The impact of design on improved learning in virtual worlds: an experimental study

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Abstract
Virtual worlds are the most advanced form of virtual environments, which offer one of the best platforms for serving various domains. They are, especially, well suited for education, to cope with the physical restrictions imposed due to COVID-19 outbreak, as they offer classroom experience to their users through immersion. They are online interactive spaces which are collaborative, persistent, coherent, and social in nature. Users immersed in these spaces are represented in the form of digital characters called, avatars. Virtual worlds offer advanced navigation methods such as flying and teleporting to facilitate quick learning. This paper analyses the use of a partial but carefully reconstructed cultural heritage site, developed in OpenSimulator framework, for learning both in terms of discourse and quantitative analysis. Discourse analysis compares the developed virtual world presence with traditional content provisioning methods in terms of a large set of well-known characteristics. Quantitative analysis, on the other hand, is based on data collected from users after conducting simple learning experiments. It revealed that the properties such as realism, friendliness, advanced navigation, and being detailed and social in nature greatly attracted user attention in learning. The learning was fast compared with traditional methods, however, it was a little hard for naive users to start exploring the content. Pre and post learning responses of users revealed that their knowledge level was significantly increased. Based on valuable suggestions, it is planned in future, to add intelligence to traditional agents, so they may help in an increased learning experience of users, based on the knowledge gained in earlier sessions.

Keywords Virtual worlds · Cultural heritage · Virtual reconstruction · OpenSimulator · Tele-porting · Learning

1 Introduction
The emergence of Internet transformed the traditional physical ways of content provision methods such as text, pictures, and videos. It facilitated the development of online interactive and collaborative environments for learning. These environments were, however,
greatly criticized for lacking social abilities and thus taking the students/users towards isolation [16]. Virtual Worlds (VWs), the most advanced form of 3D virtual environments, were developed to encounter this criticism, by introducing the concept of immersion. These worlds imitate the real world for content provision and users’ immersion in them. They facilitate users to participate in many activities, which are physically unsafe, expensive and dangerous [14]. VWs are general purpose and do provide social capabilities, where the avatars representing humans inside the spaces, interact and collaborate with each other [2, 17]. However, these environments were used mostly as an additional tool in learning process and very few organizations around the globe opted to depend mostly on these technologies. The COVID-19 outbreak, originated from Wuhan China, by the end of 2019, greatly disturbed the world affairs [32]. Education and learning was among the mostly effected domains. The organisations greatly realized moving towards using various online mechanisms, especially, when it was announced by World Health Organisation (WHO) that the world would take years to resume its normal pace [32]. VWs offer one of the best platforms to serve various domains but especially the education as they offer classroom experience to their users through immersion [15, 17]. They believe in environments, which are not only scalable, effective, flexible and efficient but also adaptive, engaging and personalized, in nature [3, 5]. The nature of these environments make them suitable for role playing activities, where role playing design bridges the technical and pedagogical essence of VWs in learning [8]. They are capable of running various businesses and reducing the risks of spreading infections. VWs are online interactive spaces which are collaborative, persistent, coherent, and social in nature. The digital characters called, avatars, represent the immersed users in these spaces. They offer advanced navigation methods such as flying and teleporting to facilitate quick learning in addition to traditional mechanisms such as walking and running. VWs have become famous for developing virtual presences of countless number of application domains including simulations, games, education, augmented reality, trainings, distributed collaborations, health-care design, commerce, visualization, and Web [18, 33]. They are also increasingly used for promoting tourism and re-constructing the past [4, 6, 25]. The re-construction of past provides an opportunity for the users to get fast and accurate learning about their culture heritage, which might not exist in its original form. They could be specifically used to get, youngsters, acquainted with the glorious cultural heritage [25]. Even, if, the heritage sites do exist physically, the development of their digital presences’ might help attract global audience, which might not be able to visit these places in person due to time, mobility, and budgetary constraints. It is expected that VWs would in future evolve based on advanced Artificial Intelligence (AI) agents for more exciting experience [28]. The world is taking benefit of these exciting environments, however, no such environments are developed in Pakistan and mostly traditional ways, both physical and online in nature, are used for content provision. These methods include text, pictures, videos, and non-interactive 3D representations [2, 16].

In our previous work [2], we introduced these environments for preserving cultural heritage and imparting education with the help of a case study of rail transportation system at Bannu – the oldest district in southern part of the Khyber Pakhtunkhwa province of Pakistan. Teleporting was added to link the two presences: one for the present (for imparting education) and the other for the past (the cultural heritage), and offer quick navigation between them. The main reason behind this construction was based on the truth that this heritage site has mostly been demolished and replaced mostly by University of Science and Technology Bannu (UST Bannu). This content was developed in OpenSimulator (Osim) - an open source virtual world development framework [2].
In this paper, we analyze our virtual presence of cultural heritage site for learning both in terms of discourse and quantitative analysis. The discourse analysis compares the developed presence with traditional offline and online methods for content provision using a large set of parameters. The quantitative analysis is, on the other hand, based on data collected from users after conducting simple learning experiments. This intended to determine the impact of various parameters for quick and concise learning compared with traditional techniques. This paper explores the worth and limitations of the developed presence, where the users are offered quick navigation through interactive signboards, which are used to initiate teleporting. This arrangement makes it easy for them to explore and learn in this space.

