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Work-in-Progress—Student's Co-creation of Collaborative Learning Spaces on the Metaverse

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Abstract. This work-in-progress paper reports on a project aimed at empowering learners through the co-creation of virtual collaborative learning spaces within the metaverse, an innovative approach where learners and educators collaborate to design immersive virtual environments tailored to their unique needs and goals. Six students, at various levels of their undergraduate engineering studies, are tasked with designing and developing virtual spaces to support student teams in collaborating on their creative engineering group projects. Through the different design propositions and peer feedback received, we gain insights into how students perceive and conceptualise teamwork dynamics in virtual collaborative spaces. The design propositions also illustrate diverse approaches to spatial organisation within the virtual environment.

Keywords: Metaverse, Co-creation, Virtual Spaces, Collaboration.

1 Introduction

While there is currently no consensus on a definitive definition of the metaverse [1], we will define it here as 'a virtual environment where individuals, represented by avatars, can interact, create, and explore in a shared digital space'. Communities of users are already socialising, working, playing games, attending events, conducting business, and learning in the metaverse. Research on the metaverse in education (Edu-Metaverse) has developed into an active research field [2, 3]. This paper reports on a project for empowering learners through the co-creation of virtual collaborative learning spaces within the metaverse.

The need for collaboration across distributed locations has dramatically increased, a trend accelerated by the COVID-19 pandemic and the emergence of new digital tools. In the metaverse, students can come together in shared virtual spaces to collaborate on projects, solve problems, and exchange ideas in real-time [4]. Faculties are increasingly harnessing the metaverse to create dynamic virtual learning environments and experiences that foster teamwork and creativity (e.g., [5, 6]). Mozilla Hubs [7] has emerged as a popular platform for creating virtual classrooms and collaborative learning spaces in the metaverse (e.g., [8–10]).

Co-creation is a process where students and staff work together as partners to design, develop, and implement learning experiences, environments, curricula, and policies [11]. The co-creation of collaborative learning spaces in the metaverse represents an innovative approach, where learners and educators collaborate to design immersive virtual environments tailored to their unique needs and goals. Students contribute their insights and perspectives, helping to shape the layout, features, functions, and content of these spaces, while staff provide guidance and expertise to ensure alignment with educational objectives and best practices. While some firms have started to leverage the metaverse to enable consumers to co-create new product ideas, there are few examples of co-creation of learning spaces in the Edu-Metaverse. One such example is reported in [12] where five students created their own VR rooms (in Mozilla Hubs) to teach each other about one aspect of their own academic field.

In the remainder of this paper, we introduce a co-creation project, which kicked off in January 2024 with the development of small-scale virtual learning space pilots, customised for one undergraduate course. These initial pilots will be used and tested by students until May 2024. Upon validation, the methodology will be scaled to include other courses within the Science and Engineering Faculty, and eventually be extended University-wide.

2 Method

Within the third-year undergraduate course titled 'Interactive Media Design and Production' students collaborate in teams of five to plan, design, and create small interactive multimedia web applications. They are instructed to brainstorm ideas, develop wireframe designs, and collaboratively produce code and various multimedia resources within their teams, as well as maintain version control throughout the development process.

The student co-creation team was assigned the task of designing and developing virtual learning spaces in the metaverse to support the collaborative teamwork of 'Interactive Media Design and Production' students. We have assembled a team of six students, consisting of three students currently enrolled in the 'Interactive Media Design and Production' course, two second-year students who will join the course in the Spring semester of 2025, and a fourth-year student from another major. While the fourth-year student's involvement is part of her graduation dissertation, all other students have volunteered to participate in this extracurricular activity.

We chose Mozilla Hubs [9] as our platform for creating shared and inclusive learning environments due to its versatility. Mozilla Hubs is compatible with any device, including desktop computers, laptops, tablets, and mobile devices. It supports all VR hardware and can also be used by users without VR headsets, ensuring accessibility for all students. Additionally, it is accessible through any browser, eliminating the need for additional software downloads. It gives users complete control over the appearance of their virtual space and who can join and participate. The Professional Plan in Mozilla Hubs includes a 50-guest capacity, 25GB asset storage, the ability to connect a custom domain, add custom code, and provides always-on functionality.

