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Inclusive design for immersive spaces.

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Inclusive Design for Immersive Spaces

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Abstract: It is vital when creating learning environments that attention is paid towards individuals using a given space, activities that they will carry out, and the available equipment that will facilitate this. It is also important that these spaces are created to be inclusive to all and to remove accessibility barriers that are caused by the designed environment. Our aim is to understand how technology can be used to inform design processes for creating educational spaces by collaborating with the primary users of this space: students. This paper is organised in three main sections. Firstly, we identify changes that academics have suggested in how designing for inclusive augmented and virtual-reality environments should be practised. Secondly, we present a workshop entitled Designing for Immersive Spaces. Finally, we discusses the implications of the issues raised and the practical constraints and difficulties of implementing Inclusive Design for Immersive Spaces that is being called for.

Keywords: augmented reality, design, accessibility, UX

1. Introduction

The perceived student expectation of disruptive, immersive, and digital technologies in teaching and learning are featured prominently in contemporary higher education discussions. There is an assumption that digital technologies are central in student learning and pivotal in maximising student satisfaction (Moskal 2013, O'Brien, 2018). Like many business organizations, universities are under pressure to minimise occupancy costs and maximise use of resources and campus facilities (HEFCE, 2006). Concerns surrounding 'strategic workspace design' (Vischer, 2007) typically occupy the minds of central planning and estates managers, but issues regarding place attachment and the fostering of community and belonging occupy the minds of educators, program leaders and 'front-line' teaching staff (Marshall, 2016). However, rather than being treated as 'partners' in the business of knowledge creation, students are often treated as 'customers' (Khalifa, 2009) of educational products (i.e. lectures) and services (i.e. online learning materials and resources). In an ever increasingly competitive higher education environment, where some students now consider themselves to be paying for a service, the centrality of technology-driven solutions as viewed from a student ('customer') point of view may be ascribed more importance than is warranted. As a results, institutions and universities face continued pressure to provide high quality facilities and learning spaces to attract students in a very competitive market (HEFCE, 2006).

We seek to explore student perceptions of immersive technology within learning spaces. In this work we present the findings from a workshop that was carried out with students from a variety of degree programs examining the use of technology in learning spaces. This paper employed empathy mapping, dream space thinking, and inclusivity hotspot activities to prompt participants to think about the usage of learning spaces and to explore how students would design their own learning spaces with an emphasis on technology. Our intent in this paper is exploratory, focusing on 21st century learning and teaching spaces that are inclusive to all. We reflect on the key themes that were apparent during this work that offers an analytic framework for more systematic enquiry and prepares the ground for more detailed research work in this field. We do not attempt to present answers and solutions to all the downsides of trying to reconceptualise the practice of learning spaces. Our hope is that, by taking a long-term and broad view, we will highlight a potential new direction for learning spaces that is not only helpful but inclusive to all those involved.

2. Related Work

2.1 Designing for Inclusive Augmented and Virtual Reality Environments

When developing workspaces, it is important to focus on factors surrounding people, context, and environment. Factors that help or hinder task completion are common, but concepts associated with technology-based challenges are normally considered only as an afterthought. In the context of developing workspaces, there are intangible aspects that need to be taken into consideration. Petriglieri & Petriglieri (2010) note the important role buildings play in creating a ‘holding environment’ in which users can craft their professional identity, ideally by bringing people (i.e. students in the case of this paper) into active partnership with agreed sharing of resources and decision-making’ (Dialogue by Design, 2012). Here students are accepted and treated as being ‘*integral to workspaces development and as partners in the processes of co-creation, co-ownership and co-evolution of plans and proposals rather than mere users or clients of services*’ (Du Plessis, 2012).

