Immersive virtual reality to enhance the spatial awareness of students

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ABSTRACT

This paper presents a study on the effectiveness of virtual reality as a medium to enhance the spatial awareness and interest of students in the subject of history in rural Indian schools. Students of rural schools of the Indian village of Kandi in Telangana were provided with a Virtual Reality solution which helped them to view a remote historical place in full immersion. The historical site which was chosen for this project was the Golconda Fort. It was in the same state as that of the school, yet most of the students had not visited the place. Each student was given a 15 minutes session with the Virtual Reality module. In parallel, another set of students were taught about the fort in regular teaching methods. The two set of students were then given a written objective exam to analyze their learning. The two sets were then reversed and combined by giving regular teaching method to the students who used virtual reality previously and vice versa. These students were then given the test and the results were analyzed. It was found that spatial awareness including perception of colors, direction and size increased in the Virtual Reality based system. Factual data was more accurately interpreted when students were provided the information through regular teaching methods.

CCS Concepts

• **Human-centered computing~Virtual reality** • *Human-centered computing~User interface design* • *Human-centered computing~User centered design* • Human-centered computing~Graphical user interfaces • Human-centered computing~Smartphones • **Software and its engineering~Interactive games** • *Social and professional topics~K-12 education* • Computing methodologies~Interactive simulation • Computing methodologies~Simulation environments

Keywords

Tour, history, immersion, Google Cardboard, Binaural audio

1. INTRODUCTION

The project was done to study how effective a virtual reality based system would be in enhancing the spatial awareness and related learning in the subject of history for students from rural Indian schools. Through student interviews, it was identified that there is a gap in the present scenario where students are not able to visualize many of the objects or places that were taught in the syllabus. This was more pronounced in the field of history, where many students realize that what they visualized through reading text was not exactly what they saw when they actually visited the place. According to teachers, it was observed that students showed a decline in interest in the field of study of such subjects since the facts and data delivered through regular teaching methods were learnt by students without a relation to the physical appearance of the place. This causes a disconnect between reality and what is learnt, similar to watching a roller coaster ride on a TV screen to actually being in a roller coaster. A firsthand experience is found missing in regular teaching methods. Many historical sites have physical properties which appall people if they are actually present at the place. This can give a sense of size, color, sound etc. of the place and could help create connections with the history of the place. If this could be simulated, such an experience could be delivered at a place far away from the actual site. If such a system is provided in early stages of education, it could increase the curiosity and sense of exploration in students. Also it would enable students to better visualize places which could also enhance their creativity. One way of enhancing the spatial awareness of a historical site could be through photos and videos. But the feelings that one would experience at the place, along with the sense of direction and space cannot be captured through photos and videos. Engaging students for the whole chapter of the subject through immersive education could be a solution for this. The amount of engagement in this method proves to be a challenge since the target group is that of students around the age of 8 to 10 years. The

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method should be able to capture the students' attention for a short span of time and deliver the content in this time in a memorable way. Recall factor of students could be increased using video and audio. This project explores how an immersive education system like virtual reality would help enhance the learning of historical sites. This project is limited to historical sites which are presently existing either in prime or ruined state. For sites which are not existing anymore or which are physically inaccessible, 3d virtual content generation would be required, which is beyond the scope of this project.

1.1 Goals

The goals of this project were to document the target historical site with audio and photospheres, to design and develop an app to incorporate virtual reality and to conduct user studies. The deliverables include an app for documenting and making virtual walkthroughs, an objective model examination, analysis of data collected and cost estimation of the project.