3 Results

The co-creation students divided themselves into three teams of two and have developed three different design propositions for virtual learning spaces. At this stage of the project, they were instructed not to let the limitations of the implementation tools constrain their designs. Additionally, illustrated descriptions of the designs were distributed to the 'Interactive Media Design and Production' course's students via the course's mailing list, using an online form to collect feedback and suggestions. Ten students responded, and their comments are shown below for each design proposition.

3.1 Proposition one: "Workflow and Team Management"

The primary purpose of this virtual workspace is to support team workflow and management. The workflow is structured into three phases (see Fig. 1.A). The lock icons in Fig. 1.A denote access control. Permission to share individual contributions must be granted by the group leader, who is responsible for quality control, ensuring that all tasks are completed to a satisfactory standard. The team operates hierarchically, with a leader overseeing task assignment to other members. Phases 1 and 3 are the primary collaborative stages.

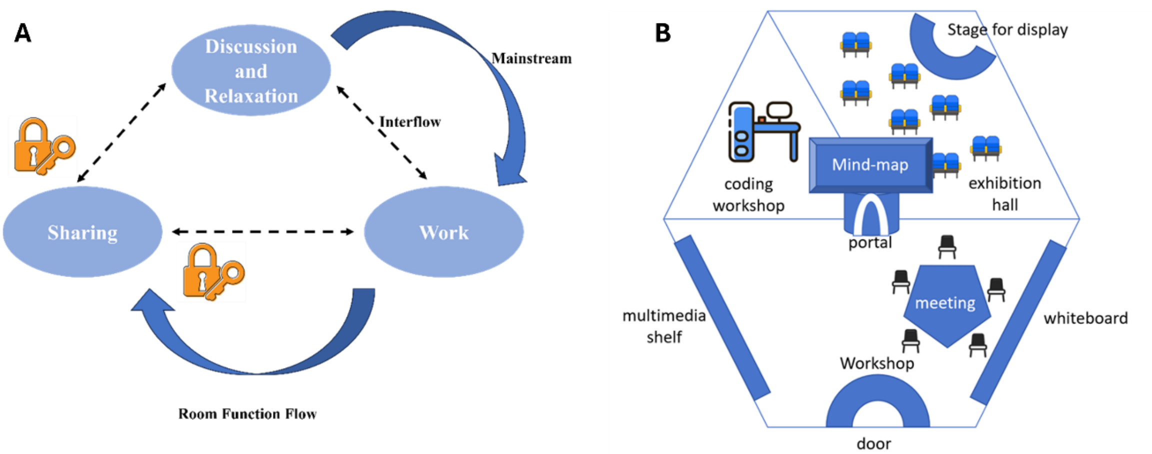

Fig. 1. Workflow in 3 phases (A): "Discussion" (e.g., brainstorming), "Work" (e.g., Implementation) and "Sharing" (i.e., Integration and Presentation); and virtual space overview with three separated rooms (B): meeting space (for the "Discussion" phase), workshop (for the "Work" phase), and exhibition hall (for the "Sharing/Presentation" phase).

The virtual space is divided into three functional areas or rooms, each corresponding to a phase of the workflow (see Fig. 1.B). At the center of the space is a 'portal' facilitating movement between rooms, provided access has been granted. A central display, labeled 'Mind-map,' remains visible from every room, serving as a constant reminder of the workflow and workplan.

The larger room, labeled 'Workshop,' acts as the main common area for group members to convene and discuss ideas (phase 1), as well as engage in team-building activities. It features a conference table for group brainstorming sessions, mind-mapping, and wireframe design. Additionally, a whiteboard is available for note-taking and summarising thoughts, while the multimedia shelf provides storage and sharing capabilities for multimedia assets.

