ID 73

VR-Enabled Participatory Design of Educational Spaces: An Experiential Approach

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Abstract
Classrooms can have an impact on enthusiasm towards learning and aid teaching; given the day-to-day experiences and difficulties teachers endure, they possess a unique perspective on how to better facilitate the tutoring experience in their classrooms. Existing review of literature indicated clear areas for improvement in classroom design using participatory design (PD) approaches where virtual reality (VR) technologies can be utilized as an effective tool to facilitate this collaborative process. To address some of the existing knowledge gaps in this area, a study was designed to gauge teachers' views on the teaching environment of their classrooms to be used to develop a collaborative design tool in VR. Considering the conventional nature of classroom design, the feedback collated from the survey was used to provide designers with the end-users' input they were otherwise less likely to be able to incorporate into their design. These findings were used to design a VR experiment to facilitate teacher's participation in the design process. The findings indicated that the teachers showed a surprising level of awareness of the design elements in educationalspaces and the approach of this study. It was also noted that some of the teachers' implicit knowhow regarding the design and layout of their classroom was very difficult, if possible, at all, to capture and apply using more conventionalcollaborative approaches to design, hence the significance of the current study.

Keywords
Virtual Reality, Participatory Design, Design Collaboration, Educational Spaces, Classroom Design

1. Introduction

It has been suggested that educational architecture has become stagnant due to the 'one size fits all' attitude towards classroom design and warn against using the "evidence from the past to inform a very similar future, when what is needed is a new approach and new solutions for school design to reflect the changing needs of learning in the 21st century" (Higgins et al., 2005: p. 4). Recent developments in design theory advocate for a more significant role for space end-users which has given rise to developments and advancements in PD. It is argued that if end-users are given the opportunity to proactively participate in the design process, this will contribute to the production of more workable and useful spaces. Traditional ways to facilitate PD are relatively researched and developed. There is limited evidence to suggest that advanced technologies such as augmented reality (AR) and VR have been trialed and utilized effectively in this area. Considering this theoretical vantagepoint, when this is being applied in the design of educational spaces, teachers - similar to any other non-expert end-user groups - may struggle to understand the implications of design decisions. To address this gap in knowledge, this study aims to use VR to facilitate the participatory process in the design of educational spaces. This research starts with a working hypothesis that VR can facilitate PD above and beyond conventional methods to improve collaborative design processes. To operationalize this working theory, this study used a qualitative research methodology where a questionnaire was formulated to collect teachers' expert perspectives on design of their classrooms and how this would affect their working environment. This was used to develop a VR experiment whereby non-design-expert users could partake in the collaborative design of their classroom space. This paper addresses the process underlying the development of the VRexperiment building upon the existing knowledge gathered through literature review and contextualized through the surveys carried out with a sample group of teachers in the UK. The findings indicated that teachers demonstrated a remarkable level of awareness of design elements in educational spaces and showed appreciation towards the approach of this study. The study indicated that capturing teachers' tacit knowledge of their profession can be used to inform the classroom design. However, this might not prove an easy or straightforward task to fulfill. The significance of this study lies in using an alternative and potentially more intuitive interactive approach compared to conventional collaborative approaches to design.

2. Literature Review

2. 1 Classroom Design

Classroom design offers an opportunity to enhance the teaching environment. In his revolutionary approach to pre-tertiary education, Malaguzzi suggests that spaces can reflect the actions within an environment and mirror ideas and attitudes. He believes that spaces can promote social relationships between people, choices, and activities, as well as influencing organization and cognitive learning (Edwards et al., 1993). Dudek (2000) also expresses that physical factors and dimensions of a classroom can affect the users' cognitive and social skills. Sommer and Olsen (1980) explored this through an experiment where student behavior and performance were observed during a class, across different classrooms, and concluded that participants were more engaged with the teacher in rooms that were more pleasant, which also reflects Malaguzzi's values (Edwards et al., 1993). CABE (Commission for Architecture and the Built Environment) Commissioner Emeritus, believes that the science of designing learning environments has so far been considerably underdeveloped (Higgins et al., 2005).