1.2 Research and Resource requirement

- Data on historical site
- Tour guide for the site
- Audio recording
- Photosphere capture
- Transportation requirement
- Mobile phone with virtual reality support
- Virtual reality Head Mounted Display
- Language translator
- Person for voice-over
- Contact at school
- Stationery

2. LITERATURE STUDY

EON Reality's Virtual 3D Learning solutions have an array of different virtual reality solutions which involve projection systems, head mounted systems and other interactive virtual reality systems [1]. These have been catered to subjects like Mechanics, Art, Chemistry etc. [6]. They primarily involve simulations and majorly computer generated content. Their systems are comparatively very expensive. They argue that VR increases attention from normal by a much higher amount and it helps learn faster. Their use of guided tour of space and geographical sites inspired this project. These had the limitations that the tours were strictly visual and provided visual information only. Issues involved in using state-of-the-art interactive virtual environments in cultural public spaces by presenting the virtual environments developed for learners of all ages at the Foundation of the Hellenic World (FHW), a cultural heritage institution of informal education located in Athens is discussed by Roussou [10]. How such systems could become expensive and hard to maintain, and how content is developed for such systems are some points of interest. These decisions helped in narrowing down the initial user group and limiting it to rural schools and to inexpensive VR systems. MissionV [2] is a company which provides a highly creative, totally immersive, game based learning environment for schools and industry. It helps students become original digital content creators with 3D modeling and programming skills. MissionV allows students to connect, create and collaborate in a 3D world entirely of their own making. How content is designed to cater to students is of particular interest here. Virtual Reality helps students in visualizing abstract concepts and to visit and interact with events that time or distance might limit. [5] The various explorations in the field of virtual reality for education include training and simulations, classroom activities, virtual classroom, abstract representation and visualization etc. These show the potential fields of improvement and potential vacancies for introduction of new methods in education. When it comes to the technology itself, three challenges that must be met before VR can be integrated into educational settings are identified as cost, usability, and fear of the technology. Studies show that students learn best when a variety of learning methods are used [7]. Vicher, a virtual chemical reaction module for teaching chemical reactions with virtual reality, was used to test a group of students. The examination methods used in testing separate groups of non-VR users and VR-users were used in this project and its subsequent works [4]. VR and AR have also being used in developing pedagogical contents in History subject [3]. One such project is on the site of the Battle of Lexington. In the project participants get to interact with historical figures and events [11]. Virtual reality has a more immersive value compared to augmented reality and Virtual Reality in our project is free of any extra devices which would restrain the hands. A Virtual Reality Modelling Language (VRML) based system was developed to explore Erectheum in Athens [7]. The content was given to 4th Grade students for exploration. Although this project used 2D displays, a strong positive impact on student's performance was observed. Virtual Reality to teach History has also been explored by Allison [3] who points at a need for further development of virtual simulations, both in terms of their realism and the immediacy of the classroom experience. This was based on the technology available in 2008. Immersive reality technologies have been developed later on and realism has reached up to the level of 360 degree spherical videos. Youtube has started providing such 360 degree video content. 2 months after the user testing of our project, a Virtual Reality project was launched by Google called the Google Expeditions. On the similar lines of this project, it helps a user experience a remote site. This was also primarily aimed at students.

3. INITIAL STUDIES

For this project, initial research on the subject was conducted through literature study and interviewing experts in the field of education. It was identified that there is a gap in the present scenario where students were not able to visualize many of the objects or places that were taught in the syllabus. This was observed during interview of students from nearby schools and the Indian Institute of Technology Hyderabad. This was particularly strong in the field of history, where many students realize what they visualized through reading text was not exactly what they saw when they actually visited the place. This disjoint could be bridged using a medium like virtual reality. Virtual reality can sensitize students' senses to a plethora of stimuli which would be encountered from the actual site. These help students to gain knowledge and will enhance conversations based on the site. Just as an actual field trip would bring the flavor of history to the here and now, a virtual field trip can help students reach into the past in a meaningful way [13].

4. TARGET GROUP STUDY

For the project, rural Indian schools were targeted. This was because technological intervention in such schools was less. A Google Cardboard based module would be less expensive to implement compared to implementing a computer based system for immersive studies in such schools. Specifically a Head Mounted Display was used to give a completely immersive solution to enhance interest. There was also the possibility that further projects related to immersion could be done in the schools, once such a system was implemented.