The 'coding workshop' room is utilised during the second phase of the coursework. Lastly, the 'exhibition hall' space is dedicated to the third phase of the workflow, where individual productions are integrated into the final coursework output. Fig. 2 showcases impressions of the virtual space created using Spoke by Mozilla.

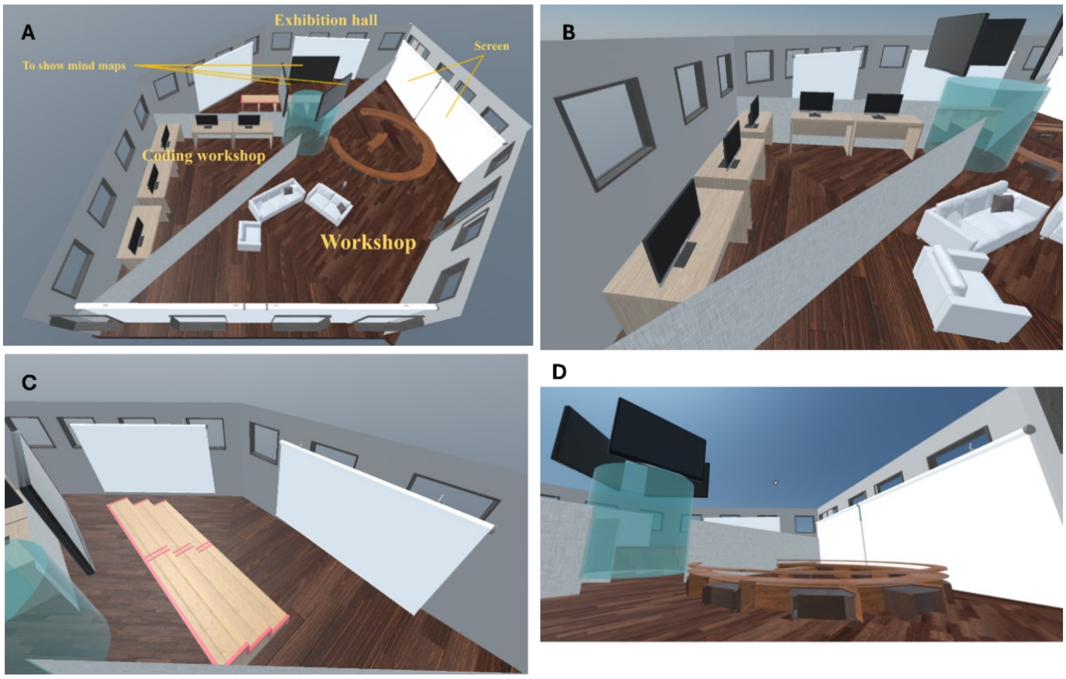

Fig. 2. Virtual space bird-view (A); coding workshop (B); exhibition hall (C); main common area (D). The entire space is surrounded by windows.

The comments received about this design proposition and the designers' responses are shown in Table 1. Some comments praise the hierarchical view of teamwork, while others express concerns about the lack of flexibility.

Table 1. Peers' comments and designers' responses for proposition one.

Comments from peers	Responses from the designers
Team management: Effective team management is crucial and seems well supported by your design, although it does place significant responsibilities on the team leader	The level of management can vary from team to team, e.g., the team leader could grant all permissions by default, when quality control is a shared responsibility.
Collaborative coding: Are you considering coding as an individual activity? What about collaborative coding?	Coding can indeed be collaborative. We could incorporate a large screen in the coding workshop area, allowing all five computer displays to be projected simultaneously, enabling students to code together and learn from one another
Workflow: I believe that more flexibility in the workflow and space usage would be beneficial.	We believe that segmenting the space and implementing access control measures can enhance teamwork efficiency in the metaverse.
Navigation: How about adding rolling office chairs to facilitate movement in the space?	This is an interesting suggestion. It could improve the usability and accessibility of our virtual space.
Visitors: How can we invite visitors, such as our lecturer and teaching assistants?	The sofa in the workshop area can be used as a welcoming space for visitors. Additionally, the exhibition hall can be used to showcase work progress, and the multimedia shelf can display assets for visitors.