It has been suggested that there is a direct link between student attention and light quality (Dunn et al., 1985) which is correlated to windows and shading devices' location, size and configuration, but also affected by other factors. Windows add some positive characteristics, such as larger or more interesting views, as well as some negative ones potentially associated with glare and sun penetration (Aumann et al., 2004; Barrett et al., 2016). Internal shading systems have been suggested as a solution which are easy to operate by teachers (Barrett et al., 2016). Daylight is a significant factor that attributes towards the well-being of space users (Wurtman, 1975). However, this entails the use of large glass panes, high ceilings and openable windows which may contribute to longer reverberation times, requiring a tradeoff between acoustic distractions and daylight gain. On the other hand, artificial lighting can impact emotions, behavior, and levels of energy (Wurtman, 1975). Research shows that using full spectrum lighting mitigates all distracting factors associated with artificial lighting (Karpen, 1998). Previous research shows that the autonomic nervous system and visual cortex are both stimulated differently when different illumination colors are experienced, with blue illumination leading into increased relaxation, decreased anxiety and hostility compared to red and white illumination (Gerard, 1958 in Hathaway, 1982). Wohlfarth and Sam (1981) found that by using relaxing shades of blue the aggressive behaviors in a small group of severely handicapped children could be reduced, inducing a less stressful environment. The layout and location of storage in a classroom is another substantial design element in classrooms. Loughlin and Suina (1982) suggests that teachers may lose track of classroom supplies if they are not present within the classroom. However, McGonigal (1999) expresses the concern that an excessive amount of indoor storage encourages dust to form thereby impacting the indoor air quality.

2. 2 Virtual Reality

For a person to have full spatial cognition they must be able to establish cognitive mapping (Briggs et al., 1973 in Walmsley et al., 1990). Spatial cognition can be identified by three correlating features: "space itself, containing immovable structures and landmarks; objects within the space, which move or change state under certain conditions; and actors whose actions cause changes within the environment" (Dalgarno, 2002: p.154). This provides the necessary information required for consciousness within an environment. According to MIT.nano Immersion Lab, virtual reality can be defined as "a computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way". McLellan (1996) asserts that when implementing VR, immersion is a critical feature to comprehend an environment. Dalgarno et al. (2002) suggest immersion is only possible with a high level of interaction and fidelity of representation. Song et al. (2018) claim that by incorporating a trackball, HMDand data gloves users are more likely to experience full immersion. Fig 1 shows the different types of technology and their associated reality/virtual immersion possibilities.

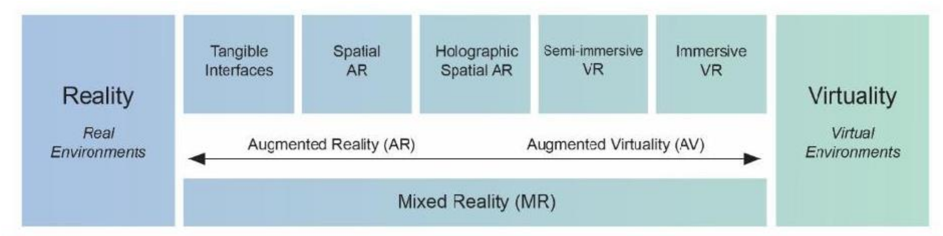

Fig. 1. Reality-virtuality continuum based on Milgram and Kishion (1994)

VR provides architectural designers with a better understanding of size and scale (Häkkilä et al., 2018), as well as the ability to effectively plan and rehearse job specific tasks (Sacks et al., 2013). Li et al. (2018), states that a VR application with a higher degree of immersion typically requires more advanced hardware. Sometimes this is not possible, and they add that designing VR technologies requires a technology trade off. Freina and Ott (2015), believes that the implementation of VR is usually associated with a high cost. Kavanagh et al. (2017) counter argues this by suggesting that VR can still be achieved through the use of smartphone applications and a cardboard headset.

2. 3 Design collaboration and participatory design

Chiu (2002) believes organization and structure can be used to ensure collaboration between teams with different end goals in a project. Craig and Zimring (2000) argue that unstructured collaboration can be more efficient, as it is less fatiguing while still offering diverse perspectives absent of any self-interest, which has been the case in design studios for years. Holmlid (2012) explains PD as end-users contributing experience to help designers better understand their needs and wants. Expanding on this, he refers to the Gulliver project in Cologne, where homeless people were involved in the design process of a self-help center. On the contrary, Molapo and Marsden (2013) warn that relying on non-technical participants disproportionately may lead to statutory non-compliance in design. Korpela et al. (1998) believe that community members that will use the space should also be involved in the design process to provide a broad range of perspectives. Blomberg et al. (1993) believe that collaborative design methods may be more beneficial to theend users than they could be to the designers. Demirbilek and Demirkan (2004) also add that the logistics required for collaboration can be time and resource consuming. Hussain (2010) believes participants that lack some basic understanding of the project may shy away from collaboration and further adds that offering some pre-understanding can create an environment where participants feel secure to share opinions. Brun-Cottan and Wall (1995) assert that in PD, the gap in technical understanding can be bridged with the use of graphical information.