One technology platform that shows promise in bridging the digital and physical worlds is Augmented Reality (AR). AR can allow for computer-type design patterns to be applied to physical locations (Rashid, Morenza-Cinos, Pous, & Melià-Seguí, 2014). This creates the ability to enable specific adaptations to content in a ‘live’ setting (Rodrigues, Lessa, Gregório, Ramos, & Cardoso, 2016). In order to ensure that these new interaction techniques are inclusive to all, AR guidance focuses on aspects such as controls, displays, physical environment, and mechanics (Seaborn et al., 2016). In this work we examine the use of AR in designing workspaces of the future and pay attention to how this can be accomplished using inclusive design principles (Microsoft, 2018). When examining the inclusivity of an environment the areas of visual, cognitive, and communication access are commonly used and we outline these separately below.

Visual Access is concerned with challenges that are associated with the way that individuals see the world. This can include users with vision issues (e.g. macular degeneration, colour blindness) but can also include temporary and situational vision accessibility issues (e.g. sun glare or low screen brightness). Opportunities exist to create AR applications for low vision users that examine reading inaccessible text, visual search, and navigation (Zhao, Hu, Hashash, & Azenkot, 2017). AR can be used to give contextual information about the number of people present in a social situation, and to present details regarding their age and gender (Tanveer & Hoque, 2014). It can also be used to simulate cues used by sighted individuals to augment the experiences for blind individuals (Cassidy &

Tyler, 2017). User vision can be augmented to include magnification, contrast enhancement, edge enhancement, and text extraction using ARglasses (Zhao, Szpiro, & Azenkot, 2015) with the Microsoft Hololens being one current piece of hardware that can be used to augment and increase text size for users (Zolyomi, Shukla, & Snyder, 2017).

Cognitive Access is concerned with challenges associated with the way individuals understand and manipulate information. This can relate to issues of memory, fluid intelligence, attention and emotiveness. AR can be used to improve precision and recall of information for participants with cognitive impairments (Chang, Kang, Chang, & Liu, 2015) and can assist in high cognitive load environments by allowing users to access information that would normally involve two or more systems (Huang et al., 2015). Locations can be augmented with an additional layer of metadata to allow individuals to have access to information that they may require (e.g. passwords) and to improve their augmented memory (Colley, Häkkilä, & Rantakari, 2014). The use of in-situ projections compared to pictographic instructions can improve the speed and reduce the error rate in construction tasks for users with cognitive impairments (Funk, Mayer, & Schmidt, 2015) and memorisation tasks performed with AR applications have been shown to improve recall accuracy for users in the short to medium term (Rosello, Exposito, & Maes, 2016). However, sensory conflict can occur in AR when visual information being shown conflicts with vestibular information being obtained by the user. The size, positioning, and content of any applications should be taken into account when developing new systems (Diels & Bos, 2015).

Communication Access is concerned with challenges in how people can communicate with the world around them with this including language, hearing and speech. AR can be used to carry out real time captioning with speech bubbles (Peng et al., 2018) with this allowing an increase in visual contact with speakers and also access to other visual material (Jain, Chinh, Findlater, Kushalnagar, & Froehlich, 2018). AR can also be used to present additional information for selected viewers of media, for example they can show a signer outside of the TV screen during a broadcast (Vinayagamoorthy et al., 2018). AR, in combination with eye-gaze techniques, can be used to do real time text translation of any information that a user is examining (Toyama et al., 2014) and also to augment text with pictures to assist in Sign Language applications (Almutairi & Al-Megren, 2017).

AR has a number of potential uses within a learning context, however a number of issues exist that make it difficult to use this technology without first considering inclusive design challenges that exist due to environmental constraints. This motivates our initial enquiry in this work where we attempt to uncover **RQ1: What are the environmental considerations that must be examined before embedding Augmented and Virtual Reality technology into learning environments?**