3.2 Proposition two: "Collaborative Coding"

In this second design proposition, the functional requirements are organised as follows: (1) Design and programming; (2) Project management, version control and other data storage functions; (3) Multimedia assets production and presentation; (4) Group meetings and project planning. Project management is a shared responsibility among all team members.

These functional requirements are translated into a virtual space divided into two areas: a workspace and a discussion area (see Fig. 3). The workspace has three tables, each accommodating two team members, and equipped with a computer and a tablet. The layout and furniture are designed to facilitate work in pairs, particularly for coding and other production activities. Collaboration is emphasised and well supported.

The discussion area has a large table with embedded media production tools for brainstorming and media production. Each of the five walls surrounding the space is equipped with a display screen to project work progress and results, making at least one screen easily visible from anywhere in the shared space. Floating above the center of the room is an object designed to store project assets and facilitate easy retrieval (see Fig. 4).

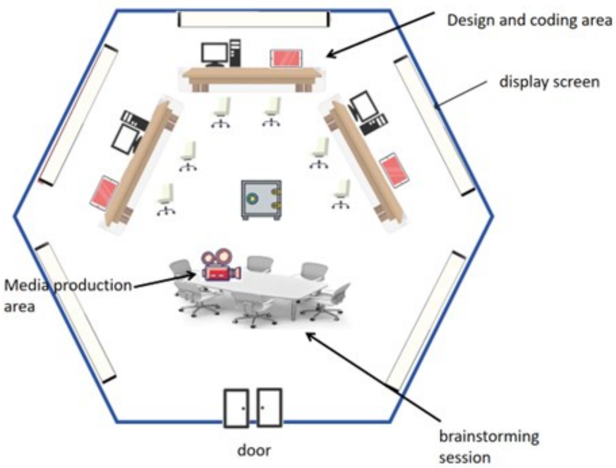

Fig. 3. Virtual space bird-view: each desk can accommodate two students collaborating on production tasks, such as coding.

