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Towards An Immersive Virtual Studio for Design Engineering

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Abstract

The sharing of ideas, collaborative making, and serendipitous discussions and groupings are essential elements that foster creativity and growth among student cohorts. This applies specially to design- and/or engineering-related courses. Enabling these features is a unique requirement for creating a virtual communication platform tailored towards corresponding programs.

During the COVID-19 pandemic, we tested various virtual platforms in the context of design engineering education to deliver online courses. However, traditional teleconferencing platforms like Zoom and Microsoft Teams – which were used on the daily basis – showed limitations in terms of interaction opportunities, group-based communication, and customisability. In previous work, we successfully tested a Spatialized Video Communication Platform which was resembling a 2D video game-like interaction: Gather.town.

In this work, we extended this approach in a test study into the third dimension using two existing Virtual Reality-based platforms (Horizon Workrooms and Spatial) aiming to improve serendipitous interactions, group-based communication and quick group formation in distance teaching and learning. We conducted a workshop with each platform and collected student feedback with a questionnaire survey.

We also ask the participants to relate their experiences to the earlier used Gather.town platform. Our finding showed that immersion is a crucial factor that impacts the effectiveness of group work in distance learning. However, we still found that there is a lot of potential for improvements before these frameworks can be used on a regular basis for teaching.

This paper presents our applications and analysis of the two platforms and contributes insights on how to build a virtual studio environment for an interdisciplinary master's programme in design engineering.

Context

Amidst the global COVID-19 pandemic, the usage of video communication platforms experienced a significant upsurge. Teleconferencing software, such as Zoom [1], which was previously used on an irregular basis, suddenly became the primary mode of education, research-related discussions, and development delivery. However, virtual communication via screens resulted in a reduction of flexibility and serendipity, causing problems such as 'Zoom fatigue' and limited interaction opportunities with classmates and educators. To overcome the limitations of traditional video conferencing platforms, new virtual spaces were developed to complement them. These immersive platforms offer customisability, creative visualisation, and navigation opportunities, introducing more flexibility, serendipity, and improved dynamic group forming by providing game-like environments.

In design education, students' work involves spending a considerable amount of time in their studio [2]. Knowledge is gained through conducting design practice and crafting artefacts, and idea sharing, collaborative making, and serendipitous discussions and grouping are crucial elements that foster creativity and growth among master's students in the *Innovation Design Engineering (IDE).* Hence, a virtual communication platform tailored towards IDE students would have to enable these features.

IDE is a course delivered in close collaboration of the two institutions Royal College of Art and Imperial College London. IDE is a 2-year program which ends with a double degree (M.Sc. and M.A.) from both institutions.

Two *Virtual Reality (VR)* platforms – Horizon Workrooms [3] and Spatial [4] enabled the teaching team at the IDE programmes to test a virtual studio-similar working space for students – which could be used especially for virtual teaching in situations like the COVID-19 pandemic when the campus is inaccessible. This paper presents how we tested two virtual studio-like environments for our masters' students and identified critical factors for developing virtual studios for a design masters' course. The testing was done during 2022 – after the COVID-19 pandemic.

The paper commences with reviewing existing works that employed VR as a teaching tool, continues by introducing the methods we used to create the virtual studio testing platforms, presents the results of testing our virtual studios, and finally provides insights for future virtual studios setups for design education.

Related Work

Numerous efforts have been undertaken to explore, study, and harness the potential of virtual platforms [5]. The utilisation of virtual platforms allows students to engage in curriculum-related experiments and procedures that may otherwise be excessively costly, dangerous, or unfeasible [6]. The transition between physical and virtual classrooms has prompted innovative endeavours to enhance the teaching environment, adapting to the changes and contradictions that arise [7]. The COVID-19 pandemic has facilitated the development of new forms of virtual teaching modes in disciplines that necessitate physical engagement. Notably, performing arts educators [8] have adopted a "flipped classroom" approach to deliver online synchronous dance lectures, utilizing various online platforms. This example serves as a valuable model for disciplines within the creative arts field. In a study conducted by Ceylan et al. [9], online architectural design studios were evaluated during the COVID-19 outbreak. The findings revealed that the online studio complemented the limitations of the traditional physical studio environment, such as providing the ability for students to review recordings of discussions from online sessions repeatedly.