The rest of this research paper is structured as follows. Section 2 provides the background of the study along with relevant literature. It also presents the motivation and goals set for this study. Section 3 elaborates the proposed work and produces the design with an emphasis on data and procedural design concerns to handle quick navigation using teleporting. The implementation of the proposed work is presented in Section 4. Section 5 produces detailed evaluation of VW presence in terms of both discourse and quantitative analysis to highlight its impact on learning. This paper ends with conclusion and future work presented in Section 6.

2 Background and literature review

2.1 Background

Kalabagh-Bannu railway line was a narrow gauge line of a width of two and a half feet. A small gauge train, which was running on coil, used to run on this track. In 1913, its first part of 142 km length was made operational [10, 21]. In 1916, an additional 73km track was added to connect it to the city of Tank [10]. This Bannu-Tank line was connected to the north western rail and ultimately the rest of the network through Kalabagh [10]. Bannu–Tank line was among many railway lines, operated under Pakistan Railways for many years. The locals would call it choti rail due to its narrow gauge track and it had seven stations namely: Bannu, Aba Khel, Serai Naurang, Lakki Marwat, Shahbaz Khel, Pezu and Tank [1, 20, 29]. It was used mainly for transporting military goods and lumber across the country [1, 20, 29]. Due to the geographical importance, Bannu has importance as a business hub and it has a cantonment established during the British regime. To facilitate the military and business, railway had a huge setup at Bannu which includes a spacious train station, guest houses, a hospital, and a police station. In 1970-71, the government of Pakistan decided not only to upgrade this track to broad gauge but also extend it till afghan boundary. This, however, could not materialize due to political and strategic problems [29]. The people of Pakistan witnessed, 1991-93, as the darkest period of Pakistan Railways, when the government started huge investment in road transportation especially buses and trucks. This decision directly affected the railway services and systematically destroyed it [1]. During this period, trains on many lines were closed, including the Kalabagh-Bannu line [20, 29]. Figure 1(a) shows the rail heading towards Bannu while Fig. 1(b) provides a glimpse of the train station at Bannu. The Bannu train was completely dismantled in 1995. Since, the Kalabagh-Bannu-Tank line was not maintained, the huge installations on this track were gradually destroyed. In 2005, when the government planned a University in Bannu, about 200 Kanal land of railway was handed over to the University to build their two city campuses. The rest of the precious assets are held under the control of different government and non-government organisations.
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Fig. 1 The glimpses illustrating the: (a). Bannu rail heading towards Bannu, (b). main train station at Bannu, and (c). old survived building in current IT campus of UST Bannu, and d). Rail map and part of Bannu rail at a random station

British rail at Bannu has a glorious history as it not only served the army and lumber business but also the common man as passengers. Unfortunately, the government neither managed to keep it operational nor it was maintained as a heritage. Most of the buildings are completely or partially demolished including the most important train station (shown in Fig. 1(b)), which has been completely demolished. The majority of its land and buildings are replaced with modern buildings of courts, and different campuses of UST Bannu. However, some of the buildings of this huge installation still do exist but under the control of different departments. The traffic headquarter of Bannu police is also housed in part of this installation, comparatively in a better form. Figure 1(c) shows an old survived building in IT campus of UST Bannu. The map of national railway network of the past is provided in Fig. 1(d).

2.2 Literature review

The VW presences offer an immersive experience, which greatly help inspiring the visitors to learn about cultural heritage instead of using traditional non-interactive methods based on text, images, and videos. They also offer social interaction among the visitors and give a realistic exposure targeting a global audience. This work, therefore, intended exploring VW presences in the Literature related to virtual world presences for preserving and reconstructing cultural heritage and comparing it with the trends used for similar environments in Pakistan.

