REALISING THE POTENTIALS OF VIRTUAL REALITY AND BUILDING INFORMATION MODELS? CIVIL ENGINEERING STUDENTS' UTILISATION OF TECHNOLOGY IN A GROUP PROJECT

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ABSTRACT
Collaboration between different actors is key to successful projects within the architecture, engineering, and construction (AEC) industry. Virtual Reality (VR) combined with Building Information Models (BIM) is an effective visualisation tool that may aid a team's communication and collaboration. Civil engineering students at Oslo Metropolitan University are encouraged to use such tools, available to them in a dedicated digital collaboration room dubbed the 'Little Big Room' (LBR) along with computers and large touchscreens. This paper explores how the tools in the LBR are utilised by three student groups working on a project and how the students view them, discussed through the theoretical lens of the technology acceptance model. The aim is to suggest how students' utilisation of the technology can be facilitated to improve their learning experiences in collaborative projects.
The students were satisfied with using the LBR. However, the full potential of VR was not utilised, such as the option to evaluate the size of the rooms and lighting conditions, something they only realised in hindsight, as not all students perceived VR as sufficiently useful for the tasks given. Changing the criteria of the task or increased focus on the students' first introduction to VR might facilitate increased utilisation of VR as a professional tool.

Keywords: Virtual reality, building information models, civil engineering education, visualisation

1 INTRODUCTION
Within the architecture, engineering and construction (AEC) industry, collaboration between actors with different specialties is key to effective and successful projects. As mistakes or inefficiencies can easily result in large costs and delays, it is important to continuously search for ways to improve communication and collaboration within groups. Although an emerging method in the industry, the use of immersive Virtual Reality (VR) in combination with Building Information Models (BIM) has proven to be an effective way to visualise a project and improve the actors' communication and understanding of the project [1, 2, 3]. 3D-representations can help participants discover errors and review the plans better than 2D plans [4], especially when viewed in VR [5]. However, studies show that VR still has an untapped potential [6, 7, 8]. This paper explores how civil engineering students utilise VR and other technology and their views on it, as part of a collaborative project. The aim is to suggest how increased utilisation of the technology can be facilitated to improve the learning experiences of students.

2 METHODS
This study combined qualitative, semi-structured interviews with quantitative timekeeping records. Descriptions of these methods follow a description of the scene of the study and participant sampling.

2.1 The scene of the study
This study took place in the Department of Civil Engineering and Energy Technology at Oslo Metropolitan University, more specifically in a dedicated digital collaboration room called the 'Little Big Room' (LBR). The LBR is a small version of the Big Rooms at construction sites, dedicated to collaboration between an entire project team [9]. The LBR is equipped with four sets of 65" touchscreens, computers, and Oculus Rift VR headsets.

In the 10 ECTS course *Introduction to Building Professions* in the first semester of the bachelor's degree programme in Civil Engineering, the students were divided into groups of 6 and asked to plan a semi-detached house. Each student in the group was given an area of responsibility, such as architect, contractor, project manager or specialised engineer. In addition to a written report, the groups made a BIM in Autodesk Revit. Lassen, Hjelseth, and Tollnes [10] have provided a more detailed description of this project in their work.

For a proper introduction to the LBR equipment and effective collaboration, the groups were encouraged to sign up for two voluntary Integrated Concurrent Engineering (ICE) meetings. The ICE-meetings were highly structured meetings assisted by a 3rd year student assistant, arranged in the LBR, lasting about 60 minutes each. The meetings observed in this study were held in September and October 2020. The first meeting was led by the student assistant, who guided them through a presentation of status reports and taught them how to use the large screens to show the BIM or draw on before instructing them on the use of the VR equipment with a walkthrough of a BIM. In the second meeting, the students themselves were in charge, with the student assistant present.

2.2 Sampling of participants

Three groups participated in the study. Groups A and B were sampled randomly, using convenience sampling. The first author participated in an ICE1-meeting to gain an understanding of the project. No data were gathered in this meeting, as this study examined how the students themselves utilised the room. An overview of the observed meetings is provided in Table 1. Groups A and B did not use VR in their ICE2-meetings but expressed an interest to view their finished models in VR. Prompted by the first author and the student assistant, a third meeting was scheduled. Group C was sampled strategically, as the authors heard that they planned to use VR in the ICE2-meeting. Including this group gave a broader image of how the room was utilised, perhaps more representative for the overall class.

Table 1. The ICE-meetings the first author participated in is marked with an X. The ICE1-meeting was used to gain familiarity with the project, while data from the other meetings are included in the study

	ICE1	ICE2	ICE3/VR
Group A	X	X	X
Group B		X	X
Group C		X	

The groups consisted of 5–6 students each, but not all students were present for all the meetings. One student did not wish to participate in the interview and left the room after the meeting. Thus, a total of 14 students participated in the observed meetings and 13 in the interviews.

