A Preliminary Exploration of the Learning and Engagement Potential of an Intelligent Virtual Environment

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***Abstract*— This paper presents initial findings from an empirical study utilising an intelligent virtual museum with the aim to explore its learning and engagement potential. The study investigates the participants' insights in terms of their learning experiences with the environment; examines their perceptions on its engagement ability; and explores how they envision future learning scenarios with intelligent virtual environments. This user-oriented exploration generated constructive observations which can inform the enhancement and further exploitation of intelligent virtual systems in education.**

I. Introduction

The world is experiencing incessant advancements in the pursuit of a sustainable digital transformation, quality education for all, and improved quality of life, amongst other sustainable development goals [1]. A key motivator for this transformation is the shift of work and education from the physical into the virtual world [2], and progressively the synergetic fusion of these worlds. Covid-19 pandemic served as a catalyst accelerating this transformation across various sectors including education. The application of emerging disruptive technologies such as Artificial Intelligence (AI), robotics, Internet of Things (IoT), and Augmented, Virtual, and Mixed Reality (AR/VR/MR) collectively referred to as eXtended Reality (XR), provide genuine opportunities for learning. As more industries and businesses deploy these technologies, the next generation of graduates joining the workforce needs to acquire digital technology skills and demonstrate competence with disruptive technologies [3]. Therefore, it is imperative to embrace the opportunities presented by these technologies to develop essential transferable skills.

This paper discusses the findings from a preliminary exploration of the learning and engagement potential of the Cyprus VR Museum of Computers – an intelligent environment enhanced with VR, AI, and Human-Robot Interaction (HRI) features. This prototype was utilised to address the following research questions: (1) How do users perceive their learning experiences with the environment; (2) What are users' perceptions on its engagement ability; and (3) What are users' visions and suggestions for improving learning and engagement in intelligent virtual environments.

II. Background and Related Work

A. *Emerging Disruptive Technologies*

Significant advancements in hardware, software, mobile digital technologies, and computer networks hold many possibilities for developing innovative systems powered by AI, XR, robots, and social networks [4]. In such multi-agent environments physical, virtual, and intelligent components are fused and the distinction between real and virtual worlds becomes less profound [4]. AI-driven developments, immersive XR applications enhancing HRI [5], the fusion of VR, robots, and social networks formulating novel Cyber-Physical-Social eco-Society (CPSeS) systems [6], and the utilisation of AI in IoT [7] constitute just a few emerging applications. Alongside core business and societal evolution enablers, such technological enablers empower digital transformation in highly data-driven social ecosystems [2].

B. *Digital Transformation in Education*

Within education, the digital transformation is shifting learning objectives from raising awareness and 'learning just in case' to 'just-in-time knowledge' – a paradigm leveraging distributed intelligence to 'delimit' the skills and knowledge required to fulfill a task or goal [2]. The knowledge one needs to acquire is no longer static or owned by a single entity; rather it is dynamically distributed across people, spaces, agents, and artefacts. Teaching and learning experiences have become uncoupled from traditional educational institutions and are now enhanced by a vibrant learning ecosystem [8]. Various emerging technologies, tools, and techniques are employed in education to enhance teaching and learning, as discussed next.

The availability of low-cost VR equipment coupled with the readiness of smart mobile devices have heightened the use of VR in education in recent years. VR enables the development of immersive learning environments where learners become an integral part of the learning process [9]. VR is conducive to many educational fields including engineering, medicine, space technology and mathematics, and supports both general and special education [10]. The educational applications of AR are also widely expanding [11] providing opportunities to visualise invisible artefacts, teach and learn content in 3D, establish collaborative and situated learning [2]. AR creates a fused environment where the physical space is dynamically overlaid with virtual, context-sensitive, personalised, location-aware information. AR and VR are combined with mobile educational games to engage learners through collaborative and situated learning activating unique sense-making and cognitive interactions [12]. Similarly, the uptake of MR – where the real world and digitally created artefacts coexist and interact – and XR in education is enabled through the deployment of immersive technologies [13] igniting learning and engagement.