2.2 Designing Learning Spaces

Learning is changing in the 21st century and when it comes to the subject of 'designing learning spaces' in the context of higher education, attention tends to focus on classrooms. With the advent of technology on campus comes the shift toward technology-based and digitally enhanced environments for learning and teaching (Brown & Lippincott, 2003). Nowadays, designing learning spaces must not only be fit for purpose but also has to be fit for the future (Watson, 2006). This is about making sure building a building (including all learning spaces) that is effectively about supporting and motivating learners and promote learning as an activity, support collaborative as well as formal practice, provide a personalised and inclusive environment, and be flexible in the face of changing needs (Higher Education Funding Council for England, 2006). This is as Watson (2006) stressed about putting people, and their learning- both in groups and as individuals- first. Balancing competing interests among students and other stakeholders and implementing the right balance of strategies will be important, as there is no one size fit approach to suit all circumstances. Thus, the design of our learning spaces as stressed by the Higher Education Funding Council for England (2006) should become a physical representation of the institution's vision and strategy for learning – 'responsive, inclusive, and supportive of attainment by all'.

Some curriculums have been criticised for being too superficial a way of learning, their conventional classrooms and learning spaces are inflexible and rigid, and relying as it does on the student essay and examination. Consequently, some universities like Warwick for example has started to introduce a classroom without desks, in which students are handed a laptop or a tablet and undertake research as part of the university's attempt to redesign teaching (The independent, 2007).

Meanwhile, in 2000, the University of Strathclyde introduced a teaching cluster that compromises an interactive classroom, seminar rooms and a teaching studio, providing a mix of peer instruction, problem-based learning and studio teaching. In some rooms curved desks have been added in order to maximise the benefit from collaborative discussion and increase interactivity into a traditional teaching space (HEFCE, 2006, p. 12).

This motivates our second enquiry in this work where we attempt to discover **RQ2: What are students' perceptions of learning environments and facilities that are used to enable successful learning?**

3. Workshop Design

We present a workshop entitled "Designing for Immersive Spaces". The aim of this workshop is to understand how technology can be used to inform design processes. In this paper we place an emphasis on designing future education workspaces with the integration of augmented reality technology. We are investigating the feasibility of designing future workspaces with an emphasis placed on inclusive AR technology. This workshop provides us with insights into the considerations that must be taken when designing workplaces of the future. Through the creation of Empathy Maps we are observing different types of users that exist within a workplace and the considerations that must be taken when designing an inclusive work environment. The identification of dream space thinking and inclusivity hotspot tasks allow us to develop an understanding of how technology can be designed into future workplaces in a way that enhances access for all.

3.1 Workshop Structure

The workshop focuses on developing an understanding of how technology can be used to inform processes of designing Immersive Environments. To enable this, we used the Double Diamond Design Process (Design Council, 2005) for the initial structure of this workshop. This allowed us to split the workshop into four phases which aligned with the four phases within Double Diamond and to create a workshop design where participants could explore our previously defined research questions though a number of activities.

Discover Phase (Character Generation and Empathy Mapping) - In this first phase of the workshop participants take part in two different activities to encourage them to think about the different people and activities that are present within a given situation. In the first, **Character Generation**, activity participants are given a number of different scenarios and asked to come up with a list of characters that exist in this space. Participants were then asked for feedback on what these characters were and are asked to give brief descriptions of the type of activities that these characters would carry out. Once this had been completed participants were then asked to create **Empathy Maps** for a single character that was discussed. Empathy maps are a useful tool that can be used when working with experts from multiple disciplines (Tschimmel, 2012), we have used them within this work to assist in generating data from students in very different degree programmes. Participants split the range of characters between all people within the workshop to ensure that no duplicates were made. Once these empathy maps were created participants fed back to the workshop on their created maps so that comparisons could be drawn between the different created characters.

