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UTILISING MR TECHNOLOGIES FOR ESSENTIAL PROJECT-BASED LEARNING IN DESIGN EDUCATION

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ABSTRACT
The increasing use of digital platforms is bridging the distance between students and their instructors by augmenting student-instructor interactions. Yet when it comes to complex project-based and open-ended education content, the development of these platforms is far from complete. Especially seen in project-based learning environment, where multiple ways to teach, learn, and practice are required, real-world interactions are integral for encouraging exploration and implementation. Though recent works have shown the possibility of immersive technologies like AR/VR for teaching and hands-on experience, they are either strictly restricted to visualisation or require sophisticated equipment to be implemented as educational content. Here, a simplified and structured approach that can be directly used in the regular education environment, both in-house and remote, is needed. By taking a bottom-up approach through realistic use-case, this work demonstrates how to investigate and utilise/combine mixed-reality technologies for use in a PBL environment, targeting the values provided for education in general. Through a use case targeting design education activity in architecture, this work conducts a technological survey, evaluating available platforms/products and establishing PBL requirements, followed by mapping them to surveyed tech. The result of this work is a valuable MR Tech-PBL-education map, which can be used as a reference for designing interactive educational material.

Keywords: Future education technology, project-based learning, mixed reality, design education

1 INTRODUCTION
Recent technological advances with the unprecedented pandemic situation have catapulted the initiative of digitally transforming the education environment. Resultingly several remote digital platforms have emerged providing MOOC-like content, flexible in delivery to students and instructors communicating through web+video communication tools. Though such platforms have worked effectively for lecture-based education content, it has been hard to adapt them to *problem/project-based learning* (PBL) like content. For example, design education requires an experience-based approach regularly and requires a higher level of immersion in the education contents, making it difficult to adapt to current digital platforms for education. With the improvements and accessibility to immersive digital technology like human-computer interaction and mixed reality (MR), researchers have shown the possibility and effectiveness to improve the design [1], concept prototyping [2], evaluating [3], engineering design steps. Given the high immersion they provide, many of such works are specialised to achieve specific tasks like capturing the voice of customers [4] or design verifications through virtual prototyping [5] and require some level of expertise to create an immersive design platform. For example, though several use-cases of MR have been demonstrated for teaching and experiencing, they are either strictly restricted to visualisation or require sophisticated equipment for interactive learning. Also, a structured approach that can be directly used for design education for both in-house and remote environments require much work. In this work, we tried a bottom-up methodology to incorporate interactive and immersive tech like MR technologies within our design educational practices. By taking a bottom-up approach and utilising a real use-case, we demonstrate how to include MR in a project-based learning (PBL) environment to provide value for instructors, students, and education in general. In this study, we target PBL in design education in field of architecture.

2 BACKGROUNDS

2.1 Project-based learning in design education, requirements and reflections

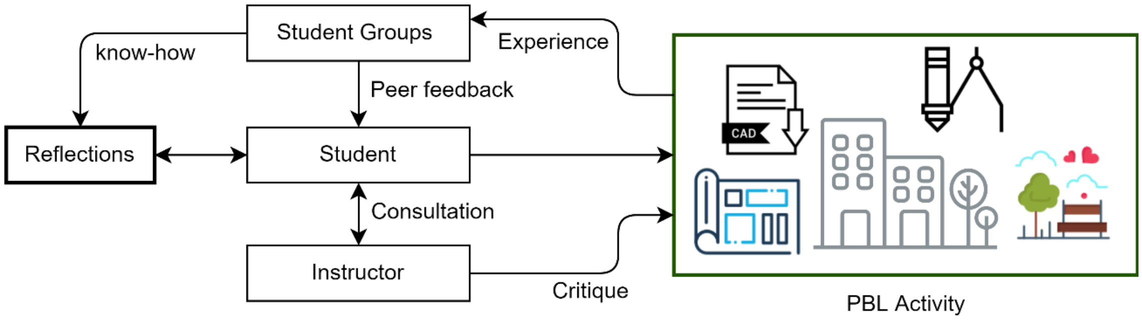

Figure 1. A generic PBL schematic

PBL is essential for students to create and learn independently, requiring students to learn a range of cognitive, thinking and technical skills to find and prototype their solutions. At the graduate level, like engineering or architecture, PBL is an essential part of the curriculum where students are expected to learn the concepts while creating something in real life. Students usually work in groups bringing their own experiences, abilities, learning styles and perspectives to the project [6]. A simplistic view of a PBL activity is represented through Figure 1, showing different interactions among students and instructors. In PBL activity, students continuously reflect on their experience constructing new knowledge. As a result, the PBL design activity/projects often resemble a complex system in which the participants create subjective reflections and values that are then interpreted, explored and standardised by the stakeholders involved in the activity [7], rather than simply measuring the objective outcomes of the design activity.