Amidst the popularity of VR, it has been employed as a teaching tool. Marougkas et al. [6] devised a framework for

personalized VR learning environments to enhance gamified educational experiences. Zhang and Liu's study [10] identified the immersive potential of VR as an advantage over traditional physical methods within pedagogy. Aylward et al.'s research [11] utilised VR technology to simulate operational scenarios in a ships' bridge for maritime education and training purpose, showcasing the potential of VR in targeted educational or training objectives. Jin et al.'s work [12] discussed VR's role in higher education highlighting its capacity to facilitate access to otherwise inaccessible learning contexts, aid in the comprehension and retention of visual and spatial knowledge, and support embodied learning. These advantages align well with our objective of constructing a virtual studio for IDE students.

In our previous publication, the Immersive Design Engineering paper from 2020 [13], we provided an initial review of various platforms that can be utilized to facilitate and teach Design Engineering. Additionally, in a separate publication [14], we specifically discussed Gather.town as a *Spatialized Video Communication Platform (SVCP)* for teaching purposes. Gather.town resembles a 2D gaming platform enabling serendipitous interactions, dynamic group forming and 1:1 communication.

We created a virtual teaching and learning space for the IDE master's programme, incorporating features that facilitate creativity. This was achieved by combining Gather.town [15] with third-party maps and/or self-created content, e.g. we utilised customized 3D environments created with 3D modelling and rendering tools such as Sweet Home 3D and Blender, and Google Maps® [14].

In the present paper, we further delve into our investigation by exploring two VR-based platforms - Horizon Workrooms and Spatial. In this way, we tested the impact of the third dimension and VR-based interaction capabilities. Our objective was – in the context of Design Engineering education – a) to find out if our students are interested to further explore the virtual studio opportunity, and b) to examine how immersion within a virtual studio setting impacts the learning experience of master's students.

Method

In order to provide students with a more immersive learning environment during situations like the COVID-19 pandemic, we used two virtual studio-like environments using existing VR-based platforms and tested them with our students. Figure 1 shows the setup in Horizon Workrooms, Figure 2 the one in Spatial.

Each student was placed in a large room with sufficient space for movement in the virtual world using an Oculus/Meta Quest 2® [16]. Students were able to communicate with each other directly as they were at a hearing distance. The Oculus Quest 2 was used without activating the See-through – therefore, students were fully immersed in the virtual world.

We organised an ideation workshop using each virtual studio, where students engaged in an ideation exercise within VR environments as a pilot study. The main target was to find out if our students are interested to engage with these new environments and if these VR studios have – from a practical point of view, the potential to be used in for teaching in design engineering.

Overall, the two organized workshops had eight participants, roughly representing 10% of the overall IDE cohort (year one and year 2). Obviously, we cannot claim that this study is representative. Instead, this is a pilot study which was used to decide if we should take the corresponding approach further forward.

The exercise involved imagining themselves standing in front of a 10-meter-wide bottomless ravine, being pursued by a crowd of zombies. Participants were tasked with employing their design thinking skills to develop tools for fighting, hiding, or escaping from the zombies. Participants were recruited from the IDE programme as they would be the primary users of the virtual studio we designed. They were required to present their ideas by constructing 3D models or creating sketches within the virtual studio. To prevent participants from experiencing motion sickness [17], [18], each workshop lasted for 40 minutes. The Horizon Workrooms workshop took place on 14.01.2022, and the Spatial workshop on 13.05.2022.