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Robots of different sizes, shapes, and capabilities are additionally employed in education for supporting inclusive learning and special education needs [14]. HRI can provide enhanced learning experiences utilising intelligent immersive learning systems [15] and social robots [14, 16]. These capabilities draw robots out of research labs and industrial settings integrating them in education and society at large [4].

AI has also energised many educational settings. Intelligent agents, serving as personal assistants or guides, can be incorporated into virtual spaces creating intelligent virtual environments [17, 18, 19]. Such environments bestow innovative functionalities and authentic experiences through highly personalised interactions. AI agents and intelligent virtual environments can respond and adapt to users' actions, identify users' needs and recommend adjustments to their behaviour [18, 20, 21]. AI modules can provide voice recognition and natural language processing and understanding features enabling more natural and meaningful interactions between intelligent agents and human users [21]. Within learning scenarios, assistive AI and cognitive digital twins become increasingly more prevalent with the aim to improve the quality of learner experience. It is envisaged that assistive AI will become more intertwined with cognitive digital twins expanding a user's competence and decision-making capability through a seamless integration with AI [2].

Advancements in the aforementioned areas illuminate a future where interactions in real and virtual spaces will be seamless, continuous, inclusive, highly personalised, and ubiquitous. Considering the learning outcomes such endeavours hold, a novel CPSeS system has recently been proposed to support immersive learning [4, 6, 22]. CPSeS systems comprise physical space(s), real and AI agents, and a virtual space that seamlessly connects these elements. An educational CPSeS system allows learners to communicate and collaborate with their peers and educators in the virtual space (via their digital twins or avatars); interact with real robots or the robots' digital twins living in the virtual space; explore digital, multimedia content at their own time and pace hence gaining control of their own learning; interact with AI agents providing personalised guidance; and engage in interactive and multimodal educational activities. These learning scenarios can disrupt conventional ways in which students experience and interact with educational materials, their educators, and each other [4]. Engaging learners through enriched realities, extending learning with AR and VR, and preparing for life and learning in the age of AI, constitute key themes amongst the innovative pedagogies that emerged over the last decade [23] and will continue to be adopted in education [24].

III. RESEARCH METHODOLOGY AND KEY FINDINGS

An experimental study was conducted to gather insights in terms of users' learning experiences with an intelligent virtual museum, their perceptions on the engaging potential of this system, and their visions and suggestions.

A. Study Context and System Description

To address the research questions guiding this study, the Cyprus VR Museum of Computers was developed based on the framework described in [6]. This prototype is a proof-of-concept CPSeS system fusing an intelligent virtual environment with the physical Computer History Museum located in Nicosia, Cyprus [26]. The museum has a great collection of historic computers and games consoles, along with educational collections and exhibits on display, including a lifeline featuring multimedia educational content from 370 AD to recent computer history (Fig. 1). Users can access the Cyprus VR Museum of Computers remotely using a cardboard viewer and their smartphone. Users can synchronously coexist and interact with (i) other remote users' avatars, (ii) a real robot (via its digital twin living in the virtual world), (iii) the real museum space which hosts the robot (via a live video feed projected in a virtual screen), (iv) additional 3D virtual models of rare or expensive computer devices with significant educational value which only exist in the virtual museum, and (v) an AI agent in the form of a museum curator capable of interacting with users and navigating them in the various exhibition areas of the virtual museum (Fig. 2).