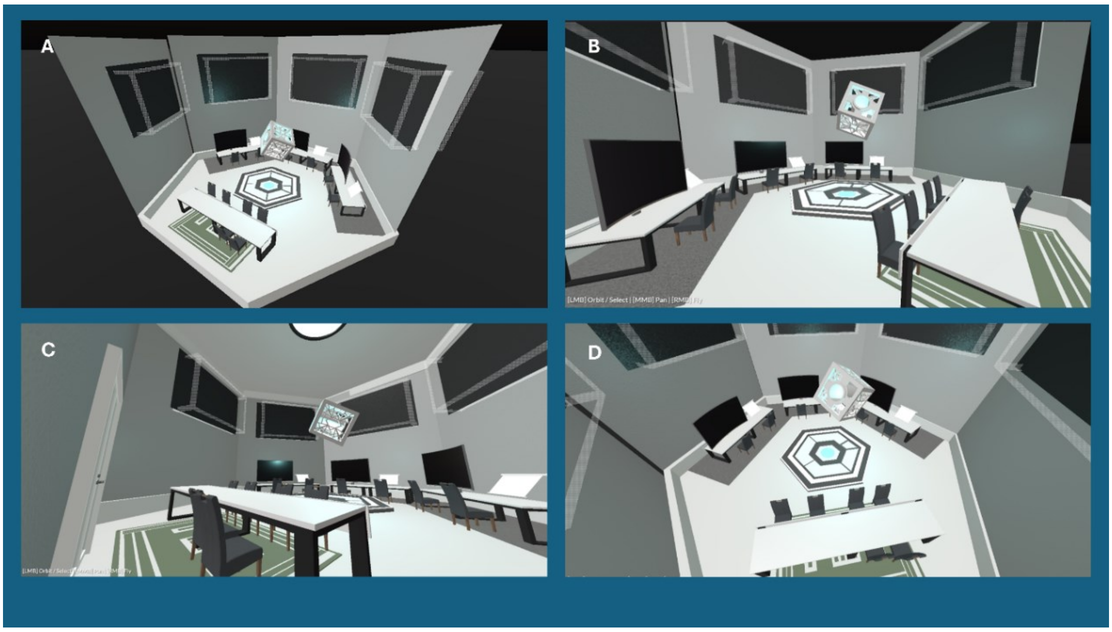

Fig. 4. Virtual space bird-view (A, D); eye-level view (B, C). The entire space is surrounded by screen displays, the two functional areas are indicated by different colours and patterns on the floor.

The comments received about this design proposition and the designers' responses are shown in Table 2. Some comments praise the layout, while others express concerns about the overall lack of space.

Table 2. Peers' comments and designers' responses for proposition two.

Comments from peers	Responses from the designers
Simultaneous viewing: Can all five wall-mounted displays be viewed simultaneously for easy comparison of different productions?	Unfortunately, they cannot be easily viewed simultaneously. To address this, we could consolidate all screens onto one or two walls, eliminating the need to change viewpoints.
Individual vs Collaborative: It is not clear which areas are designated for individual versus collaborative work.	The computers and tablets on the desks serve both individual and collaborative purposes, primarily between pairs of students. The large table with media production tools is specifically for collaborative work, while the screens are intended for sharing progress and may also be utilised during group discussions.
Look: While the overall rendering of the space is sleek and intuitive, the enclosed environment with gray walls may feel somewhat oppressive.	To enhance the ambiance, we could consider changing the wall color to light green, creating a livelier and brighter atmosphere.
Use of space: The room appears a bit crowded.	We can consider expanding the size of the room.
Views synchronization: Can views be synchronized across multiple computers to avoid the inconvenience of switching between devices?	This is a good suggestion. We could potentially implement a system where computers share their displays to enhance collaboration efficiency.

3.3 Proposition three: "Looking into the Future"

The third design proposition is forward looking, both in style and with its emphasis on scalability. The room adopts a honeycomb shape, designed to facilitate seamless expansion of workspaces akin to a beehive structure. Functional partitioning is achieved through strategically placed wall-mounted displays, as illustrated in Fig. 5.

The room features a single shared area characterised by a large interactive table surrounded by expansive wall-mounted displays. The interactive table boasts built-in projection surfaces and a range of embedded production tools, empowering each team member to seamlessly switch between their own system and a sharing mode. Additionally, a holographic projection hovers above the center of the table, facilitating real-time 3D asset rendering. This projection also serves as brainstorming aid, allowing students to link thoughts and ideas on the projection cube, culminating in the creation of a team mind-map.