3. Research Design and Methodology

This paper presents the process devised to support the design and development of a research instrument for a research project which aims to gauge the educational space users' expert views and their participatory design experience using VR technologies. A critical review of the literature was carried out to construct the underpinning of this study around PD, application of VR technologies, and design of educational spaces (classrooms). The study uses a mixed methodology. The primary research methods consisted of an online questionnaire designed for school teaching staff. The data collated from the literature was used to inform the design of the questionnaire. The questionnaire was designed to record participants' background (age, gender, teaching subject, key teaching stages), their understanding of VR (the concept and how design elements might affect their teaching) and their professional opinion regarding classroom design factors as indicated in this study. All data collection procedures were designed and conducted according to GDPR and were vetted and approved by the University of Brighton's Tier 1 Research Ethics Committee.

4. Data Collection and Analysis

4. 1 Participants Background

10 teachers participated in the survey (gender: 8 Female/2 Male and age range: 4: 18–24, 1: 25-34, 3: 35-44 and 2: 45-50). The participants were mixed in their teaching subject (2: languages, 3: science teachers, 1: English, 1: humanities, 1: teaching assistant, 2: did not specified) and their key stages [3: key stages 1/2 (primary) and 7: key stages 3/4 (secondary)].

4. 2 Understanding of the Study Background and Context

The participants were asked if they were familiar with VR (Yes: 8/ No: 2), and their awareness of design elements within a classroom (No: 4/ Yes: 6). When asked to provide additional comments, participants stated: "poor layouts encourage disruptive behavior" and can "increase difficulty to navigate the classroom", "the location of windows affects the visibility of the display white board". Furthermore, the availability of technology in the classroom was also raised as a general concern. Subsequently, the participants were asked if they were satisfied with the layout of their classrooms (No: 6/ Yes: 4), and when asked to provide further clarification "creating a calming environment through display boards" and "ensuring adequate storage was provided" were some of the positive points noted, while "limited natural daylighting", "uninspiring layouts", "insufficient displays boards", "storage in other classrooms" and some H&S concerns were among the negative points raised.

The next question was aimed to determine whether these factors impede teaching styles (No: 3/ Yes: 5/ No answer: 2). Participants highlighted reduced classroom size as having an impact on decisions on group work, small whiteboard impacting quality of notes and large windows creating acoustic [noise] distractions. The question about the participant's ideal classroom indicated that the majority were in agreement that acoustic performance, layout flexibility and natural lighting were elements to be included. It was also mentioned that the classroom's internal finishes should be easy to maintain, and modern equipment [no specifics were given] should be provided.

4. 3 Classroom Design

The teachers were asked if, in their current practice, the level of lighting is changed to suit specific teaching activities (Y: 7/ N: 3). The general consensus was that a low level of lighting was used when presenting digital media and when students are copying notes from the boards, and higher level of lighting were utilized when students were reading or having a group discussion. Dimming was used to calm the students down; this was achieved through dimmers when available, blinds and/or by switching main lights off. Participants were then asked if they find their current lighting fixtures practical (Y: 6/ N: 4) and they described fluorescent lighting as undesirable due to high glare and preferred having two independent lighting sources to be able to afford broader control. The next question was aimed at determining the preferred lighting warmth in the classroom (Warm: 4/ Neutral: 6/ Cool: 0).

The next series of questions were aimed at teacher's opinions of their classroom layout including how often they changed the layout and if the layouts provided enough circulation spaces. The majority of respondents found their current layouts convenient (Convenient: 5/ Inconvenient: 3/ Not noticed: 2). When asked about how many times per week they changed the layout, the majority did not change the layout (0:6/ 1-2:2/ 3-4:1/ 5+:1). Most teachers feltthey were not provided with sufficient circulation space (N:6/ Y:4). There was a mutual opinion among all the responses that a lack of circulation space creates a static teaching environment, impeding creative teaching styles and "causing difficulty in 1-on-1 teaching". Participants were then asked if there were any visual distractions and if so, what the source of those distractions were (Y:9/ N:1). It was noted that "large windows provide acoustic [noise] and visual distractions". It was also mentioned that impact "noises from floors above can cause disruptions". The majorityof teachers also stated that the internal shading devices do not contribute to any distraction (No distraction:7/ distraction: 3).