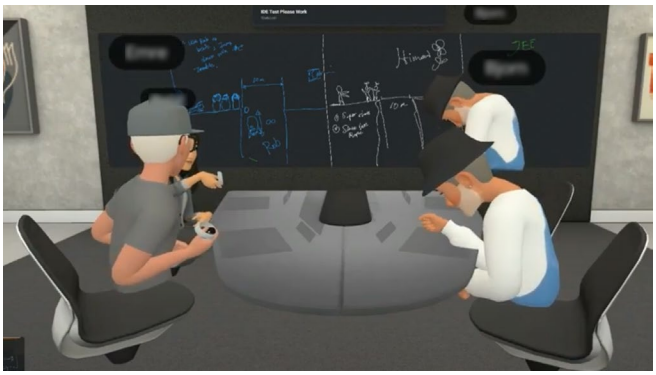

Figure 1 Horizon Workrooms workshop in progress.

Figure 2 Spatial Workshop in progress.

Figure 1 and Figure 2 present two workshops in progress. Students were allowed to use all tools available in the different platforms and experiment. Both platforms provided a blackboard (Horizon Workrooms) or whiteboard (Spatial), and students were also able to draw on individual virtual sheets. Whereas the virtual avatars were located in Horizon Workrooms in a sitting posture – resembling a table-centred office space, the avatars were standing in Spatial and had more freedom in movement.

Following the workshops, we collected students' feedback through an online questionnaire survey. The questionnaire utilised rating-scale questions to gather data on participants' experiences with different functions, the outcomes of the ideation exercise, and the emotions elicited during the workshop. Participants were also asked to speculate on the future potential uses of the two platforms. The rating scale questions employed a semantic differential (SD) scale, which consists of a seven-point scale contrasting two bipolar adjectives (e.g., strongly disagree (-3), quite disagree (-2), slightly disagree (-1), neither agree nor disagree (0), slightly agree (1), quite agree (2), strongly agree (3)). This choice of incorporating UX metrics into our questionnaire was based on the proven effectiveness

of this approach in transforming qualitative experience data into quantitative data for comparative analysis [19]–[22].

The questionnaire was divided into two parts: the first part collected participants' basic information (age, gender, and the online platform they typically use), while the second part focused on their experiences with Horizon Workrooms or Spatial. Towards the end of the second part, participants were also asked to compare their experiences with the two VR-based platforms to a non-VR based platform, Gather.town, which they had previously used in their course (see Figure 3). Participants provided feedback on Gather.town based on their retrospection of their past experiences. The last major event on Gather.town took place on 14.03.2021. After collecting the data, we calculated the means for each question and created bar charts to facilitate a comparison of participants' experiences between the two platforms.

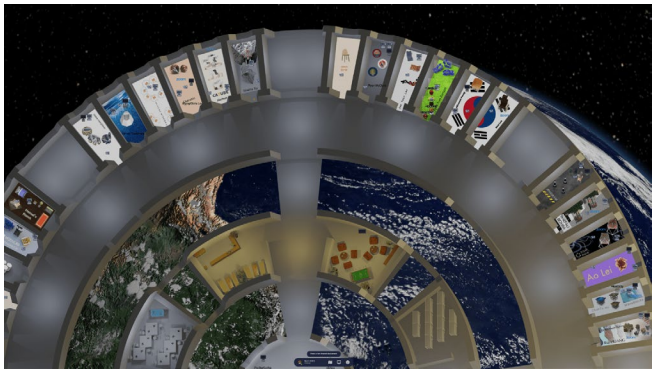

Figure 3 Previous virtual studio we built with Gather.town [14].

Results

A total of three participants took part in the workshop organized in Horizon Workrooms, comprising 66.6% females and 33.3% males. On the other hand, the workshop organized in Spatial involved five participants, with 40% females and 60% males. All participants fell within the age range of 24 to 27 years. They possessed a bachelor's degree in a design-related field and were pursuing a master's degree in Innovation Design Engineering. Interestingly, all participants stated that their usual online platform for study and practice was Zoom. For anonymity purpose, we refer to our participants as P1 to P8 in this section.