2.3 Video observation with timekeeping records

Five meetings were observed in their entirety and recorded through a video camera placed in the corner of the room. The first author was positioned close to the camera, taking notes, attempting to observe the students' natural use of the room and affect their behaviour as little as possible, despite her presence.

The recordings were analysed through quantitative timekeeping records (Figures 2–4). The exact times of when the students started and stopped using (1) the large touchscreens, for viewing the models or drawing; (2) the VR-equipment; and (3) other items such as personal computers or pen and paper notebooks were entered into an Excel spreadsheet. This showed how much time the students spent using each of the tools, how they switched between them or used them simultaneously, and when they were used in the meeting.

2.4 Semi-structured interviews

Directly after the meetings, the students participated in semi-structured, qualitative group interviews resembling everyday conversations but following an interview guide with set themes. The students were asked about their shared experience from the meeting, their use of VR and the LBR in general, and the tools that had helped their collaboration. The interviews after the ICE2-meetings lasted 8–12 minutes and the interviews after the ICE3-meetings lasted 3–7 minutes.

The transcribed interviews were coded thematically. The interviews have been used for illustrating how the LBR was utilised and in answering how the students viewed the LBR.

2.5 The technology acceptance model (TAM) as an analytical tool

To understand the students' views on their use of the LBR, the observation and interview data are viewed through the theoretical lens of the TAM proposed by Venkatesh and Davis [11], visualised in Figure 1. Although originally designed for predicting technology use, it has been used in this paper to serve as a framework to discuss the students' initial experiences. Of particular interest are the following two constructs (1) *Perceived Usefulness*, the belief that using a specific technology will increase job performance and (2) *Perceived Ease of Use*, the degree to which the use of a specific technology is expected to be free of effort [12]. Together they influence the intention to use technology, which in turn influences its actual use. However, these are affected by *External Variables*, which in this study include factors like the students' prior knowledge of the technology, along with the tutoring and the tasks given. Discussing these constructs separately allows us to distinguish which variables can be changed to facilitate increased utilisation of the LBR and improve the students' learning experiences in collaborative projects.

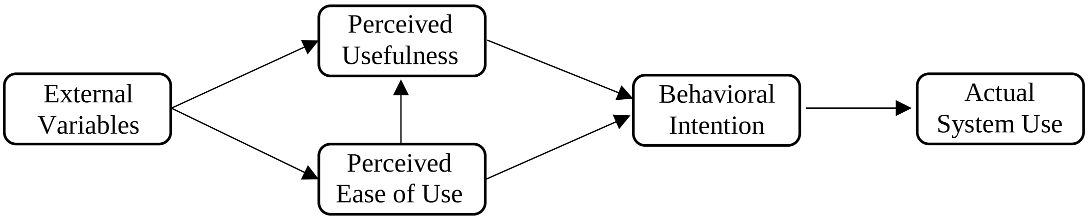

Figure 1. The technology acceptance model created by Venkatesh and Davis

3 RESULTS

3.1 Utilisation of the LBR in ICE 2

Groups A and B followed the ICE-structure learnt in the first meeting, where each group member presented what they had done since the last meeting. While talking, they showed relevant parts of the BIM from Revit on the large touchscreen. The option to draw on the screen was only utilised by the Contractor of Group A, who drew roads, barracks, etc. on a pdf showing the building site. During the presentations, one team member used their own laptop to make notes for the report. Their time spent using touchscreens and/or their personal computers is presented in Figure 2.

Figure 2. Utilization of the available technology in the ICE2-meeting by Groups A and B
Note: The dark segments of the top bar indicate drawing on the touchscreen. VR was not used at all

Group C utilised the LBR in a way different from Groups A and B. They switched between walkthroughs in VR and editing the model in Revit on the touchscreen, as shown in Figure 3. Immersion in VR was delegated to two of the students, while the rest of the group watched the walkthroughs on the screen. They used the walkthroughs to discover errors in the model, such as small holes in the floor or excessively narrow passages. The project manager made notes of errors using pen and paper, but some were also corrected directly. Group C stated in the interview that they had no need to spend time in the LBR presenting to each other, as they preferred updating each other through other channels.
Group C used VR for 25 minutes out of the 60 minutes, while Groups A and B did not use VR at all.