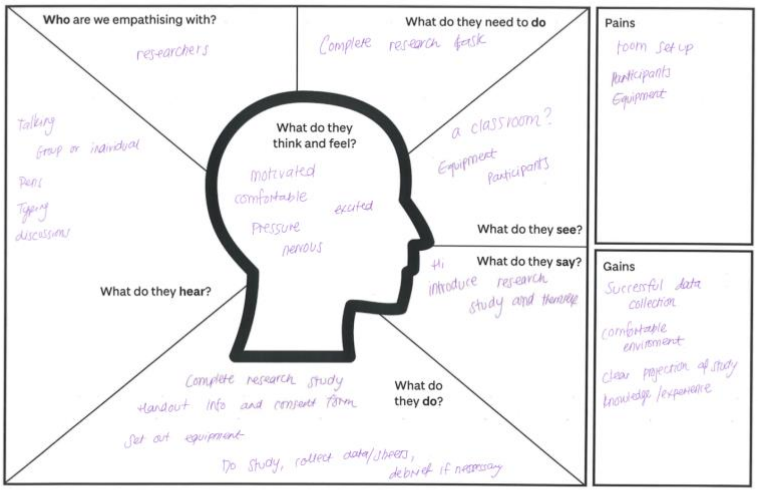

Figure 1: Example of a completed Empathy Map from our workshop

Define Phase (Intro to Inclusive Design and Persona Creation) - In the second stage of the workshop participants were first given a short introduction to Inclusive Design. This was based on materials within the Microsoft Inclusivity Toolkit (Microsoft, 2018), the Cambridge Inclusive Design Guide (Clarkson et. al 2007), and our own previous work in this area. Inclusive design is defined as ‘t*he design of mainstream products and/or services that are accessible to, and usable by, as many people as reasonably possible … without the need for special adaptation or specialised design*’ (Clarkson et. al 2007). Participants were then asked to take part in a **Persona Creation** task based on the previously created empathy maps. The persona creation task was used to act as a method to familiarise workshop participants with inclusive design and not to generate research data. The results from this are, therefore, not included in this paper.

Develop Phase (Dream Space Thinking) - In the third phase of the workshop participants were firstly asked to think about what specific tasks each of the developed personas would carry out within a learning space. They were then invited to think about what sorts of technology may exist in the future within these workspaces to support learning. Participants were asked to take part in a **Dream Space Thinking** task where they were given the pre-existing layout for a research-lab / learning-space and were asked to redesign this so that it would be suitable as a flexible learning environment. Participants were encouraged to think about inclusive design and what technology and physical space adaptations would need to be used to assist with this. Once completed, participants fed back to the workshop group, explained the design and technology choices that they had made, and explained how this would create an active learning space of the future.

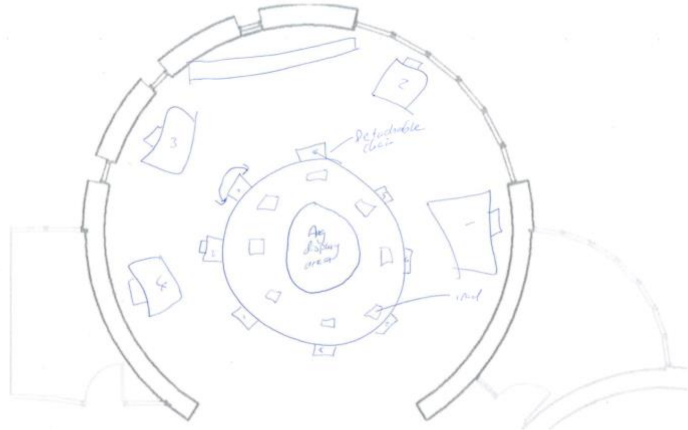

Figure 2: An example completed Dream Space Thinking activity diagram from our workshop

Deliver Phase (Inclusivity Hotspots) - In the final phase of the workshop participants were asked to take part in an **Inclusivity Hotspot** task where they were given an image of a current research-lab / learning-space and asked to make suggestions for what challenges exist within this space related to inclusive design. They were then asked what users of this space would be affected by these particular challenges. To carry out this task we created a panoramic picture of our own lab space with slight modifications made to act as a stimulus for participants to begin discussing inclusive design challenges.