The students of the schools of Kandi village near IIT was identified for the project due to proximity to the Indian Institute of Technology Hyderabad and considering the ease of travel and access. The syllabus of the students were studied and it was found that there was a portion covering a particular historical site, the Golconda Fort [Fig.1]. On interviewing the students [Fig.2], it was found that most of them had not actually been to the historical site. Though the students had English as a subject, they found it easier to read and write in their native language, Telugu. From this observation, it was decided that the medium of instruction for the project should be Telugu. The students from class 3 to 5 were taken as study group since they were familiar with the site and their syllabus covered the same.

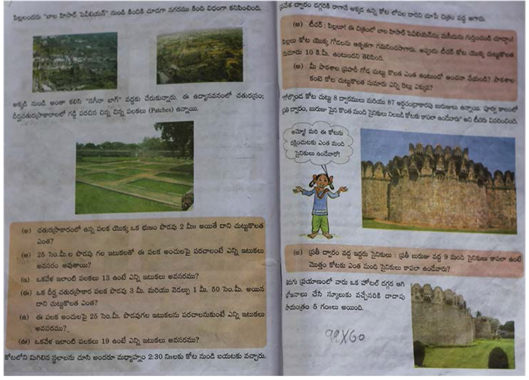


Figure 1. Syllabus covering Historical site.

Figure 2. Interaction with students. © Fabin Rasheed

5. Data Generation

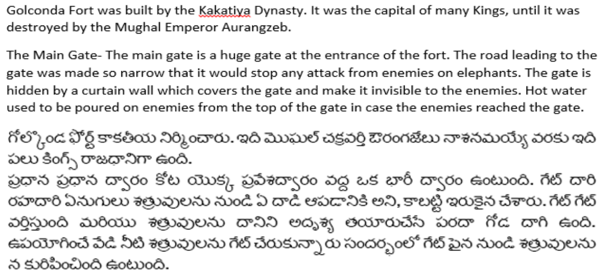
The documentation of the site required 360 degree photos to be taken and audio of the tour guide to be recorded. For the photos, it was ideal if there were no moving subjects so that no blurred portions occur after the stitching process of 360 photospheres. For this, the site had to be documented early morning when there were no tourists. A tour guide was hired and data was collected at all main points of the Fort using an audio-recorder and 360 spherical photos using the Google Camera app. The photos taken were then reduced in size to decrease latency when using the app. After the first iteration of the module, it was observed through regular user testing that there was a lack of sense of direction. Hence markers were manually added on these photospheres. Red was identified as the color for the present place of interest, because it attracted attention most. The symbol used was similar to the location markers commonly used in maps. The yellow marker was identified as the next place of interest in the tour and white as other points of interest. The yellow symbol was designed in such a way as to give an appearance of moving from an inner portion to the next portion (a circle within a circle). The texts in respective colors were used to give the names of the places of interest in Telugu. White color texts were used for details other than the places of interest (e.g. a cannon ball in the armory). The font size was considered in relation to readability and to avoid clutter [Fig3]. This was on an average 2.5% of the height of the photosphere document and 8.5% of the virtual reality display height.

📍 Present place of interest ● Next place of interest

Figure 3. Photosphere with markers and types of markers. © Fabin Rasheed

6. CONTENT CREATION

The voice of the tour guide was in broken English. This was then grammatically corrected. With the help of experts in education, this content was made into a narrative with simple and easily understandable text for the students. The content was then condensed into 8 major sections - one introduction and 7 locations on the basis of the chunking theory [9] [Fig.4]. The data was then translated into Telugu with the help of students from Indian Institute of Technology Hyderabad who were well versed in Telugu. The content was recorded as audio in Telugu and was used as voice over for each place of interest in the tour. The voice was narrated in the manner of a tour guide (This was later decided to be a squirrel character. The pitch of the voice had to be changed to match a hypothetical and popular squirrel voice.) The content was narrated as a story and as a conversation with added elements of humor.