Lercari [23] investigated the use of VWs for simulating history. According to him, VWs provide more precise and accurate visualisation of the past. According to Sequeira and Margado [31], traditional approaches to virtual archaeology involve intense technical procedures, which require huge costs. They, therefore, recommended using VW presences as
alternatives to present historical information or manage heritage based projects. Kennedy et al. [19], developed a virtual model of St. Andrews Cathederal located East Coast of Scotland. Mayan pyramid in Palenque, Mexico are the historic archaeological and cultural heritage site, which is visualised through virtual content, freely available in an OpenSim Archive (OAR) file [27]. This content includes the temple of the inscriptions, spacious houses and palapas - small thatched huts, in addition to the pyramid. This content is developed by Pentecost and it could be accessed through OSim. Coy developed a virtual telephone museum in Second Life (SL) [7], to help people know the evolution and glorious history of this invention of the past. Forte and Pietroni [11] investigated the VW capabilities for collaboration between individuals of multidisciplinary scientific community integrating historians, archaeologists, and social and communication experts. Davies et al. [9] presented a cross reality system named, mirror shades, which integrates both real world and virtual reality environments. The Network System Laboratory at Tokyo University of Information Sciences has developed a number of games using OSim framework. They include car, plane, and train games to test various concepts of OSim such as mega-regions [24]. It includes a station, a bridge, and a railway track. Role playing community has developed a mysterious laboratory in SL, which allows the residents to step in to 18th century through a time portal. The users can visit the laboratory and an 18th century estate representing somewhere just outside Paris [30]. The residents enter the estate and find no one around, knowing nothing about the estate, its owners and servants. Thus, they are given an opportunity to explore all this on their own. A virtual presence, Museum Island [34], developed in SL, provides a collection of more than 30 monuments of middle east and Mediterranean area. This content is based on the dream of Carlolello Zapatero. It is a nice place to visit, take photos, admire the art work, and listen some great music.

Beck et al. [4] analysed VR based research in tourism and presented a comprehensive review on state of the art in these initiatives. Nemtino et al. [25] have developed a database of 3D models constructed for the typical objects regarding cultural heritage and related concerns of memorial sites of famous Russian personalities of Tambov region. These objects include the structures of buildings, household buildings and items, utensils, local plants, and animals. Table 1 summarizes some of these mechanisms and applications along with their worth and limitations.

2.3 Motivation and goal

Pakistan is a country having huge cultural diversity and many world famous heritage sites. People around the globe, however, have a very limited exposure about us. Global practices are, now-a-days, using advanced techniques such Non-interactive 3D and VW presences in addition to using the traditional methods such as texts/images and videos. Pakistan is still hugely using traditional ways of content provisioning for both learning and preserving cultural heritage. 3D non interactive virtual tours were found but very limited in number. State Bank of Pakistan museum was the only known institution that has such an improved existence on the Web [13]. These environments are, however, not offering advanced and unique features like VW presences. The use of VW presences was not found, when this research work explored the content provisioning methods in Pakistan.

The tremendous benefits offered by VWs and the non existence of VW presences for our rich cultural heritage motivated us to encourage global audience for tourism through the development of such environments. In this connection, we developed VW presences for the present and past of the British rail system at Bannu and linked them together, as a case study, in our previous work [2]. This work intended to get two folded benefits. Firstly, it targeted preserving/re-constructing the old heritage site almost completely demolished.
| Research paper                          | Theme                                                                 | Remarks                                                                 |
|----------------------------------------|----------------------------------------------------------------------|-------------------------------------------------------------------------|
| Lercari [23]                           | Simulating history in VWs and investigating the precise and accurate visualisations | An investigation study with certain outcomes                           |
| Sequeira and Margado [31]              | Explores and compares the virtual presences for archaeology in SL and OSim | A comparative analysis of two well known VW environments               |
| Kennedy et al. [19]                    | A virtual model of a Scottish east coastal St. Andrews Cathedral     | A detailed but simple traditional VW presence                         |
| Pentecost [27]                         | The virtual presence of Mayan pyramid and some traditional Mexican houses | A very simple traditional VW presence for cultural heritage            |
| Coy [7]                                | The virtual telephone museum in SL                                   | A detailed but simple traditional VW presence about one of the best inventions of the past |
| Forte and Pietroni [11]                | The reconstruction of 3D models for archaeological past in collabor-ative environments | A 3D realization of a multi user virtual space for sharing 3D information between the personnel involved in a multidisciplinary research |
| Davies et al. [9]                      | A cross reality system which enables a user presence and awareness of both virtual reality and real world spaces | A simple cross reality platform for comparing the virtual reconstruction of a heritage site with its physical existence |
| Network System Laboratory [24]         | Tokyo University of Information Sciences lab developed using OSim framework for developing and testing various concepts | A virtual space for testing different scripted game setups of restricted nature |
| Second Life [30]                       | A SL Lab that facilitates users to visit the past through time portal | An interesting and exciting environment for exploring an 18th century estate of Paris through role playing |
| Zapatero [34]                          | Museum Island - a good collection of middle eastern and Mediterranean monuments | A detailed and interesting virtual space with a traditional design |
| Nemtino et al. [25]                    | A virtual library of heritage objects of memorable objects          | A good collection but in a database form and lacks an operational VW presence |

Secondly, it intended to use it for learning about the glorious past and rich cultural heritage. The previous work concentrated on partial development of both presences and linking them together. However, this work is concentrating more on exploring the impact of VW presence for heritage in learning. It uses discourse as well as quantitative analysis for this purpose. Before evaluating the proposed environment, it presents a detailed analysis for a careful design to implement customised support for quick navigation to facilitate fast learning.