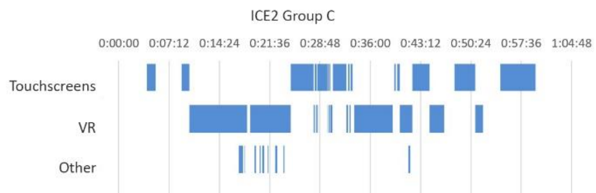

Figure 3. Group C's timekeeping record show switching between touchscreens and VR throughout the ICE2-meeting, spending about equal amounts of time on these two tools

3.2 Utilisation of the LBR in ICE3

In the ICE3-meeting, primarily set up so that Groups A and B could view their models in VR and take screenshots for the presentation, these two groups showed different approaches, as demonstrated in Figure 4. In Group B, the three participants that wished to try VR took walkthroughs lasting about 3–6 minutes each. After this, they spent the rest of the time working on the model in Revit, both correcting mistakes discovered in VR and taking screenshots, using both the large touchscreen and a private laptop. Group A's approach was similar to Group C's in the ICE2-meeting, where VR was used by all team members to discover errors in the model. These were subsequently corrected in Revit on the large screen. In addition to switching between Revit and VR views, one student worked in Revit while another student was viewing the model in VR. The student who used VR the most mentioned that communication was challenging, as the rest of the group was not necessarily viewing the same part of the model as he was. The duration of Group A's ICE3-meeting was about two hours, which was almost twice that of the other observed meetings. However, as they solved most of the issues with the model during the meeting, instead of taking notes for later work, this does not necessarily imply an inefficient meeting.

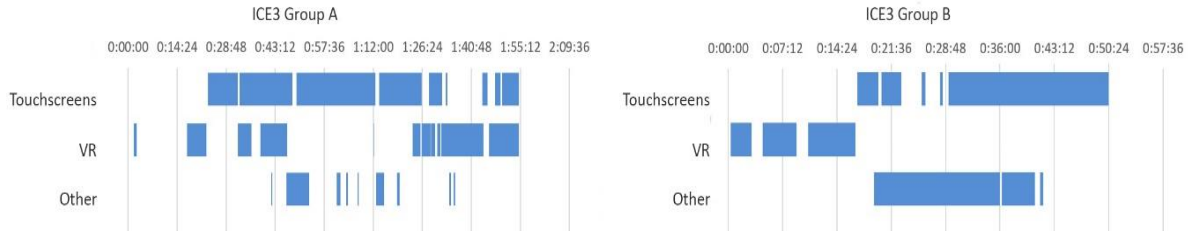

Figure 4. Utilization of LBR tools in ICE3-meetings by Groups A and B. Group A used VR throughout the meeting, while interested students in Group B took walkthroughs only at the start of the meeting

3.3 The students' views on using the LBR

After the ICE2-meeting, Groups A and B described it as a useful and efficient way to keep the entire group informed. Group B's Structural engineer said that he never collaborated with the Contractor of the group but appreciated to be informed and that he was able to contribute to that part of the project.

The large touchscreens were mentioned as very useful for the presentations. The Contractor in Group A, who drew on the touchscreens while talking, stated that the screens made it 'a lot easier to visualise'. When the rest of the group commented that the screens made it easier to follow the presentations too, the Contractor followed up by saying 'It's possible to ask questions; you easily can explain and clarify without too many explanations because you can show or point'. Group B attributed the discovery of a large mistake – a difference in the area between the two supposedly identical halves of the building – to viewing the model on the large screen. The Project manager commented that this probably would have been difficult to see on the small screen of a personal computer. The Structural engineer in Group A also commented that the large screens and switching between VR and working on the model in Revit facilitated a good workflow.

All groups talked about the ability to discover small and large errors as a big advantage with the use of the available technology, especially VR. Group C, who were well acquainted with each other's progress, mentioned this as the biggest advantage of using the LBR. In their model, a deep window frame had been placed in a flight of stairs, making the stairs too narrow. This was discovered during the VR-walkthrough, as it created a barrier impossible to pass and thus mentioned as an issue they could only discover in VR. Visible loadbearing beams in the ceiling was an issue discovered by both Groups A and B during the VR-walkthroughs. The Architect in Group B commented that in Revit, "you have the 3D-view, but you might not be inside the house then', which provides the necessary point of view.

Before viewing their own model, Groups A and B considered the use of VR primarily as something fun, something to try just for enjoyment. Both groups also mentioned viewing how the finished house had turned out and evaluating the lighting conditions. The Architect in Group A commented that it would be wiser to try VR earlier in the process. During the ICE2-meeting, they realised that the kitchen did not receive any natural light, something they regarded as a mistake. The Architect mentioned that they could have obtained a clearer feel for this issue by viewing the model in VR earlier, rather than just looking at drawings. However, most of the students in Groups A and B wished to wait with the VR walkthrough until the model was completed and fully furnished. The Project manager in group B stated that when they had finished everything they could 'do something that's not so educational and just play around with the model'.