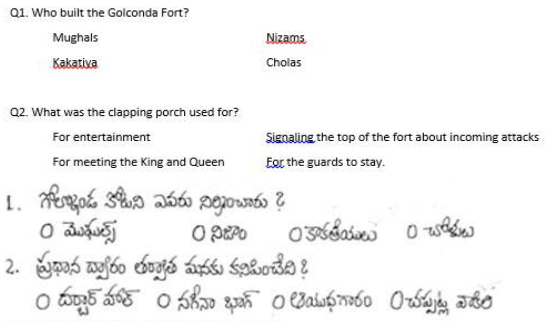
Golconda Fort was built by the Kakatiya Dynasty. It was the capital of many Kings, until it was destroyed by the Mughal Emperor Aurangzeb.

The Main Gate- The main gate is a huge gate at the entrance of the fort. The road leading to the gate was made so narrow that it would stop any attack from enemies on elephants. The gate is hidden by a curtain wall which covers the gate and make it invisible to the enemies. Hot water used to be poured on enemies from the top of the gate in case the enemies reached the gate.

గోల్కొండ ఫోర్ట్ కాకతీయ నిర్మించారు. ఇది మొఘల్ చక్రవర్తి ఔరంగజేబు నాశనమయ్యే వరకు ఇది పలు కింగ్స్ రాజధానిగా ఉంది.
ప్రధాన ప్రధాన ద్వారం కోట యొక్క ప్రవేశద్వారం వద్ద ఒక భారీ ద్వారం ఉంటుంది. గేట్ దారి రహదారి ఏనుగులు శత్రువులను నుండి ఏ దాడి ఆపడానికి అని, కాబట్టి ఇరుకైన చేశారు. గేట్ గేట్ వర్తిస్తుంది మరియు శత్రువులను దానిని అదృశ్య తయారుచేసే పరదా గోడ దాగి ఉంది. ఉపయోగించే వేడి నీటి శత్రువులను గేట్ చేరుకున్నారు సందర్భంలో గేట్ పైన నుండి శత్రువులను న కురిపించింది ఉంటుంది.

Figure 4. Content as chunks and translation.

7. EXAMINATION QUESTIONNAIRE



Q1. Who built the Golconda Fort?

Mughals
Nizams
Kakatiya
Cholas

Q2. What was the clapping porch used for?

For entertainment
Signaling the top of the fort about incoming attacks
For meeting the King and Queen
For the guards to stay.

1. గోల్కొండ కోటని ఎవరు నిర్మించారు ?
○ మొఘల్స్ ○ నిజాం ○ కాకతీయులు ○ చోళులు
2. ప్రధాన ద్వారం తర్వాత మనకు కనిపించేది ?
○ దర్బార్ హాల్ ○ నగీనా బాగ్ ○ ఆయుధాగారం ○ చప్పట్ల వాకిలి

Figure 5. Examination questions.

From the created content, objective questions were created for the students to answer. These included factual historical questions like “who built the Golconda Fort?”, spatial awareness questions like “how big is the Golconda Fort in relation to your school/Kandi”, error-finding questions like “was there a roof for the *place*(the *place* being the answer to a previous question)”. These were again translated into Telugu [Fig.5].

8. APP DESIGN AND DEVELOPMENT

At first the app was planned to be developed as a holistic app with which anyone could make an immersive audio walkthrough with 360 photospheres. This app was named Xplor [Fig.6].