During the data analysis, we initially compared the overall feedback received for the two VR-based platforms (see Figure 4). It is noteworthy that both platforms received positive feedback in terms of their graphics and visualization, which were rated close to the slightly satisfied level (1). However, the navigation experience in both Horizon Workrooms and Spatial was reported as negative by the participants. Particularly, the discomfort associated with Spatial's navigation fell within the range of slightly unsatisfied (-1) to very unsatisfied (-2). Although the layout of both platforms generated positive experiences for the participants, Spatial's rating only slightly exceeded the neutral level. Regarding the overall experience, Horizon Workrooms received a neutral rating, whereas Spatial was slightly unsatisfactory according to our participants. As for the addition of other features such as video calls (Zoom) and a platform for presentations, exhibitions, and discussions to the two VR-based platforms, participants in Horizon Workrooms expressed significant disagreement, while those in Spatial showed a slight level of expectation towards such features.

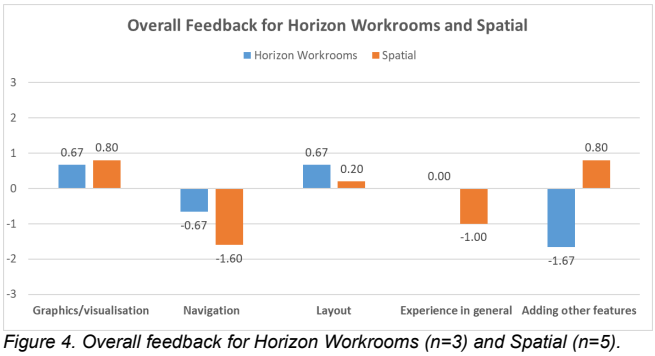

Figure 4. Overall feedback for Horizon Workrooms (n=3) and Spatial (n=5).

Subsequently, we proceeded to compare the participants' individual evaluations concerning the ideas generated in the two workshops (refer to Figure 5). To measure ideation effectiveness, we adopted Shah's metrics [23]–- novelty, variety, quality. The participants who attended the Horizon Workrooms workshop expressed a belief that their ideas possessed a remarkably high level of novelty, accompanied by a slightly elevated level of variety and quality. In contrast, participants in the Spatial workshop reported that the level of novelty and quality of their ideas fell slightly below the neutral point. However, the variety of ideas they generated was rated close to a moderately high level. Participants shared their opinions on using VR-based platforms for ideation through open-ended questions. They highlighted several advantages of these platforms, including the ability to overcome space and time constraints (P2), the creation of a studio culture that fosters teamwork (P3), and enhanced concentration on their work (P6). However, they also acknowledged certain disadvantages associated with these platforms, such as limitations in the available creation tools (P1, P7), the occurrence of motion sickness (P2), fatigue from prolonged use (P3, P7, P8), and the high barrier of entry due to the complexity of controlling devices (P4, P6).

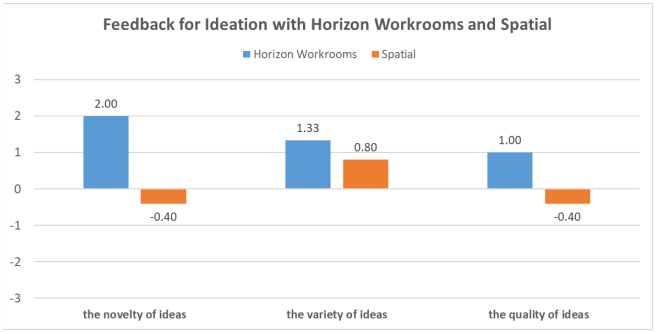

Figure 5. Feedback for Ideation with Horizon Workrooms (n=3) and Spatial (n=5).