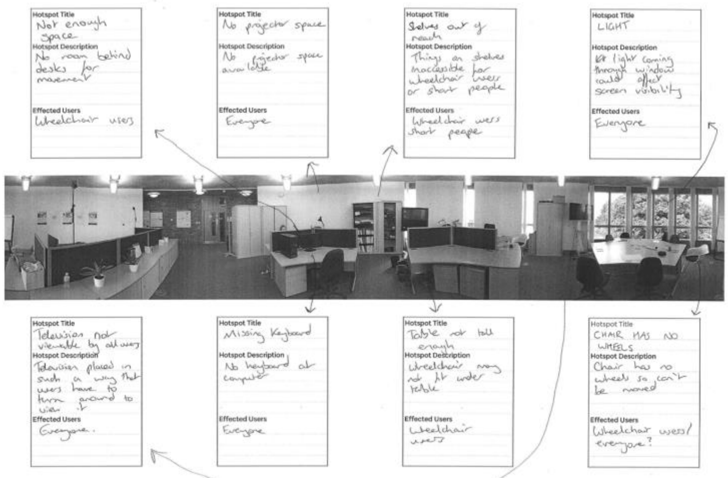

Figure 3: An example completed Inclusivity Hotspot activity sheet from our workshop

3.2 Workshop Roll Out

Once the workshop had been created and materials developed the overall structure was passed by our university ethical approval board. Over the period of two months this workshop was performed with 32 participants. As students themselves are one of the primary users of learning spaces we included these are our sole participant group. Participants were a mixture of final year and Masters level students studying a range of subjects. This included Applied Computing, Business, Computer Science, Augmentative & Alternative Communication, and Design for Healthcare & Assistance Technologies. Students participated in the workshop as part of extracurricular activities that were related to classes they were currently studying. Due to varying numbers of participants that took part in workshops it was necessary to conduct sessions as a mixture of individual and group work. Materials for this workshop are all available online (Crabb & Clarke 2018).

4. Results

4.1 Character Generation and Empathy Mapping

In the first workshop activity, participants were asked to create a list of characters that exist within a learning space. Participants described a number of characters that could be present within a space with this being split into four categories:

1. **Learning and Teaching**: Participants described a number of characters that are directly related to learning and teaching. This included *lecturers, guest lecturers, advisors, students* and *professors.*
2. **Research**: Participants also noted that a number of participants that may use a learning space include those with a focus on academic research and that this included *researchers* and *research participants*.
3. **Support Staff**: Participants discussed that additional characters within a learning space may be present to assist in facilitating any activities. This included support staff such as *cleaners, security, IT support, and Building staff.*
4. **Public**: Participants described how there can occasionally be individuals within a learning space that are visiting as part of external, non-learning, events such as open days and outreach activities. This can include *council/society leaders, general public, parents, and children.*

Once these characters had been described, participants were asked to create empathy maps based on individual user groups, these empathy maps featured sections asking participants to consider what individual groups may see, say, hear, and do within environments with additional information about pains (i.e. fears) and gains (i.e. rewards) also given.

Learning and Teaching - Participants commented that Learning and Teaching characters would take part in a number of activities within the environment that would affect what they see, say, hear and do. Participants commented that most of the noise from within this environment comes from *lecturer* or *guest lecturers* talking about the subject being taught, with secondary noises coming from interaction with students in the room and ambient noises of the room itself (e.g. projector fans). However, there was also a mismatch in activities that take place within this space, with participants acknowledging the activities that students need to do (e.g. listen, take notes, learn) and the perceived activities that they actually do (e.g. daydream, use laptop, sleep). Participants felt that one of the pain-points that exists within learning spaces for lecturing staff is in the ability to keep students engaged but and that factors relating to this are mostly based on external distractors with items such as a busy nearby environment, lack of space, and inability for students see the lecturer.