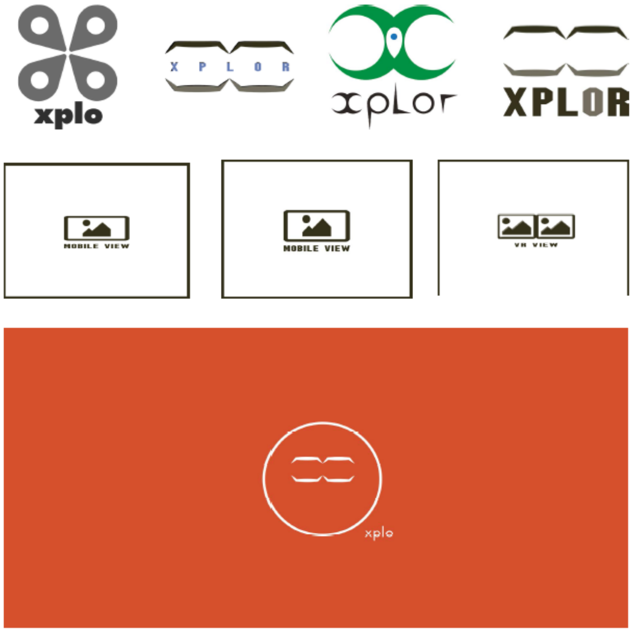


Figure 6. Initial iteration of app- Variations of logos and interface © Fabin Rasheed

For the final app design, a friendly squirrel character, Fanny, was considered as the primary character for the app. Squirrel is an animal found widely in Telangana and can be thought of having access to many inaccessible places. The squirrel was given a Nizam’s hat and cane to give it a more “Hyderabadi” and royal feeling. The squirrel is one of the ministers of the King of Golconda in the narrative [Fig.7].

Figure 7. Final iteration of app- Logo and character © Fabin Rasheed

The interface was limited to 2 screens to give it a game like feeling. The splash screen and the main screen were designed keeping the historical site in mind and the age of the target group [Fig.8]. There were two modes for the app. One was the Virtual reality mode which required the Google Cardboard and one was the normal mode which used only the mobile screen. Upon selecting one of them, the story/module starts. The story would be the 360 view of specific places in the historical site. Markers helped in giving the users a sense of direction. The dynamic map also helped in giving a sense of direction and size [Fig.9]. This map rotated according to the direction in which the user was looking. The app used the sensors in the phone to dynamically render the photosphere according to direction of viewing. It also showed where in the nearby area would be the next place of interest using markers The North direction was denoted using an orange arrow on the outer circle of the map. To move from one place to the next, the user had to pull the Google Cardboard trigger. To move to a previous place, the person had to pull the trigger twice (similar to a double-click). Since going forward would be more often than going backward, single pull was assigned to the forward action. The recorded voice was then incorporated into the squirrel character within the interface. The audio was binaural, which again gave the sense of space for the viewer and helped to enhance the presence of the squirrel. Ambient sounds were added, like birds and wind along-with a background music to help the user to be completely separate from external noise and to be more engaged (the music had a pleasant game tone). Every time the trigger was pulled, an intermediate loading screen was shown which had the text that meant "travelling" instead of "loading" [Fig.9]. This was to provide the feeling of transition rather than the feeling of a computer interface. The app was developed in the Unity3d engine with Cardboard SDK.

Figure 8. Final app interface © Fabin Rasheed

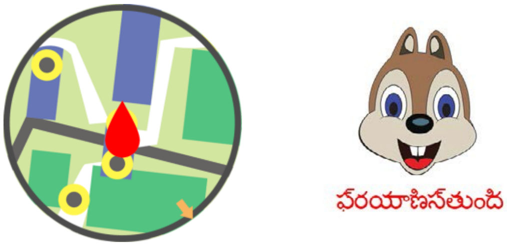


Figure 9. Dynamic map and loading screen © Fabin Rasheed

9. USER TESTING

The setup for testing consisted of a Nexus 4 android phone with the Fanny World app installed. This was placed in a Google Cardboard. Headphones were connected for audio. The user testing was done in 3 sets. Separate groups were randomly formed for Virtual Reality based testing and regular teaching method based testing. In VR based testing, the students were given the module and were provided basic instructions about its working [Fig.10]. They were allowed to use it for as long as they wanted (The VR module set was generally completed in 15 minutes). Students were seated on the floors and provided education in the school. Hence there was ample area for VR usage without obstructions within the classroom. The student who was using the VR was allowed to stand in a free area in the room, which gave enough area for moving and turning around. In parallel, the text about the site, which contained the same content as that of the VR module audio, was given to a teacher to teach in the regular teaching method to the other group of students. The teacher having previously visited the location was expected to share the knowledge about space as well. The second group students were given the same examination questions. Then, the groups which used VR was taught by regular teaching method and vice versa and then the same examination was taken by all of the students. The same examination was given in order to analyze the progressive changes in their answers. This was also to find if they had changed their answers to certain questions, especially some of the error-finding questions. Results of all three sets (VR, Regular teaching method and Combined) were compiled and analyzed. Feedback from students were also taken.