### 2.4 Contribution

VWs offers exciting virtual spaces, however, we believe that their benefits could be further improved, if they are carefully designed and optimised for certain concerns. The majority of related studies discussed here are designed with traditional mind set, which makes it difficult
to navigate through and, thus, adopt them for quick learning. The main contribution of this work is the design of a local heritage site optimized for learning purposes with the help of careful navigation through teleporting while maintaining the societal traits intact. It is, then, compared with traditional mechanisms using both discourse and quantitative analysis.

3 The proposed presence and its design

3.1 The proposed virtual presence

This paper presents the VW presence developed for the cultural heritage part (the past) of our case study about the present and past of the rail transportation system at Bannu. This work partially reconstructs the mostly demolished part of heritage site along with a survived building. It introduces explicit support for advanced navigation through teleporting with the help of interactive signboards. Scripts are added to the content for making it dynamic.

The British era rail at Bannu had huge installation, but in this work, we propose developing the main train station, management offices, main waiting hall, the platform and the train model. Guidance maps and signboards are introduced to help users in standard ways of navigation (walking and running) as well as flying. Since, quick navigation is key to fast learning, these guidance maps and signboards are further made interactive for explicit navigation using teleporting. This saves the time of users, as they reach out at arbitrary locations in short time. The proposed presence implements societal and ethical norms and concerns.

3.2 Analysing explicit requirements

OpenSimulator (OSim) framework is a complete platform for hosting and managing VW environments both in standalone (for simple experimentation) and grid mode (for highly scalable worlds). It uses both files and databases to manage data requirements of the framework, in general, and VWs, in particular. It provides support for three different database engines: SQLite, MySQL, and MSSQL. Filing system is used mainly for archiving purposes such as OpenSim Archive (OAR) files are used for backup purposes while inventory archive files are used for archiving inventories.

Since, the VWs imitate the physical world, the OSim framework provides the whole functionalities required to materialise VWs in a single package. The package is capable of hosting and managing VWs in both standalone and grid modes. However, the implementation of additional activities such as customised navigation and introducing societal and ethical norms, requires not only explicit functions but also managing their corresponding data.

3.2.1 Data requirements (the conceptual model)

Since, this work intends to incorporate teleport based navigation in the proposed system while keeping societal norms and ethics in mind, we have to store the information regarding all buildings and the amenities such as train station, offices, platform, and the train. Figure 2 provides the conceptual model for both the present and past in terms of an Entity Relationship Diagram (ERD). A building or a section is called a location while the term presence keep the present and past distinct. The current work will use the data required for teleporting within the same presence, which is the past. The attributes are not shown in the ERD for clarity but they are, instead, provided in logical design.
3.2.2 Functional requirements (the data flow model)

Data Flow Diagrams (DFDs) are used for modeling different levels of data flow in a system. The most detailed level of DFD is converted directly into the procedural design. Figure 3 provides the final level DFD, which models the explicit requirements of proposed presence, in terms of processes and their corresponding input(s) and output(s).

3.3 The design

3.3.1 Logical design

Logical design for the explicit data requirements is obtained by directly converting an ERD to relations. The set of following relations is obtained, when the ERD given in Fig. 2 is converted to relations:

- Campus(CampusID, Name, Address)
- Building(BuildingID, Name, Address)
- Department/Section(DepartmentID, Name, Address)
- Presence(PresenceID, Name, Address)
- Campus-Build-Dept(CampusID, BuildingID, DepartmentID, Location)
- Campus-Build-Dept-Presence(CampusID, BuildID, DepartmentID, Presence)

3.3.2 Procedural design

The standard rules are used to convert the detailed DFD presented in Fig. 3 to procedural design. A main module is added to integrate the procedures obtained through the conversion. The conversion of data flow model presented in Fig. 3 resulted in four algorithms namely, the Main Module (Algorithm 1), Get the Teleport Location Request Module (Algorithm 2), Get Teleport Location Details Module (Algorithm 3), and the Teleport Module (Algorithm 4). These modules are used to teleport the player, who initiated the teleport operation, from its current location to a given location.
Fig. 3 The detailed level of DFD, which provides explicit data flow requirements to support teleporting

Algorithm 1 The Main Module().