Next, we proceeded to compare the feedback regarding VR immersion for the two platforms (see Figure 6). Participants who utilised Horizon Workrooms exhibited a lesser awareness of the real-world surroundings when immersed in the VR environment, although the level of awareness of the real-world surroundings in Spatial was also below the neutral point. Both groups of participants concurred that their experiences in the VR environments were not like perceiving pictures, with agreement levels ranging between sli-

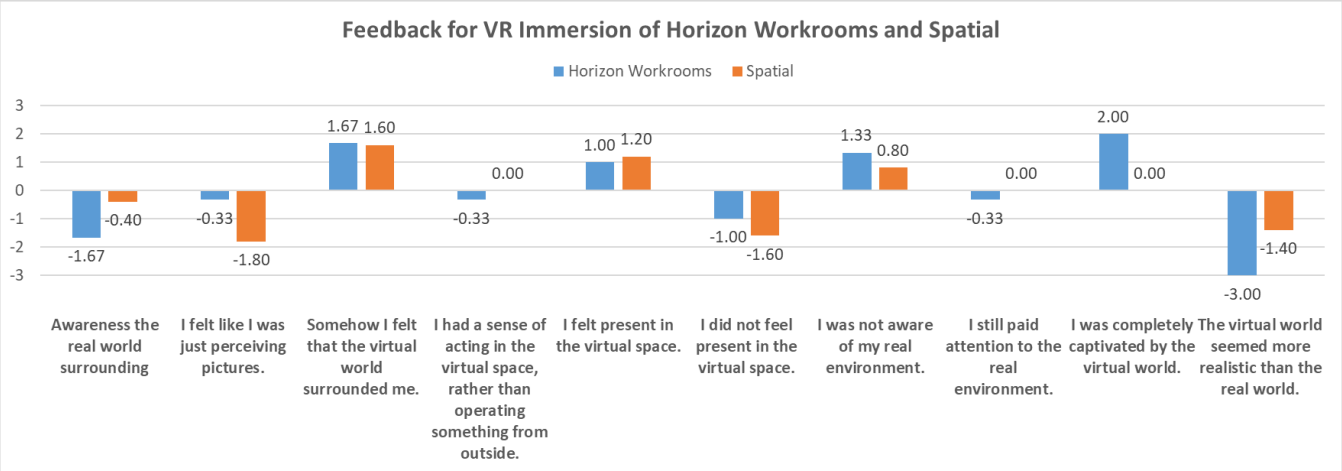

Figure 6. Feedback for VR Immersion of Horizon Workroom (n=5) and Spatial (n=3).