After using VR in the ICE3-meeting, the students highlighted other positive aspects of the experience. The Architects in both groups commented that they realised the dimensions of the building and rooms by viewing the BIM in VR. In a discussion, the Architect and the Structural engineer in Group B agreed that one of the bedrooms had turned out to be a bit small and that they could have looked at it earlier and tried their hand with different sizes. Both groups also mentioned the satisfaction of seeing a result that could be interpreted as an actual finished building when viewed in VR. As the Project manager in Group B said, 'This is a project everyone in the group has been a part of. […] So, we are proud that, okay: at least we managed to create a finished building'.

4 DISCUSSIONS

4.1 Perceived usefulness

The access to the LBR was regarded as very useful by all groups to keep each other updated, to discover large or small errors, and as a dedicated room for collaboration. Groups A and B highlighted the usefulness of the large touchscreens for presenting and viewing the BIM, while Group C regarded the access to VR-equipment to search for errors in the model as the LBR's biggest advantage. After the ICE3-meetings, Groups A and B commented that VR would have been a useful tool in making design decisions. However, this potential was not utilised as they had regarded VR as a fun reward upon finishing the model rather than as a useful tool to improve the model.

4.2 Perceived ease of use

In the observed meetings, there were no signs of the students struggling to use the tools in the LBR. Most of the time, a student assistant was present to help them with unfamiliar tasks, but generally the tools appeared to be easy to use. The only remark on this came from a student in Group A who commented that the simple switching between VR-mode and editing in Revit offered a good workflow. At the end of Group A's ICE3-meeting, one student edited the model while another student was in VR, which made communication difficult as they did not know what the other was viewing and commenting on. This was mentioned as a challenge, although it could have been solved by using two screens.

4.3 External variables

The groups had two different approaches in the ICE2-meetings. Groups A and B followed the structure from the ICE1-meeting, presenting a status report while mainly showing the BIM on the large touchscreens, while Group C prioritised to use the VR-equipment. Group C's first ICE-meeting was not observed by the authors, but in the interview they said that they had viewed their own model in VR, while Group A, perhaps also Group B, viewed previous students' finished BIM. This suggests that the first ICE-meeting shapes how the students choose to utilise the LBR later in the project. The full potential of viewing their models in VR should therefore be demonstrated in the first meeting. Viewing an early draft of their model as part of this meeting could help them see how VR can be utilised in the process of making design decisions.

Despite their different approaches, the three groups were satisfied with their technology use. VR was not perceived as sufficiently useful, as they felt the assigned tasks could be completed successfully through viewing and editing their models on the large touchscreens and personal computers. To facilitate a better utilisation of the technology in the LBR, tasks more suitably solved with the use of VR should be added to the list of assignments. Included in this list could be tasks such as fault detection, window placement for maximum utilisation of natural light during specific hours, room layout, and perhaps furnishing. We also believe that students should be pushed to explore new ways of model-based teamwork, with a larger emphasis on the process rather than the product. Findings from a previous study on this course show that students spend considerable time on such projects, even though they regard the assessment 'Pass' as a disappointing reward for their hard work [10]. This suggests that there is a potential to nuance the focus towards exploration of new methods of collaboration in teamwork, without compromising their outcomes, and thus laying a solid foundation for the rest of their education.

5 CONCLUDING REMARKS

Considering the students were positive towards the technology and found it easy to use, there is potential for increased utilisation of the LBR. Not all students realised the potential of VR combined with BIM in time to implement it during their process. Small changes to the procedure of the ICE1-meeting and the criteria in the task may contribute to shifting the students' perception of VR from a tool for detecting small errors or a reward for finishing a project to one of a valuable professional tool.

One complaint from the students was the difficulty of communicating while using VR, if the others were not seeing the same view. Technology has advanced in recent years to allow multiple actors to view the model in VR simultaneously while interacting, and one conclusion of this study should be to test the impact of such advances on the students' collaboration. The authors plan to do this in the fall of 2022.

Some of the advantages of using VR mentioned by the students such as gaining an understanding of the dimensions of the building lie beyond the scope of an engineer's responsibilities. However, in a world of increasing complexity that demands the ability to draw connections and to collaborate across disciplines, tools that aid in this will certainly add value. Familiarisation with such tools early in their educational curriculum may push students towards challenging the existing learning objectives.

5.1 Limitations and suggestions for further research

This study included a small sample of participants. Based upon the different approaches shown in this material, it is likely that including other or more groups would have given a different result. Doing a larger study, including more groups, would perhaps provide a more nuanced picture. A bigger task such as a shopping mall could encourage students to use VR to get a feel for the space while planning.

Effects of implementing the changes suggested in this paper, such as changing the list of criteria to pass or increased focus on the students' first introduction to VR, should be explored. Another suggestion for further research would be to investigate whether such lab-experiences will influence students to utilise such technology later in their education.

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