Input: Teleport Request  
Output: Player Teleported to New Location

1 //This tele-ports a player to a requested location after a request through interactive map/sign board
2 String TeleportLocationName = "";
3 TeleportLocationName = Call GetTeleportLocationRequest();
4 if (TeleportLocationName != NULL) then
5 Struct TeleportLocationInformation(Char regionName, int X-Coordinate, int Y-Coordinate);
6 Struct TeleportLocationInformation TeleportDetails;
7 TeleportDetails = Call GetTeleportLocationDetails(TeleportLocationName);
8 if (TeleportDetails != NULL) then
9    Call Teleport (player, TeleportDetails);
10 else
11    Print: No location found, select a proper location.;
12    exit();
13 end
14 else
15    Print: Not a correct place to tele-port to, select a proper location.;
16    exit();
17 end
Algorithm 1 manages the whole process. It is capable of successfully teleporting a player to the new location, if it finds teleport details. Otherwise, it generates an error message. In start, it calls the module presented in Algorithm 2, which collects players teleport request through interactive signboard or map and returns it back to the main module. The main module, then, initiates the module given in Algorithm 3 to get details of teleport location, if user has made a valid request. The process, otherwise, terminates. Algorithm 3 takes teleport location name as an input and get the corresponding details from the database, stored earlier, and returns it back to main module. Once the details are provided to the main module, it calls the module presented in Algorithm 4. Algorithm 4 prepares the parameters required for initiating the ‘teleport to location method’ of scene object of OSim framework, over a grid environment. If the scene for a requested region is not available, the user is prompted with ‘region possibly down’ message, and the process is terminated. When the scene is found, the teleport method transfers the user to the requested location.

Algorithm 2 GetTeleportLocationRequest ()

**Input:** Get teleport Request  
**Output:** User teleport request  
1 //This module collects user choice and returns it to main module  
2 String UserTeleportRequest = " " ;  
3 UserTeleportRequest = Get user teleport request from interactive map or sign board;  
4 Return UserTeleportRequest;

Algorithm 3 GetTeleportLocationDetails (string TeleportLocationName).

**Input:** Teleport location name  
**Output:** Region name, 3D Co-ordinates of requested location for teleport  
1 //This module determines the region name and co-ordinates of requested location for tele-porting and returns it to main module  
2 Struct TeleportLocationInformation(Char regionName, int X-Coordinate, int Y-Coordinate, int Z-Coordinate);  
3 Struct TeleportLocationInformation TeleportDetails;  
4 TeleportDetails= Get region name and 3D co-ordinates of the requested teleport location from the database;  
5 Return TeleportDetails;

Algorithm 4 Teleport (player, TeleportLocationDetails).

**Input:** player, Structure TeleportLocationDetails  
**Output:** Player moved to new location  
1 //Initialisations: X and Y co-ordinates on grid for recognising the region and absolute position for the teleport location  
2 int TargetRegionX = Get X-coordinate of the target region on 2D Map();  
3 int TargetRegionY = Get Y-coordinate of the target region on 2D Map();  
4 <Vector> AbsolutePosition = <0,0,0>;  
5 //generate the 3D position of the location where the avatar is teleported to.  
6 AbsolutePosition = <TeleportLocationDetails.X-Coordinate, TeleportLocationDetails.Y-Coordinate, TeleportLocationDetails.Z-Coordinate>;  
7 if regionScene != NULL then  
8 //Call teleport method to transfer player based on location  
9 regionScene.Teleport-to-Location(player.ControllingClient, TargetRegionX, TargetRegionY, AbsolutePosition, player.LookAt);  
10 else  
11 Print: No Scene is available for the given Region, try again, it seems down;  
12 exit();  
13 end
4 The implementation

4.1 The tools used in implementation

In this work, we used the OpenSimulator (OSim) framework, an open source alternative to SL, for developing and integrating the whole content developed in this work. OSim is written in C# language and it supports various client viewers and communication protocols. It, therefore, makes it easy for users to select from a wide range of options [26]. It supports both Windows and Linux platforms. This work was developed using version 0.8.2.1 of OSim framework. It used Windows platform and, thus, needed .NET framework 4.0.

Blender, again an open source graphics software, was used in this work for developing complex graphical content. It has an easy to use interface for modelling 3D content, and introducing animations, rigging, and texturing to the content. Its base is written in C/C#, however, the advanced capabilities are developed in Python [22]. In this study, Blender was used to create various models, textures and rig them all. This work used the version 2.77 of Blender. The content developed in Blender were produced in mesh format, which were, then, loaded to the region hosted by OSim.

This work used the Singularity viewer due to its compatibility with OSim framework. It was found to be the most compatible viewer due to its friendly nature to incorporate meshes, images and animations [12]. This work used version 1.8.7 of this client, which was the most recent version available at the time of implementation of the proposed presence.

Since, OSim is written in C#, we used it to develop programming module for the advanced explicit features. To add dynamic features to various objects, however, we used linden scripting language.