2.2 Immersive tech-based solutions in education and practice

The use of technology in design education or practice can be categorised primarily into two categories: design platforms or design tools. Design platforms, often seen in professional practice, can facilitate the complete design process from idea generation to final product and implement education frameworks like CDIO (conceive, design, iterate and operate) approach [8]. Design tools generally achieve a specific task and are relatively common for design visualisation, validation and concept prototyping [9, 10]. The application of such tools can be easily seen in the field of product design [11], spatial co-design [12], manufacturing [13], or STEAM education [14], to name a few. Some work on implementation frameworks like flowcharts has been proposed that (inexperienced) instructors can quickly develop AR experiences for higher education content [15]. In recent work, researchers showed the implementation [16] of an education system that uses Artificial Intelligence (AI) instead of instructors' direct instruction, indicating the digitalisation of educational practices in PBL activity.

2.3 Challenges

Students and instructors work in a studio in a traditional setting and often use a hands-on approach through rapid prototyping tools. In a studio environment, there is a possibility of working and getting feedback parallel to working with other students. When this setting is translated to the current online location, students and instructors work together through file-sharing or collaborating through a 3D environment and interact through video and audio. Concerning this online transition, a few challenges were observed considering the expected availability of such settings as non-verbal communication issues, variable instruction quality, varied motivation or stimuli for participants, difficulty to build team relations over hands-on activity, degree of collaboration etc. In conclusion, the contents and methods of the traditional approach cannot be transferred as it is to the digital space. The following sections present the process we followed to determine the suitability of MR tech for design education PBL in specific and discuss investigation results.

3 METHODOLOGIES FOLLOWED

To map out a reference framework to help educators create immersive and interactive PBL environments and education content, existing MR technologies and design education needs were surveyed. We focused on technologies and their feature that may suit specific requirements of a PBL concerning student and instructor activities. Resultingly, a relative mapping method focusing on `MR tech features` and `Target use-case criteria for PBL activity` was created, and then used as the evaluation criteria to judge the suitability of the surveyed tech with our project goals. Followed steps:

Part I: Survey MR tech in practice

- Surveyed the use of MR for education in various fields
- Highlighted common traits among them and identify their core contribution to education
- Defined a simple PBL activity performed in an architecture design course
- Extracted the MR features that would be required for PBL implementation

Part II: Mapping steps

- Established a generic student use case concerning course activity (architecture)
- Evaluated a list of available tools for relevance for use in PBL
- Mapped the extracted MR features to the tools based on required

4 ACTIVITY AND OBSERVATIONS

4.1 MR Survey Step Observations

First, a technological survey targeting immersion and engagement was conducted to understand and collect information on existing MR systems. Based on the surveyed tech, the following categories were observed: (1) headset-based solutions, (2) real-time simulation, (3) collaborative activity, (4) enhanced campus/laboratory experiences, (5) design Implementations like architectural design, and (6) physiological data-based user evaluations. A survey sample is shown in Table 1, showing special features of the surveyed tech and the categories they fall in.

Table 1. (Sample) Summary of surveyed MR tech in practice

Surveyed tech	Special features	Target
Spatial visualisation	Remote users can brainstorm and share content as if they were in the same room	Headset based solution, Collaborative activity
VSI HoloMedicine®	Streams lectures, procedures, and live surgeries directly into students' fields of vision	Headset, Real-time simulation
nextech AR - RALE	Creating AR experiences with live demos helps manage courses, Q&A, and Live sessions	Laboratory Experiences
SketchUp Viewer	Experience projects at a full 1:1 scale; teams can virtually inhabit a design	PBL, Implementation: Architectural Design
Verto Studio 3D	Able to convert about any format of the 3D model into a hologram	Headset, Implementation: Architectural Design
AR Spaceships by ARWAY	Captures unique feature points of the building by the camera, creates point cloud for later designs	Real-time 3D Measurement
Cardiolens	Potential for collecting feedback based on users' physiological behaviours	User Testing, behavioural data

4.2 MR contribution to PBL-educational activity among the surveyed solutions

We broadly identified the following attributes which make MR suitable for use in respective educational environments the capabilities and possibilities of MR technology in the field of education:

- Creating a more immersive experience - delivering immersive and interactive digital content)
- Enabling field observations/Exploratory expeditions: "virtual travel", untethered by the place
- Transforming to hands-on learning
- Promoting better collaborations and teamwork, and problem-solving - soft skills development
- Improving PBL activity thorough support for meetings, presentation, course prototypes (teaching), problem prototypes (student activity)
- Enhancing the knowledge understanding
- Recreation or simulation of past experiences for new learners
- Individualised learning and facilitation of self-directed learning - Course Management Platform

4.3 Selecting MR features required for facilitating the PBL activity

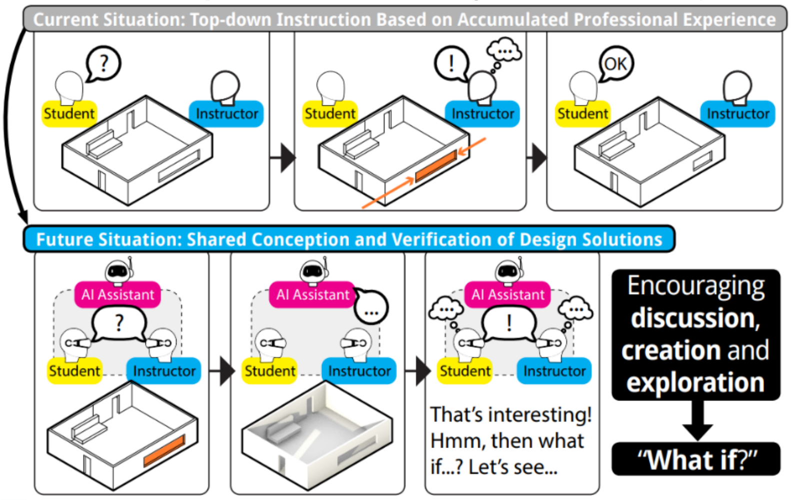

Figure 2. Explorative PBL project scenario: (top) traditional and (bottom) using digital tech

We considered a simple PBL activity for listing the *required features* in the solution system. It includes discussions and hands-on activities by the student, where students can work together, and the instructor can provide constructive feedback. A sample PBL scenario, where students design room considering furniture arrangement, lighting, position and size of windows and resulting shadows, is represented in Figure 2 as a traditional setup and future setup. Here traditional setup activity represents student and instructor simply discussing over a model (physical/digital). The Future setup activity, MR based setup, represents student and instructor individually supported through quick visualisations and smart checks. Based on the individual evaluation of the activities and support required for the mentioned PBL use case, we outlined the MR tech features that can be used to create an explorative educational environment that promotes discussion, mentioned in Table 2.

Table 2. Identified required-MR functionality suitable to PBL activity in Figure 2

	Definitions/explanations	**Req. features**
1	The ability to engage as a team remotely	remote collaboration
2	View and share models with others like HoloLens user/ mobile devices	visual sharing
3	Making notes or symbols by a gesture using 3D objects	tracking/ 3D marker
4	Multiple people interaction on the design, on-premises/remotely	multi-device support
5	Available for conference/meeting recording	Capture activity
6	Instantly turn speech into context for remote/ digital content	speech recognition
7	Search for information and visualise them in the surrounding space	Info. collection
8	Real-time speech recognition and translation	live translation
9	Change the conference environment or outside scenery	VR environment
10	Place holographic 3d model in any space at any angle, any scale	holographic mobility
11	Working with design in layers for easier handling	manipulate layers
12	Combine real space with a holographic model in 1x1 mode and experience the model from an inside viewpoint	immersive mode
13	The ability to duplicate, subdivide, smooth, extrude, rotate, scale, weld, apply textures in the 3D model by using gesture	3D modelling
14	View/interact with 3D tools like Grasshopper parameters in real-time	real-time edits
15	Simulate shadows and shadings resulting due to light simulations in the design environment that allows informed user decision and design	Scenario simulation
16	Ability to review structural MEP that can be referenced with PBL design activity assets, overlaying them onto the real world	3D model review

4.4 Mapping required PBL-related features to survey MR tech

Targeting student activity in a typical PBL exercise, we tried to identify the ability of surveyed MR tech (or lack of) to support the future PBL scenario from Figure 2. Here, the higher the support a given MR tech provides, the better it is for PBL in design education. A sample MR tech evaluation is shown in Figure 3 where the presence of required feature is checked if they are present in the surveyed MR tech. A summary of user scenario-based MR solutions evaluation is shown in Table 3, in which the presence is indicated by the feature number mentioned in the table taken from Table 2. A relative normalised value (RV) is calculated considering all the required features mentioned in Table 2 as the complete set for the PBL scenario, where all features are considered equally important. RV is shown as a percentage, indicating relative significance or Value for the PBL scenario.