Figure 10. VR based method and regular teaching method © Fabin Rasheed

10. OBSERVATIONS

The primary analysis from 2 days of testing with an average of 10 students per day, with 5 students per set provided the following insights:

- The Virtual Reality - Regular teaching method combination (3rd group) gave the most accurate results as compared to the other two test groups.
- Colors were better identified by students who used virtual reality (82% correct in VR, 45% in Regular Teaching Methods, 88% in Combined).
- Though some students who used virtual reality got factual questions wrong (E.g. where did the dance performance take place?), the adjacent spatial question (did that place have a roof?) was answered right in accordance to their previous answers. Though the teacher had previously visited the site and had used sketches to describe places, the regular teaching method students failed to answer these questions consistently.
- Size awareness was magnified. Majority of the students compared the site to the size of Telangana (the state).
- Regular teaching method had better accuracy (84%) of factual questions. This decreased in the virtual reality only group (68%).
- Students each spent an average of 15 minutes per session in virtual reality while the same content was delivered to a group of students in 10 minutes through regular teaching method.
- Students who used virtual reality for a second time and had extended the usage for more than 30 minutes, had started rubbing their eyes.
- Some students said it was humorous.
- Some students reported some places to be frightening (these places were generally rooms with a roof and no people).
- In the first session, some results were inconsistent. Later it was observed that this was due to spelling mistakes in Telugu which happened during font conversion.

11. CONCLUSION AND FUTURE WORK

11.1 Conclusion

From the 2 sessions, it was concluded that the spatial awareness of students in relation to a particular historical site can be improved through Virtual Reality when used as an addition to regular teaching methods in rural schools of India. This spatial awareness included facts via observation, colors, and direction. Since factual data was more accurate in regular teaching method, virtual reality and regular teaching method could go hand in hand. Thus virtual reality could be an add-on tool to education. The fact that it arose curiosity and interest in the particular site is to be noted. But whether this is a consistent interest is a fact which should be studied more. Implementation of such a system would require a cost analysis to see its feasibility for rural schools. This is as follows:

If a virtual reality module was to be given to school of 200 (average of schools in the area) students, with a class period of one hour and taking into consideration that each session was not for more than 15 minutes, a total of 10 virtual reality kits could cover a class of 30(which is the average strength of students in the schools in the area).

For one kit the cost estimate would be:

Google Cardboard:	INR 300
Android Phone:	INR 6500
Headphones:	INR 300
Total:	INR 7100
For one school this would be INR 7100*10 =	INR 71,000.

11.2 Future Work

Multiple iterations of the module can be made by continuously testing in different schools in the area. Larger data sets can be obtained for verification of the results obtained so far and to improve on the data and content given. The examination questions can be made more suitable and a game based examination could be tried. Different examination sets for each test group could be made, tested and analyzed. Different historical sites can be tested and the results could then be compared. Also students can be taken to the actual site and a comparative study can be done. A holistic product could be made which would reduce the overall cost of the module. This could use a dedicated hardware instead of an expensive android phone. A 3d rendering of a proposed design is shown in Fig.11.

Figure 11. Proposed holistic module © Fabin Rasheed

Expanding on the present technology, the photospheres could be replaced by 360 videos, which would give a better engaging experience. This could also be made an interactive experience using technologies like the leap motion. The app could be further modified or extended to become an app with which anyone could make an audio walkthrough with 360 video.

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