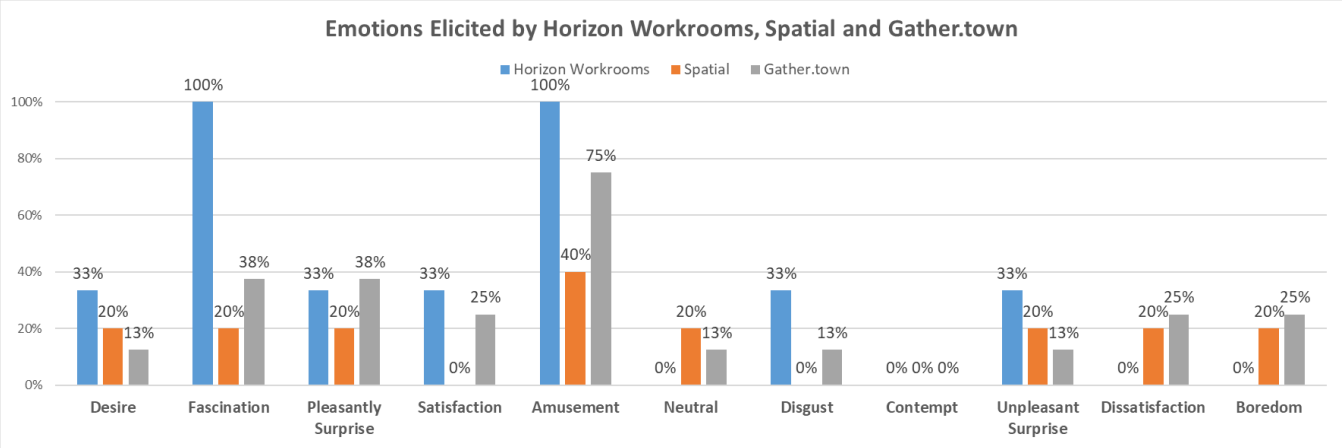

Figure 7. Emotions Elicited by Horizon Workrooms (n=5), Spatial (n=3), and Gather.town (n=8).

ghtly agree (1) and quite agree (2) that the virtual world somehow surrounded them. Participants felt relatively neutral about whether they had a sense of acting within the virtual space rather than operating from an external perspective. Both groups expressed more than slight agreement that they felt present in the virtual space and not present in the real world. Horizon Workrooms appeared to outperform Spatial in immersing individuals within the VR environments, as participants who used Horizon Workrooms exhibited a lesser awareness of the real world and were more fully captivated by the virtual world. Interestingly, although Horizon Workrooms users quite agreed that they were completely captivated, they reported strong disagreement that the virtual world appeared more realistic than the real world, whereas the agreement level in Spatial ranged between slight disagree (1) and quite disagree

In the subsequent analysis, we compared the positive and negative emotions elicited by Horizon Workrooms， Spatial (refer to Figure 7). In addition, we compared the two VR platforms to the non-VR-based platform Gather.town. We add the comparison to Gather.town in this part in order to compare the virtual studio experiences between VR and non-VR based platform at the same time. However, whereas Horizon Workrooms and Spatial were used by the students during the study, the questions regarding Gather.town were retrospective, as the last Gather.town-based event with the corresponding cohort was over 10 to 14 months ago.

The selection of emotions in our questionnaire was based on studies conducted by Desmet et al. [20], [24]. We found that Horizon Workrooms elicited all positive emotions that we asked as well as Gather.town while Spatial only elicited three of them (Desire, Pleasantly Surprise and Amusement). In relation to these three emotions, it is evident that a greater proportion of participants in Horizon Workrooms reported experiencing them compared to the proportion of participants in Spatial. It is noticeable that all participants who used Horizon Workrooms reported feeling a sense of Amusement compared to 75% for Gather.town and only 40% for Spatial. While using Horizon Workrooms, participants encountered two types of negative emotions (Disgust and Unpleasant Pleasure). On the other hand, the use of Spatial also triggered three types of negative emotions (Unpleasant Surprise, Dissatisfaction, and Boredom). The non-VR based platform Gather.town, elicited four types of negative emotions (Disgust, Unpleasant Surprise, Dissatisfaction and Boredom). The summed percentages of the negative emotions reveal that Gather.town received the most negative rating with 76%, then was followed by Horizon Workrooms 66%, and finally Spatial 60%.

Lastly, we compared the participants' feedback regarding the potential future uses of the two VR-based platforms (refer to Figure 8) and Gather.town. Participants in both workshops expressed a level of fatigue beyond very strong (2). However, the fatigue experienced in Gather.town was only between the levels of slightly strong and neutral which is expected for a 2D game-like interface. Regarding Horizon Workrooms, participants demonstrated a mild inclination to use it for their own projects and expressed a willingness to potentially purchase or subscribe to it in the future, slightly surpassing the neutral point. In contrast, participants who experienced Spatial reported a slight reluctance to use it for their own projects and expressed a mild hesitancy towards purchasing or subscribing to it.