B. Study Participants and Experimental Procedure

Both female (n=6) and male (n=10) users, between 18-45 years old, participated in the study. A standardised experimental procedure was followed. Participants were first briefed about the study and directed to install the Google Cardboard app [27] and the custom-built Computers Museum app on their smartphones. A cardboard viewer was provided to each participant in advance. After calibrating the Cardboard app with the viewer by following on-screen instructions, participants could insert their smartphone into the viewer and launch the Computers Museum app. Upon entering the virtual world participants land in a virtual orientation area which provides instructions on how to navigate and interact with the environment. The orientation task lasted 2-3 minutes. After orientation, users were advised to freely navigate and explore the environment and then proceed to perform a set of specific tasks including locating and interacting with the robot's digital twin, following the robot around and exploring the video broadcasted live from the real Cyprus Computer History Museum [26], reading through the informational signs next to the virtual computer exhibits, approaching and interacting with other participants' avatars, sending and reading messages, and interacting with the AI agent floating in the environment. The navigation and exploration session lasted approximately 40 minutes. During the experiment, the research team was observing the users' behaviour and their response to actions and events occurring in the virtual world. Following each experimental session, participants completed an anonymous online questionnaire (n=16), and several interested participants were invited to a follow-up interview (n=5) to further explore their experiences, feelings, and perceptions.

Figure 1. Cyprus Computer History Museum: (a) computers and educational exhibits, (b) physical robot located at the museum [26].

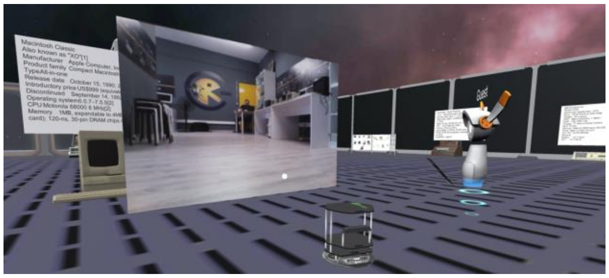

Figure 2. Cyprus VR Museum of Computers prototype.

C. Data Analysis and Discussion of the Findings

Given the number of study participants qualitative analysis was performed combined with descriptive statistics. The research team aimed to invite participants who are familiar with VR (44%) but also some who have never used VR in the past (25%). Irrespective of each participant's level of familiarity with VR, the overall feedback was positive, and participants agreed or strongly agreed that it was an interesting experience. Most users quickly adapted to the virtual environment (81%), even though some reported that their experiences in the virtual environment seem only slightly or moderately consistent with their real-world experiences (44%).

In terms of their learning experience with the intelligent virtual museum environment, the following positive aspects emerged as the most significant (they were provided by at least half of the participants): raises enthusiasm about computers and computer history (81%); increases interest about computers and computer history (75%); increases engagement with the subject area (69%); enhances desire to learn more (63%); gives more flexibility to control the learning process (50%); allows useful interactions with agents to get detailed information (50%); and presents relevant information when needed (50%). Participants perceived the possibility to closely examine objects in the virtual environment (94%) and the opportunity to gain an enhanced understanding on the history of computers using VR (88%) as constructive learning experiences. Most participants felt that their proficiency in navigating and interacting with the virtual environment improved at the end of the experience (88%) and that using VR could enable them to understand computing concepts quicky (75%). The vast majority (81%) found VR technology useful in teaching and learning. These findings are particularly important indicating a key dimension of the learning potential of such initiatives, that is learning 'through' the system and learning 'about' the system. Participants also discussed the experiences in terms of mobile learning with almost everyone declaring they enjoyed learning about computers using their own smartphones through a mobile app (94%). Some negative aspects associated with the learning experience with the intelligent virtual museum also emerged. The most stated negative aspect is that prolonged use made participants feel dizzy (38%), following by finding the environment confusing (25%), and that it makes collaborative learning difficult (19%).

In terms of engagement, most participants found the system fun to use (94%), and enjoyable (88%), extremely or very compelling (69%), and reported they felt involved during the virtual environment experience (69%). These findings may suggest that such experiences can contribute to learners' engagement and motivation. Almost all participants (94%) considered the feature allowing them to see the real world (i.e., the physical museum) through the virtual display attached to the robot's digital twin in the virtual world, as attractive, inspiring, and compelling. In fact, despite the delays in video synchronisation, participants perceived the quality of the video feed as good (94%) and only a few (25%) reported that the quality of the visual display interfered or distracted them from performing the assigned tasks or required activities.