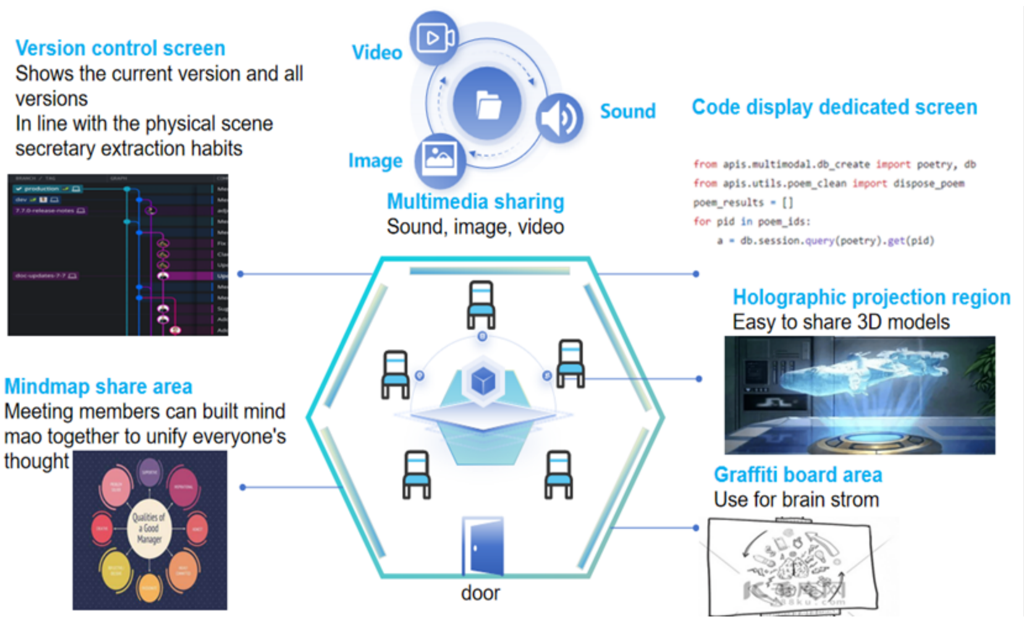

Fig. 5. Virtual space overview: the wall mounted displays are used to support the functional requirements of the teamwork.

Surrounding the room, five walls are outfitted with LED screens to accommodate various functional requirements. Each screen can be configured into one of five modes or functional zones: (1) multimedia zone for asset display and sharing, (2) coding area for collaborative coding sessions, (3) blackboard area for painting and writing, particularly during brainstorming sessions, (4) version control zone for file storage and management, enabling seamless switching between different versions, and (5) mind-map and wireframe design area. The design theme draws inspiration from cyber technology, as depicted in Fig. 6.

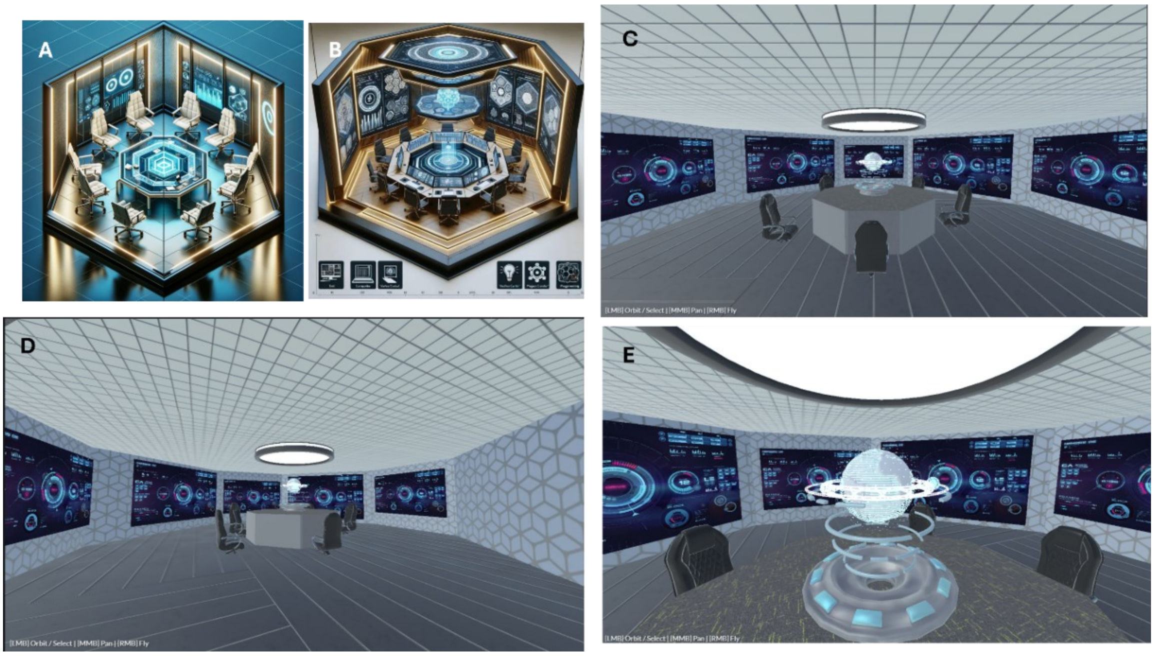

Fig. 6. OPEN AI Dalle renderings of the virtual space (A, B); Spoke renderings (C-E).