4.2 The implementation of proposed presence

To develop the proposed presence, described in Section 3, along with societal and ethical norms, we took help from existing material. The locations made accessible through teleporting were stored in the database. The teleport operations to various locations were linked to the navigation maps and signboards. The textures of actual environment were used in the developed virtual presence. The content, we developed include the train station along with various offices and waiting hall, the platform, the train model and the old survived building in IT campus. Signboards and maps, especially related to the rail network, were added to the developed presence. An interactive screen was added, which is used by the visitors to gain historical information. Many scripts were added to make the objects such as doors, interactive screen, and train model to offer their corresponding functionalities. The script added to the train model moves it towards the platform. Figure 4 provides some glimpses from the developed presence, with self-explanatory captions.

5 Evaluation

This section evaluates the developed virtual presence with the help of both discourse and quantitative analysis.

5.1 Discourse analysis

The VW presence developed in OSim framework is compared with three well-known standard methods for content provision namely: 1) texts and images, 2) videos, and 3) non
Fig. 4 The developed virtual presence for the past of rail transportation system. The snaps, illustrating the: (a). train station, (b). main hall at train station, (c). map of rail network in waiting area, (d). old survived building in IT campus, (e). interactive smart screen displaying the historical information, and (f) one of the navigation support signboards for teleporting.

interactive 3D. It is important to note that the developed environment is almost physically demolished and the physical presence was not considered in the comparison. A set of twenty (20) parameters is used for this comparison, which is adopted and extended from our work in [2]. These parameters include representation, interaction, collaboration, target audience, persistence, availability, immersion, creativity, content type, coherence, sociability, scalability, adaptability, contextual, realistic, engaging, personalized, navigation methods, role playing ability, and intelligence. Table 2 summarizes this discourse analysis in a tabular form.

The first two methods (text and images, and videos), usually, represent content in 2D while the rest of the two methods (non interactive 3D and VW presence) describe them in 3D form. There are, however, particular type of videos, whose content are presented in 3D form. In general, the content presented using all traditional methods, lack interaction, collaboration, creativity and immersion. Some text and image based platforms, however, do offer collaborative activities. These parameters are, on the other hand, core capabilities of VW presences, which make it better than the rest of the methods. Since, the users are immersed
in VW presences, they offer sociable platforms where the users interact and collaborate to generate knowledge. The standard methods lack social capabilities and, thus, offer limited learning opportunities, especially, learning based on social interaction. The VW presences are multi user in nature, while, standard methods generally serve individual users through a separate copy of the content. The standard methods are much more scalable as they put no restrictions on creating duplicate copies of the content. On the other hand, VWs do not offer content duplication and, therefore, the content is offered to a limited number of users at a time for an improved performance. All the standard methods as well as VW presence target global audience and their content are available full time for the users. The standard methods are not persistent and their content disappear when the content is closed. They use certain concepts to help users start from the place were they left in earlier sessions. However, the VW presence keep the content online, even if the user goes offline. The standard methods provide static content while the VW presence offer highly dynamic content based on users’ mobility and continuous changes occurring in the environment. VW presence offer coherence and, thus, no duplication of content is allowed while the traditional methods allow multiple copies of the content as they, usually, provide a separate copy of content to each user. VWs are not only adaptive but also contextual in nature as compared with traditional techniques. Similarly, they offer more realistic real time environments, where the existing techniques do not offer real time but static behavior. In short, the VW presence offers much

### Table 2  Comparison of the proposed Virtual World environment for content provision (simulating cultural heritage) with other standard methods in Pakistan

| Parameters            | Non-physical content provisioning methods | The VW presence |
|-----------------------|------------------------------------------|-----------------|
|                       | Texts and images | Videos | Non interactive (3D) | |
| Representation        | 2D | 2D | 3D | 3D |
| Interaction           | Not possible | Not possible | Not possible | Possible |
| Collaboration         | No | No | No | Yes |
| Audience              | Global | Global | Global | Global |
| Persistence           | No | No | No | Yes |
| Availability          | Full time | Full time | Full time | Full time |
| Immersion             | Not possible | Not possible | Not possible | Possible |
| Creativity            | Not possible | Not possible | Not possible | Possible |
| Content type          | Static | Static | Static | Dynamic |
| Coherence             | No | No | No | Yes |
| Sociable              | No | No | No | Yes |
| Scalable              | Yes | Yes | Yes | No |
| Adaptive              | No | No | No | Yes |
| Contextual            | Very limited | Limited | Limited | Fully contextual |
| Realistic             | No | Limited | Limited | Fully Realistic |
| Engaging              | No | Limited | Limited | Fully engaging |
| Personalized          | No | No | No | Yes |
| Navigation            | Static | Static | Static | Dynamic (Walk, run, fly and teleport) |
| Role Playing          | No | No | No | Yes |
| Intelligence          | No | No | No | Yes (the future) |
more advanced, entertaining and conducive learning environment than standard methods, however, the content are offered to limited users, if implemented with its core philosophy. The users in VWs are fully engaged as they perform the activities within the space compared with books and videos, which do engage them in a limited capacity but with a different dimension. They are not only highly personalized but also offer real time navigation within the space through exciting methods such as flying and teleporting in addition to walking and running. The nature of VWs makes them natural fit for real time role playing activities as compared to fixed and static narration of role playing in texts, images, videos and interactive 3D environments. The future evolution of VWs is expectedly based on intelligent agents to make them more exciting compared with the traditional techniques.

