to children through similar interactive learning approaches.

8 Conclusion

With the restriction on physical trips and outdoor activities due to the lockdown of schools in the COVD'19 pandemic, children have been confined to their homes for months without any school or family trips. Through our user research we also discovered that even without the lockdown, there was a lack of education trips and also the fact that these trips were not beneficial to the students due to the lack of an engaging experience. Additionally, the lack of active learning in schools and over dependence on the classical form of teaching has left a void in the learning experience of children and led to a declining interest in history related subjects.

It was imperative to provide a solution that can provide the children with an opportunity to go on trips and at the same time, learn from their experience. After an extensive user research, design and development process throughout the semester, we are proud to provide a solution that provides an opportunity for parents to also be a part of the learning experience of their children and keep a track of their children's' performances. Apart from providing a fun and interactive platform to go on trips virtually, the mobile application also provides a learning aspect to the children. Thus, it brings together tours, stories and quizzes, to provide a perfect combination of entertainment, fun and academics.

The evaluation of the complete application helped us identify both the positives and negatives of the application. Most users appreciated the features and functionality provided by the app. They were excited about the use of Augmented Reality and 3D models which provided an element of interactivity. There were also certain complications identified by the users that proved to be vital contributors to the overall user experience. Marker identification was somewhat complicated. In case a quiz was not successfully completed, some users found it difficult to identify what needed to be done. Multiple usability heuristics and measurements were tested including efficiency, effectiveness, learnability and others. The positives and negatives of the application were identified and mentioned in the document. The suggestions from the surveys were also identified as vital for improving the application and making it better for the overall user experience. Thanks to the feedback by the users and our own observations, several changes will be made in the application in the future to incorporate those changes. Overall, the application provided a unique and interesting solution towards improving the interest of children in history and culture.

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