P3 expressed the belief that VR-based platforms are better suited for co-working purposes, stating, "Co-working boosts productivity in many ways. Having peers sitting next to you made me feel much better than working on Miro. I however strongly disagree that it would be good for individual work, as screens are much superior to that. For example. I would not wish to read an essay on VR. And I don't want to write anything in VR". P8 highlighted the shortcomings of Spatial, stating, "I want the Spatial platform to take advantage of the ability to draw something in a stereoscopic environment. And it should have enough content. In this three-dimensional environment, it is expected that users will be able to make a map of their thoughts and make plans using three-dimensional tools rather than drawings in the form of a maze board. In addition, the most important thing during a meeting in a three-dimensional space is that you can expect each other's reactions." Regarding Gather.town, participants expressed an even stronger unwillingness to use it for their own projects or to purchase or subscribe to it compared to Spatial.

In terms of future educational use, participants from both workshops believed that the platform they used was suitable for virtual studios and workshops. However, participants who used Horizon Workrooms only slightly agreed that it could be used for lectures or tutorials, whereas those who used Spatial tended to slightly disagree with these two purposes. Participants' responses in open-ended questions provided insights into the reasons behind these perspectives. P4 stated: "I still think usability is an issue even though it is quite good already. It is all the little things like sometimes can't select the object I want, or the menu buttons do not work that makes is a bit frustrating to use. Other than that, yes of course this will be useful for remote work". P6 claimed: "Overall, it was a great experience to ideate using the VR environment. I think it is especially useful when it comes to team ideation, because there is a more variety of ways of communication using 3D environment. The only downside for me using this device is that I was very tired after using it, even thought it was just 30 min of usage." In contrast, participants demonstrated a tendency to disagree with the future use of the non-VR platform Gather.town for all four teaching purposes.

Discussion

The findings of our study provide valuable insights into the design implications for future virtual studios in design education. In this section, we will discuss how different elements of a VR-based platform influence teaching and learning in a master's Design Engineering programme. The concept of "Immersive Engineering Design" was previously introduced [13], highlighting how immersive technologies impacted the field of Design Engineering. However, in this study, we further explored the immersion as a crucial element influencing Design Engineering students' experiences in VR-based platforms.

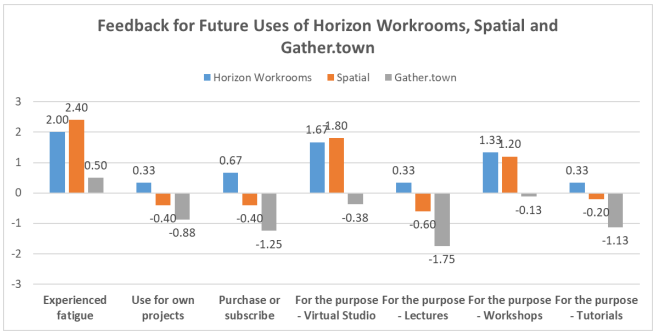

Figure 8. Feedback for future uses of Horizon Workrooms (n=5), Spatial (n=3), and Gather.town (n=8).

Our study showed that Horizon Workrooms surpassed Spatial in terms of immersion. Moreover, it seems that Horizon Workrooms enabled students to generate ideas of higher quality, novelty, and variety, while eliciting more positive emotions. Overall, Horizon Workrooms delivered a superior user experience compared to Spatial. Building upon the observations made by Jin et al. [12] regarding the advantages of VR in delivering visual and spatial knowledge and supporting embodied learning, a VR-based design studio should empower students to create and communicate their ideas in a fully immersive manner, overcoming the limitations of non-VR virtual platforms. Based on our study's findings, it can be inferred that VR platforms with a higher level of immersion are likely to facilitate ideation activities for design students.

While VR-based studios can be effective teaching tools during situations like the COVID-19 pandemic, they cannot entirely replace physical studios and non-VR virtual platforms for all purposes. Our results indicated that students were hesitant to use VR-based platforms for lectures and tutorials due to the challenges associated with operating VR devices and the occurrence of motion sickness. In agreement with Paimani and Kamalipour [25], design educators need to consider equity and diversity when designing virtual studios. Not all students may have access to the necessary technologies to fully participate. For instance, in our workshop, participants who used VR headsets for the first time, faced more challenges compared to those with prior experience. Virtual studios can be effective in special circumstances where physical studios are inaccessible and can serve as a supplementary teaching tool in the post-pandemic period, as argued by Ceylan et al. [9], especially in specific sessions such as ideation, as we discovered. However, as design educators, we must learn from Ahmad's perspective [26], and acknowledge that despite advancements in virtual teaching technology, it may not significantly impact the level of teaching and learning in design education.