When asked about white board preference, the majority favored using an interactive whiteboard over traditional whiteboards with marker pens (Interactive:9/ Traditional:1). It was expressed that these smart boards are now a necessity as they can easily facilitate other learning resources and applications including "YouTube" and "PowerPoint". Most participants preferred the whiteboard(s) on one wall only (Single wall:6 Two walls:4); some believed that creating a singular point of interest will help retain students' attention, whereas some others suggested that display on multiple walls will ensure all students have eyesight of information being displayed.
The next set of questions aimed to understand the participant's current use of storage cupboards and preferred location. The number of usages per day showed some interesting patterns where the majority of participants used the storage three times or more per day (1:1/ 2:2/ 3+:7). They also stated that they preferred to have their storage within the classroom as opposed to a storage room (within classroom: 9/ storage room: 1).

When asked how many display boards participants would prefer, the majority chose more than one (1:1/ 2:2/ 3:4/ 4+:3). When asked where the participants would prefer the location of the entrance door, a mixed response of Front:4, Back:4 and Middle:2 was provided. It was also noted that multiple entrances would be desirable, and that having the door located at the back would minimize distractions from hallways and arrival of late students.

When asked about window preference, majority of teachers preferred an openable window (Openable:9/ Fixed:1); out of nine who preferred openable windows, six preferred horizontal [casement] and three vertical [sash].

When asked if participants preferred a specific wall color, the majority said yes (Y:7/ N:3), explaining that neutral colors should be closer to white to avoid students getting distracted and to give an optical illusion of a larger room. Conversely, It was highlighted that [pure] white walls may be subject to easier and faster wear and tear, whilst also reducing stimulation of students.

The participants were then given a chance to mention any additional features they would have liked to have control over to improve the overall learning experience of their pupils'. A point was raised about including an automatic shading device that can adjust according to the natural light intensity. Comments were also made in regards to providing additional storage and more comfortable [ergonomic] chairs for students.

5. Discussion of Findings and Concluding Comments

5. 1 Significance of Primary data for development of the application

This research built upon the existing literature to set the boundaries of the experiment in identifying the elements and factors which could and should have been incorporated in the design of the VR experiment. However, we extended the scope of this study by including primary data collected from a sample of school teachers in key stages 1-2 and 3-4 in the UK pre-tertiary education system. It was important to bear in mind that there was significant non-conformity between the primary data with what was suggested by the literature, the primary data was prioritized in development of the VR experiment. For instance, current research did not conform to previous research where it has been suggested that storage should be within teachers' eyesight (Loughlin & Suina, 1982). However, participants voiced concerns regarding storage being poorly placed. Therefore, static storage placement was considered in this study and an option to enable teachers to dynamically place storage in their preferred locations was left out for future research.

5. 2 Primary and secondary data alignment for application development

Previous research suggests that participants' involvement in PD is subject to their comprehension of the assignment (Hussain, 2010). Although participants in the current study were familiar with VR technologies, they had not utilized it. This indicates the importance of incorporating an application tutorial, ensuring participants are capable of running the application without any external assistance. Previous research also indicates that the PD process can be time consuming (Bodker, 1996), the tutorial aims to minimize the practice period.

Although light colors were documented as a means to increase stimulation and decrease anxiety in previous research (Gerard, 1958 in Hathaway, 1982), the primary data did not record any teachers' use of different colored lighting. It has been suggested that participants are unable to differentiate effects of different colors shown to them on a piece of paper out of context. It was found that teachers use different levels of light intensity (lux) depending onthe task and the use of digital media. This research aimed to address this gap from a slightly different angle by providing the participants with an ability to control the light warmth levels (Kelvin). This can be expanded to light intensity and color in future research.

5. 3 Promoting proactive user participation in design process

Current research concurs with previous research where it has been suggested that spaces present opportunities to nurture cognitive thinking; where teachers asserted that poor classroom layouts affect behavior and the ability to physically access students. Giving teachers the ability to re-configure their classroom layout with variety encourages involvement in the design review process without conflicting participants with a predetermined 'correct' result. This in turn creates a user-friendly platform, enabling teachers' participation in the design process without needing to have specialized design knowledge, expertise, or experience.

Classroom layouts are subject to change depending on activities considering that physical factors can affect students cognitive and social skills (Dudek, 2000). Comparatively, the primary data showed that teachers felt space restriction forced them to stick with static teaching, which hindered creativity in teaching. To use VR to help plan job specific tasks (Sacks et al., 2013), the VR application developed in this study presented participants with the ability to create typical layouts for multiple activities. Additionally, the approach used by teachers can help broaden the designers' comprehension of teaching needs and requirements. Following on from this research, the next stage of this study will consider ways to document the teacher's decisions, so a design feedback loop can be established to help future designers of educational spaces.

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