Research - Participants discussed the use of learning and teaching spaces to also be used as a place where research can be carried out. In this context, the two main characters that were developed surrounded *research participants* and *researchers*. In this context our participants discussed how researchers may view learning spaces as a creative environment and one where the design of the room can facilitate any data gathering from participants. They also discussed how participants themselves will be expecting to see information on the research that is taking place, empty chairs (acknowledging the mismatch between study size and available space) and may be asking for clarification on research being carried out. Participants finally discussed some of the potential gains of research taking place within learning environments and discussed how these should be comfortable places to enable successful data collection.

4.2 Dream Space Thinking

In this task, participants were asked to design a learning space of the future. Participants were asked to consider how new technology might fit into this space and to also consider how this could be accomplished in an inclusive manner. In this activity participants created their chosen learning space and were then asked to feed back to the workshop group as a whole on what they had created.

Technology as a Secondary Consideration in Design - Very few participants directly included technology within the learning spaces that were designed. When presenting their work back to the workshop as a whole, participants initially described the learning activities that would be taking place in their designed space and how the interaction between learners and facilitators would take place. Some participants then described technology as a secondary consideration within the space with items being retrofitted into the space. No participants described what type of activities would take place on these new technologies that were being added into learning spaces and instead discussed how the activities would be led by learners themselves with technology being an afterthought in the design process.

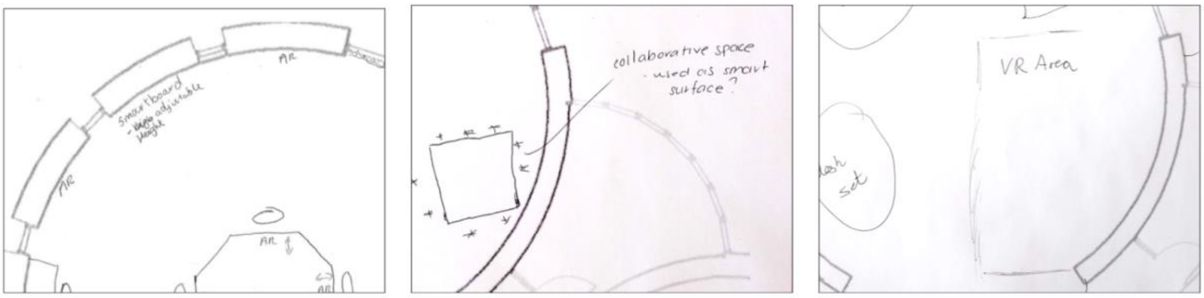

Figure 4: Examples of "Technology Afterthought" from Dream Space Thinking Activity

Zoning of Space for Different Learning Activities - Many of the learning spaces that were created in this activity subdivided space into different sections so that learning could take place in different environments. These zones existed to facilitate activities that ranged from student-led learning through to lecturer-led activities and participants perceived that rooms were being made multipurpose by the subdivision in space that was taking place. Zones were broken down into low intensity learning situations where break out areas (e.g. sofa areas) were used for learners to collaborate, medium intensity learning situations (e.g. collaborative desk area or individual work spaces) where learners could work together as a group (or individually) with optional space for lecturers leading work, and high intensity learning spaces where groups would focus on learning directly from a lecturer.