As previously mentioned, this pilot study has several limitations that prevent the generalisation of the findings:

Firstly, the number of attendees was relatively small, with three participants in the Horizon Workrooms workshop, and five participants for the Spatial workshop. However, the overall number of participants represents around 10% of the cohort. Secondly, the task was limited to an ideation exercise, which –is usually only the initial phase of a design engineering process. Especially in the later design stages, when spatial elements are to be engineered in the virtual environment, the full potential of a virtual environment might become apparent.

Furthermore, different attendees participated in each workshop, making it challenging to directly compare the two

platforms based on the same individuals' feedback. Additionally, there was a gap of approximately four months between the two workshops. It was discussed already that the perception of virtual studio-related environment was initially very positive during the COVID-19 pandemic, but after coming back to in-person teaching, students' interest in virtual solutions quickly diminished.

Moreover, while the VR workshops were evaluated immediately after the events, the last Gather.town event at the time of the VR workshop occurred more than 10 months ago and in this way, only retrospective answers were possible. Furthermore, in our previous study using Gather.town – with an appropriate number of participants – the platform received highly positive evaluations during the ongoing COVID-19 pandemic, when these platforms had positive impact on the wellbeing of students [14]. However, during the time of the evaluation, students expressed enthusiasm for returning to in-person teaching and were reluctant to use virtual environments.

Conclusion

In this paper, we conducted an exploration of two VR-based platforms: Horizon Workrooms and Spatial.

Overall, the study showed that both platforms received mixed feedback. The overall ratings in Figure 4 show that students were not entirely convinced that these approaches would be significantly beneficial for their daily work. As a direct consequence, we in the first place did not further explore the opportunity to use these platforms in daily teaching context.

This situation starkly contrasts with the initial studies conducted with the Gather.town platform in our previous publication [14]. In those early tests, the results were highly successful, which motivated us to start a number of iterations and further developments of the virtual studio environment in Gather.town. However, it is important to note that the key difference during that time period was the ongoing COVID-19 pandemic which left no option for in-person interaction.

Through our tests and evaluations, Horizon Workrooms demonstrated superior performance compared to Spatial. The results obtained from the questionnaire surveys and our evaluation underscored the critical role of immersion in the effectiveness of VR-based virtual studio environments. Furthermore, we observed that the choice of immersive communication platforms should be carefully considered, considering the specific activity and project theme being delivered. Design educators need to make informed decisions in selecting appropriate platforms for constructing virtual studios based on their intended purposes.

However, it is important to acknowledge that this study has limitations in terms of its representativeness, primarily due to the small number of participants involved in the research.

This paper addresses the unfulfilled need for virtual communication platforms that facilitate creativity among master's students in the field of Design Engineering. We anticipate that VR-based platforms may continue to thrive in the post-pandemic era, as online delivery of conferences and teaching remains an integral part of the research and educational landscape. Design educators can also utilise VR-based platforms as a supplementary tool when students resume their physical studio activities.

In this study, our focus was solely on testing ideation activities within the VR-based platform. However, it is important to acknowledge that there are other potential applications that warrant investigation, such as presenting works and simulating interactions between users and products. Future studies should aim to explore and evaluate these additional applications to provide a more comprehensive understanding of the capabilities and limitations of VR-based platforms in various educational contexts in design engineering. Platforms like Gravity Sketch which are optimized for a very specific design task have good opportunities to be widely adapted in a specific context [27] A number of other related platforms were discussed in a previous publication [13].

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