The comments received about this design proposition and the designers' responses are shown in Table 3. Some comments praise the atmosphere, while others express concerns about the complexity.

Table 3. Peers' comments and designers' responses for proposition three.

Comments from peers	Responses from the designers
Scalability: You could consider extending scalability of your design to the central table by configuring it into smaller desks or tables.	We can explore remodeling the central table, perhaps adopting a honeycomb or segmented cake-like structure.
Balance: The design feels overwhelming; there should be a balance between high-tech elements and user-friendliness.	We can introduce elements like plants and skylights to soften the atmosphere.
Learnability: The design lacks intuitiveness.	We can address this by incorporating a demo animation showcasing the operation of devices such as the central hologram and the control of wall-mounted display modes.
Look: The walls seem overloaded with functions, leaving no room for decoration or furniture.	Some functions can be relocated to the interactive table, and we can also consider making the central table reconfigurable into smaller desks for added flexibility.
Usability: How can display modes be controlled?	We will implement a control system on the central table along with explanatory materials.

4 Discussion and Future Work

Through the different design propositions and peer feedback received, we gain insights into how students perceive and conceptualise teamwork dynamics in virtual collaborative spaces. Some favour a hierarchical model, where a designated team leader oversees task assignment and quality control (proposition one), while others advocate for a more collaborative approach, emphasising shared responsibility and workflow flexibility (propositions two and three). These differing views highlight the importance of understanding and accommodating diverse preferences and working styles within collaborative environments, enriching our understanding of effective teamwork practices in educational settings.

The three design propositions also illustrate diverse approaches to spatial organisation within the virtual environment. The first design proposition adopts a model of closed rooms with access control, providing distinct areas for different phases of the workflow and creating distinct zones within the workspace. This compartmentalised approach offers clarity and structure, allowing users to focus on specific tasks within designated areas. The second design proposition eliminates "physical partitions" but demarcates functional areas with floor markings, still requiring users to navigate the space for specific activities. In contrast, the third design prioritises the integration of versatile tools and display modes within a single, multipurpose open space. By leveraging interactive tables, wall-mounted displays, and flexible projection surfaces, this design enables users to seamlessly transition between different activities without the need for physical navigation. Overall, these varying spatial configurations reflect different philosophies regarding the organisation of collaborative workspace organisation, highlighting the importance of balancing dedicated spaces with flexible tools to create effective virtual learning environments.

Furthermore, the three design propositions exhibit distinct stylistic approaches, ranging from conventional to futuristic aesthetics. While the first and second designs embrace conventional layouts characterised by traditional furniture arrangements, prioritising functionality and familiarity, the third design adopts a bold and innovative approach, featuring unconventional shapes and cutting-edge technology. The inclusion of elements like holographic projections conveys a sense of innovation and forward-thinking, as well as an understanding of the possibilities offered by VR compared to what is possible in the physical world.

Moving forward, our future work will focus on implementing and deploying the collaborative spaces in Mozilla Hubs. From April to May 2024, student teams will actively engage with these virtual environments as integral components of their coursework. Throughout this period, we will collect learning traces, conduct observations, and administer questionnaires and interviews to probe students' experiences. Our specific objective is to assess the level of collaboration facilitated by these virtual spaces and evaluate the quality of coursework outputs produced by teams utilising the metaverse, in comparison to those who do not. By conducting rigorous comparative analyses, we seek to gain insights into the effectiveness of leveraging co-created virtual collaborative environments to enhance teamwork and improve learning outcomes in higher education settings.

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