During the follow-up interviews, some participants re-emphasised that they perceived the intelligent virtual environment and the learning experience alike, as very useful, enjoyable, and engaging because that they had a specific set of tasks to perform while given an appropriate level of flexibility to exercise autonomous and self-directed learning. This can indicate that when learners perceive a learning activity or experience as useful, flexible, and meaningful, they are more likely to engage. Another prominent finding which emerged during the interviews was that participants felt intrigued to see the collections of computers, games consoles and old gaming equipment through the visual display (shared by the robot's digital twin), which sparked their desire to visit the physical museum as well. This suggests that intelligent virtual learning environments can have synergetic learning outcomes and help sustain learner engagement beyond the timeframe in which learners are connected in the virtual world. Further research is however needed to explore these eminent findings in depth.

When comparing their overall learning experience of using the intelligent virtual museum with visiting a real museum, both advantages and limitations were identified. The most popular advantages of the intelligent virtual museum as perceived by participants include: the possibility to access it from anywhere (94%) and as many times as needed (88%), to visit models and exhibits which do not exist in the real museum (e.g., very old computers) (88%), the possibility to complete museum tours in the users' own pace instead of visiting all exhibits on a single museum visit (81%), interacting with other users (56%), and guided by virtual intelligent agents without having to ask for help (56%). Various limitations of visiting an intelligent virtual museum, compared to a real one, were also reported: finding it difficult to interact with others in the virtual environment (50%), not being able to take pictures of the real exhibits (50%), and not being able to see or use the actual computers (as may be permitted in the real museum) (43%).

Participants were also asked to reflect on the feelings they experienced while using the environment. The most prominent positive feelings were interest (88%), enthusiasm (63%) and entertainment (56%). Negative feelings were less emphasised, but it is still important to consider that many participants felt overwhelmed or exhausted after this experience (44%), experienced frustration (25%), confusion or disorientation (25%) while using the system. These were also reflected in the participants' expressed suggestions for improvement such as allowing avatar personalisation, making each type of virtual agent (i.e., the robots' digital twin, users' avatars, AI agent) more distinctive, improving the environment's communication and collaboration capability, adding structured activities with specific learning outcomes to raise engagement, improving the quality of graphics, and including quizzes and videos to assess/test learning. These findings reveal core areas of improvement and indicate that future enhancements need to look beyond the technological interventions and collectively consider the learners' personal feelings, preferences, and experiences; the dynamics amongst learners; and the broader pedagogical, technological, and social context.

To further elaborate on their experiences, we asked participants to propose other learning scenarios where such intelligent virtual environments could be deployed. Participants provided some noteworthy suggestions: "*discover and learn about things you cannot in real life like the ocean or universe*"; "*visit places you cannot actually visit, like inside the body or the microbes world*"; "*a lot of work can be done in the field of medicine*"; "*visit dangerous places or labs that do not allow access to people*"; "*go inside the PC and learn about hardware'; "performing experiments in a virtual lab*"; "*learn a new skill such as public speaking and negotiation*"; "*learn new languages*". The visions of participants hold manifold opportunities for further exploration and exploitation of immersive virtual environments in education.

IV. Conclusion & Future Work

The study findings reveal various areas of improvement and provide directions for future research, development and innovation while also demonstrating that CPSeS systems, like the Cyprus VR Museum of Computers prototype utilised in this study, can have an overall positive impact on learning and engagement. To investigate the full educational potential of such systems, further empirical research is needed to explore learners' as well as educators' perceptions, feelings, and behaviours. More emphasis needs to be placed on making interactions more natural, intuitive, or 'immersive' through higher quality of interactions and greater range of sensory information which help to seamlessly blend real and virtual worlds. Undeniably, the fusion of immersive and intelligent technologies, robots, wearable and mobile devices, games, and other emerging disruptive techniques can empower the pathway to digital transformation in education and beyond.

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