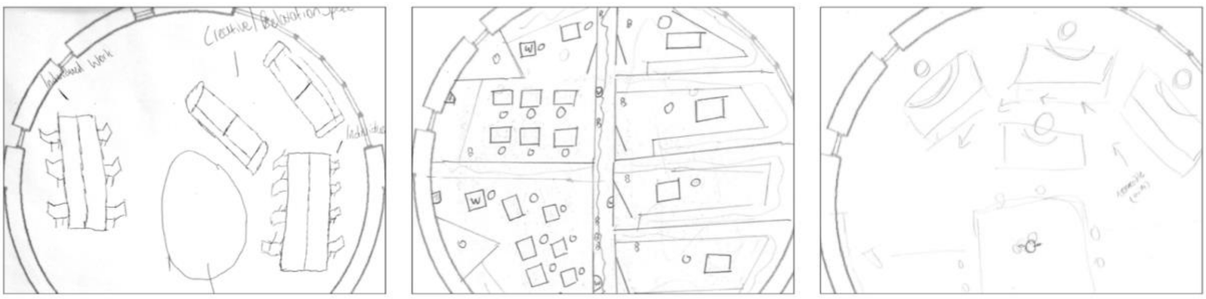

Figure 5: Examples of "Space Zoning" from Dream Space Thinking Activity

Inclusive Consideration through Personalised Interfaces - As previously described, only a small number of workshop participants included technology within their learning spaces. However, those that did made careful consideration of how technology could be made more inclusive. Participants included a number of augmented and virtual reality applications in their designs, however instead of attempting to make these technologies inclusive, participants used a fall-back method where any interactions that were shown in AR would also be shown on a standard touchscreen tablet in front of individual students to enable inclusive interaction.

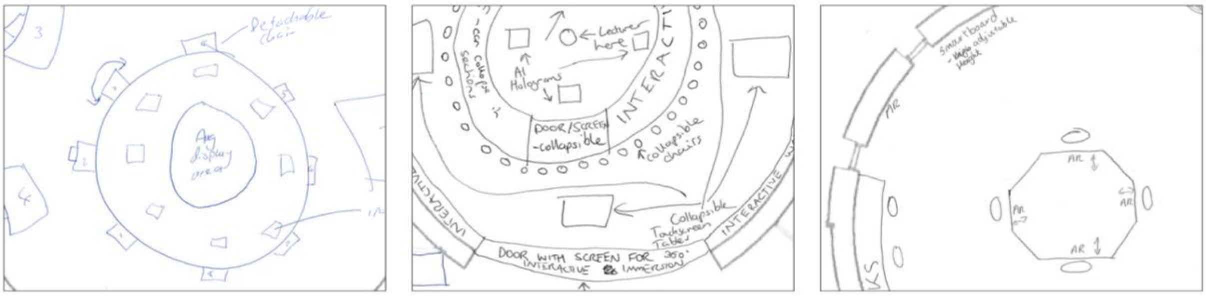

Figure 6: Examples of "Inclusive Consideration" from our Dream Space Thinking Activity

4.3 Inclusivity Hot Spots

In the final workshop activity, participants were given an image of a pre-existing university lab environment that is used for a combination of research and teaching activities. Participants were asked to identify any inclusivity issues that exist in this space and what users would be affected by these issues. In this task participants discussed issues affecting the interaction that users have with technology with inclusivity hot spots surrounding the positioning of technology displays so that users can easily see what any relevant information whilst also considering aspects such as sun glare. Participants also discussed the issue of noise within this type of environment and that learning spaces should take into consideration their surrounding environment and how this may influence a learner's ability to interact with technology and others that are in the space. Finally, participants discussed issues surrounding physical movement in spaces and how consideration should be taken when designing inclusive learning environments regarding the movement of individuals around the learning space.

5. Discussion

5.1 Designing Inclusive Learning Environments

RQ1 - What are the environmental considerations that must be examined before embedding Augmented and Virtual Reality technology into learning environments?

Learning spaces do not exist in isolation and consideration has to be taken to acknowledge the surrounding environment. Participants acknowledged that sounds and stimuli from other environments can 'leak' into learning spaces, causing distractions for learners. We believe that this is especially true when AR/VR technology is embedded within an environment due to the unique mix of physical and digital properties. It is estimated that 20% of students use technology for non-class activities with this leading to lower levels of academic engagement (McCoy 2016) and that student performance in a class can be increased by the removal of technology (Beland, 2016). However, AR technology does show promise to improve the learning experience and may lead to greater levels of student immersion, but this must be treated with caution as it may also lead to higher levels of distraction if not designed properly.