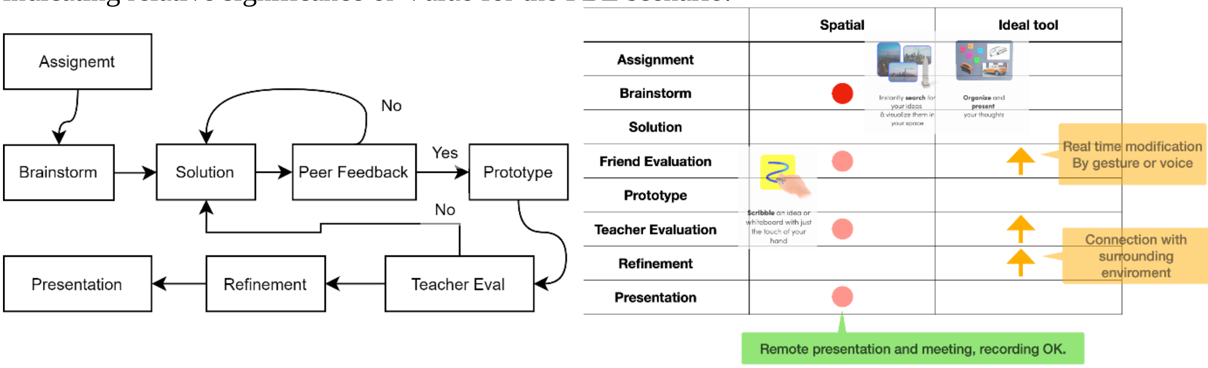

Figure 3. (left) typical student activity; (right) sample MR tech evaluation

Table 3. Potential for use in mentioned PBL Scenario: Sample set of surveyed MR tech

Surveyed tech	**Sketch up Viewer**	**Mr Builder**	**Fologram**	**Verto Studio VR**	**basics-model**	**Microsoft Mesh**
Available features	2,10,11,12	2,10,11,12	2,4,10,11,13,14	10,13	15	1,2,3,4,10
RV (%)	25.00	25.00	37.50	12.50	6.25	31.25
Surveyed tech	**Spatial**	**Whiteroom**	**Trimble XR**	**nextech AR-RALE**	**AltspaceVR**	**VSI Holo Medicine®**
Available features	1,2,3,4,5,7,8,9	1,2,3,4,5	2,16	1,2	1,2	2,10,16
RV (%)	50.00	31.25	12.50	12.50	12.50	18.75

5 DISCUSSIONS

The survey and evaluation activity are in its early phase, and its robustness is expected to increase with the increase in surveyed tech and application fields. With variations in the use-case scenario implementations, the created evaluations and *MR Tech-design Education map* can be directly used to identify the minimum MR tech required based on the features necessary to support a given PBL activity. Referring to this map, two or more MR tech can be combined to realise the whole required features for the target PBL activity. This map allows for customising MR implementations, which can be further improved by considering special requirements that can be different for students, instructors and education in general. The *value for the PBL scenario*, mentioned in Table 3, currently assumes all features have equal significance; here, the required features can be weighted based on the target scenario, where the weights would indicate the importance for students, instructors and education in general. Value for students can include features allowing quick prototyping, stimuli generation and peer discussion; value for the instructor can focus more on activity evaluations focusing more on the path followed by the students. Value for education can be treated as combined value for students and instructors. Still, it may include external factors like the availability of particular MR solutions, the cost of implementing it in a PBL classroom that can have multiple students, and finally, the difficulty of setting up or adapting to a specific PBL activity.

6 CONCLUSIONS

This research aims to create a structured methodology for positioning existing MR technologies within our future interactive educational practices. By taking a bottom-up approach and constructing realistic use-cases, we demonstrate how to include MR in PBL environments to provide value for instructors and their students. The result of this work is a valuable MR tech map, which can be used as a reference for designing interactive educational material towards the boundaries of MOOCs or online classes in PBL. We surveyed existing commercial MR systems and platforms used in practice in the real world. For example, MR tech usage in medical, civil/architectural, or educational activities, to name a few. We then designed generic use-cases representing typical in-person lectures and PBL activities, both instructors' and students' perspectives. By aligning these use-cases with the unique features identified in our survey, we formed a relational map that sheds light on the suitability of each platform/technology for PBL. The resulting map proposes clear insights into the relative importance of each technology for PBL, emphasising its potential value for instructors/students in a given educational use case. Future work would include improving the robustness and ease of use of the created map.

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