5.2 Quantitative analysis

5.2.1 Setup

This work used the heritage part of our virtual presence, presented in [2], and, therefore, teleporting to the part of environment discussing the present was disabled. To conduct experiment(s) with this presence, we used two HP Core-i5 laptop systems, each, having 2.4 GHz processor, 4GB RAM, and an Intel HD graphics card. One system was used to run a MySQL instance and a Robust.exe instance (which offers all grid services) while another was used to run an OpenSim.exe instance (the region server). The developed content (named UST Bannu - The Past) was uploaded to the region server, stored in an OAR file. 64 Bit Windows, Firestorm, client viewer was used by the participants to connect to and experiment with the content.

5.2.2 Methodology

The work in this paper was evaluated for two different aspects: 1) user response to various characteristics of VWs such as realism, ease of use, and being sociable, and 2) checking the impact of VW presence on learning. Quantitative analysis used user responses to the questions in a questionnaire. For this purpose, we asked participants to fill the questionnaire twice, once before and, then, again after the experimental learning process.

5.2.3 Statistical parameters(s)

This work used a single statistical parameter called, User Responses, measured in terms of percentage. This measure is used not only to show responses of users against various concepts such as realism, level of detail, and ease of use but also used to illustrate the relationship between the pre and post learning outcomes.

5.2.4 The experiment

For this work, a simple experiment was developed aiming giving an exploratory learning exposure to the users about the developed presence. This included steps to give an opportunity to the participants to use various navigation methods and use various tools in facilitating the learning experience. It further offered some basic activities for users to participate in social interactive experience. This work invited users with different backgrounds to participate in the experiment. The researchers helped the participants to start this experiment. To take advantage of learning in virtual space, participants were advised to keep the questions...
just asked in pre learning step in mind during this experiment. The participants were asked to perform the following steps in chronological order:

1. Fill the questionnaire (the pre learning copy A) on your disk based on your current knowledge.
2. Get user account, password and login details for server hosting the content.
3. Login to the system and it will by default take you the the developed heritage site.
4. Navigate through the space using walking, running, flying and teleporting (use the interactive boards at various locations in the presence).
5. use the interface near old survived building in IT campus to teleport to platform of the station.
6. sit on a bench on platform and see the train moving towards platform.
7. explore the train station
8. visit the offices in train station
9. explore the map of rail network and learn about various connections from this station.
10. explore the train model and get into its coaches.
11. go inside the main hall and watch the presentation on historical aspects of this station.
12. experience interaction with screen and turn it ON and OFF.
13. interact with other users/bots using text messages and talking.
14. tease other avatars and see their response.
15. develop a simple object (allowed for this work).
16. log out.
17. log-in against to see if your content does exist (to explore the persistence property).
18. experience the disappearance and appearance of avatars representing various users.
19. Log out.
20. Fill the questionnaire (the post learning copy B) again but based on learning through this experiment.

5.2.5 Factors to evaluate

This work used the following factors (included in the questionnaire used for this study) to evaluate and compare the unique characteristics of VW environments against the standard methods, and the pre and post learning outcomes:

1. Unique Characteristics: This part of questionnaire collects user opinion about various characteristics described below:

   (a) Realism: asks the users how realistic was the developed content.
   (b) Ease of Use and interaction: determines the user opinion about their experience of exploring and experimenting with virtual content.
   (c) Completeness: determines user opinion about the details of the content provided in the form of virtual presence.
   (d) Navigation: asks the users about their experiences while using the four methods offered for navigation within the virtual presence.
   (e) Sociable: users responses for this characteristic were collected to determine their social interactive experience within the presence.
   (f) Navigation Impact: asks users about the impact of quick navigation offered through interactive boards on learning.
   (g) User Satisfaction: collects users overall experience compared with traditional learning practices.
2. **Pre and Post Data:** This part of questionnaire collects data

It also collected demographic data such as the gender, age and qualification of the participants.

5.2.6 Analysis

The experiment in this work was conducted with the help of students from the department of computer science, UST Bannu. About 30 students volunteered to participate in the experiment. They were 20 to 40 years old and enrolled in BS to PhD level programs. Most of them had no experience of VW environments but some of them were aware of standard online and off-line games. They were, therefore, briefed in detail regarding the use of VWs, in general, and the developed content, in particular. They were taught, how to navigate within the environment, and select and manipulate virtual objects in VWs. They were facilitated throughout the experiment. The responses are represented in the form of percentage values.