Environmental considerations of AR are multi-faceted, and it may be simpler in the short/medium term to rely on older, more established, interaction methods when developing inclusive technology solutions. Within our dream space thinking activity, some participants proposed that augmented and virtual reality displays could be replicated on personal, touch screen, devices that could be adapted to individual's needs. Whilst this solution does not deal with the accessibility constraints of augmented reality technology itself, it does help to alleviate one-size-does-not-fit-all (Tigwell 2018) accessibility issues that occur in multi-user experiences.

There are many inclusive barriers that exist within the physical environment that must be overcome before a proper examination of augmented reality accessibility can be accomplished. In our inclusivity hotspot activity participants were able to identify a large number of inclusivity challenges that exist within a computing lab environment. These challenges were based around our previously defined accessibility areas of visual, cognitive, and communication issues. Based on our findings in this work, we believe that it is very difficult to retrofit an environment to be suitable for usage with AR and VR technology, and that future work should look at the design of physical and digital environments in tandem - one cannot be placed as coming before the other.

5.2 Student Perceptions of Learning Environments

RQ2: What are students' perceptions of learning environments and facilities that are used to enable successful learning?

Lectures don't only take place, they make place. And just like 'house' is to 'home', lecture spaces (i.e. halls, theatres, seminar rooms) can be cold and unwelcoming without people but become 'alive' with students (Tuan, 1991).

The traditional lecture based on the 'empty vessel' view of student learning often takes place in a learning space where students sit at desks, in rows, and lecturers speak at students. In this view, the 'sage on the stage' has all the knowledge that needs to be transmitted to students and this 'filling up' is achieved mainly through talking, from one-to-many, in front of students. Within our dream space thinking task, we asked participants to develop their own learning spaces of the future. In this, one of the themes that arose was the continued centrality of the 'lecturer' within the teaching space. In this work, we had initially hypothesised that technology would be central to students' perceptions of future learning spaces but this was not the case. Our participants described clearly how their created spaced fostered collaboration between learners and teachers. Whilst the sage may no longer be on a stage, he is still present and central to expectations of student learners.

We live in a digital and visual era. The lecture spaces we now occupy, as students and educators, have long since been adapted and retrofitted to accommodate the pervasiveness of technology-enabled (learning) devices and; these spaces seem much more immersive, flexible and hybrid (i.e. smart, re-configurable and multi-purpose) than before. However, many are still victims of poorly thought-through plans, where digital solutions have been shoehorned into the fabric of the building, sometimes with little consideration given to inclusivity and accessibility issues. This was echoed by participants in our dream space thinking activity, where technology was viewed as a secondary consideration within learning places. Participants created a learning space with a primary focus on the learning tasks that were perceived to take place, with attention then turned to the inclusion of technology. As a result, the shoehorning of technology within a space seemed to continue with the methods used by our participants. This is an area that deserves future research in order to determine how teaching spaces are designed with technology central to this design process.

6. Conclusion

In this paper we have presented a workshop that can be used to uncover issues present in designing learning spaces with a focus on inclusive practice. We carried this workshop out with 32 participants and have made the materials for this workshop available online for others to use (Crabb and Clarke, 2018).

Participants showed to have a good understanding of the characters that are present within learning spaces and the different activities that take place within. Our findings show that there are many opportunities for current technology to act as a distractor when learning and that **the inclusion of technology within learning spaces should place an emphasis on educational activities and not on general purpose work.** Our participants also described a large number of inclusive design issues that were present in pre-existing environments, with these being core to the overall design of the physical space. These inclusivity challenges are compounded when augmented reality technology is placed on top of an existing environment. It is important, therefore, that **the design of augmented reality environments should take place with an understanding of physical and digital space concurrently and should not view one as more important than the other.**

Finally, within our work, participants described a number of methods in which learning environments can be created. Central to the design of all these environments was aspects of collaboration between learners and teachers. Our participants viewed technology as an afterthought in the design process and not as a central part of the teaching environment. It is therefore vital that **the design of learning spaces should fit the learning *needs* of all stakeholders and not the perceived *wants* of a select few**.

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