For this experimental study, we received responses from 33% males while 67% females. 60% of the total population were 20 to 30 years old while the remaining 40% ages were between 30 to 40 years. This work received 53% responses from MS/PhD students, 40% from master while only 7% from bachelor students. Though, the questionnaires were filled twice during the quantitative analysis. However, user responses about the unique characteristics of VW presence are based on the post learning experience, as they required exposure of VWs, in general and the developed presence, in particular.

In response of questions regarding realism, the participants 100% agreed (Strongly Agree (SA) responses were 67% while Agree (A) responses were 33%) that the content provided by the virtual presence was realistic and more entertaining. In start, about 40% participants found it hard to start with, however, they were thoroughly guided for smoothly conducting their experiments. The participants also agreed 100%, in their responses to two similar questions, regarding ease of use and interaction as well as user friendliness. However, the actual responses in terms of SA and A were 73% and 27% for the former but 67% and 33% for the latter question. In response of the query regarding the completeness of presented content, the participants agreed 100% (SA responses were 60% while A answers were 40%) that sufficient details of content are provided. The participants had mixed feelings while answering the question regarding navigation methods and navigation support. Individually, the provided options: walking/running, flying, teleporting, and all the three were favoured respectively by 20%, 20%, 27%, and 33%. Thus, about 60% liked teleporting while 53% liked flying as well as the traditional navigation through walking/running. However, all agreed that customised signboards (supporting teleports) were of great help in reaching the content and, thus, helping in quick learning. This is possibly the reason behind gaining the most favoured response from the participants. The responses recorded for social interactive experience showed that about 20% population was un-decisive about this. However, 80% agreed (SA responses were 60% while A answers were 40%) that the virtual presence is social and offer opportunities to get involve in social interactions. It seems that the 20% un-decisive respondents did not pick the concept clearly. In response of query regarding the overall experience, 90% participants agreed that they had a fully satisfied experience while 10% were not sure about their overall experience.

This work asked the participants mostly, local, about fifteen different questions regarding the historical perspective of the heritage site for pre and post learning analysis. This comparison is based on the correct responses before and after the experiment for each question. Figure 5 illustrates this comparison.
Fig. 5 The comparison of pre and post learning outcomes for fifteen different questions

It clearly shows that the learning level of participants increased from 7% to 100% (for questions 6 and 13 both), 86% (for question 7) and 79% (for question 1). It was increased from 57% to 100% for question 2 and 3 both. The knowledge level was increased from 14% to 86%, 100% and 79% for question 4, 9, and 14 correspondingly. The level of correct response for question 5 was increased from 64% to 93%. The rest of the responses are self explanatory and, therefore, not further explained.

In short, this work obtained a minimum of 29% (for a comparatively easy question numbered 5) but a maximum of 93% (for hard queries given in question 6 and 13) increase.

5.2.7 Discussion

The quantitative analysis, revealed that the properties such as realism, friendliness, advanced navigation, and being detailed and social in nature greatly attracted users. They especially attracted youngsters’ attention in learning about their heritage. According to the participants, learning was fast, reliable, and more accurate compared with traditional methods, however, it was a little hard for naïve persons to begin exploring the environment. We believe that user satisfaction was due to content development after careful investigation and proper design. Pre and post learning responses revealed that the learning level was increased up-to a maximum 93% to reach a total 100% correct responses for more than 60% questions.

6 Conclusion and future work

This paper explored the Bannu rail system - a heritage site in Pakistan and introduced its virtual world presence, developed earlier as a contemporary social and collaborative space for learning historical perspectives. It presented the explicit data and procedural requirements for a customised design in detail, as it was believed that careful investigation and proper design is key to a successful development.

The developed virtual presence was investigated both in terms of discourse and quantitative analysis, where the former used a set of twenty parameters and the latter used a simple but detailed experiment for data collection regarding various aspects of virtual worlds for their potential in learning. The discourse and quantitative analyses both confirmed that the
proposed presence offered better environment for learning compared with traditional methods. Quick learning was facilitated by customised teleporting through signboards and maps. The pre and post learning analysis confirmed that Learning level of users’ was significantly improved.

The current presence has partially developed the heritage site. In future, we intend to develop more components of this huge installation. The current work used discourse analysis and implicit knowledge of users’ for the comparison of virtual world presence with traditional methods. In future, we intend to conduct detailed explicit experiments on all mechanisms to come up with more detailed analysis and comparison.

We further intend to introduce intelligent bots, based on the concept of intelligent agents, recently proposed by Petrović in [28]. These intelligent agents might be used to accompany visitors and answer their questions, especially, when actual players go offline. It would make the developed presence more realistic, entertaining and interesting. It would further help visitors to get continuous social interactive experience. The avatars of the players could be used in addition to bots for the same purpose, where both of them would be made capable of gaining knowledge and storing it for later use in assisting visitors. The same idea could be extended for use in interactive education based environments.

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