



Developing Immersive Experiential Learning Experiences: Assessing Learning Outcomes

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Abstract. This iLEAD contribution evaluates user perceptions of two immersive learning experiences designed as pre-training tools for professional practice in distinct fields of knowledge. The Plating MR application, utilizing mixed reality, was developed to teach plating skills in gastronomy, while the Chain of Custody VR application, using virtual reality, aimed to assess knowledge of forensic digital evidence collection procedures. User perceptions were analyzed regarding engagement, motivation, learning, usability, and cybersickness. Results revealed that both experiences were positively received, with the Chain of Custody VR demonstrating higher consistency in feedback, particularly in realism, user confidence, and minimal cybersickness reports. In contrast, the Plating MR experience faced challenges related to usability and cybersickness, likely due to device limitations, including a restricted field of view and hand tracking issues. These findings align with the Cognitive Affective Model of Immersive Learning (CAMIL), highlighting the importance of presence, agency, and effective design in immersive education. Future studies should include larger participant samples and explore the addition of multiplayer functionalities to enhance collaboration and simulate real-world teamwork dynamics.

Keywords: Experiential Learning, Cognitive Affective Model of Immersive Learning (CAMIL), Extended Reality.

1 Introduction

Providing experiential learning opportunities for higher education students faces several barriers, such as high costs, lack of suitable situational locations, and geographical constraints. These challenges often limit the availability of practices needed for professional skills development. Extended reality (XR) technologies, including virtual (VR) and mixed reality (MR), offer potential solutions to overcome these limitations by providing immersive and interactive environments for experiential learning [1]. Researchers highlight the effectiveness of immersive VR applications in enhancing instructional design and learning outcomes across various educational contexts, reinforcing the role of XR technologies in addressing these barriers [2].

Experiential learning supports the development of practical and technical skills by allowing students to engage with realistic scenarios in a controlled environment before encountering them in the professional world. Immersive virtual reality (IVR) experiences offer benefits as pre-training tools that can enhance students' confidence and preparedness for real-world interactions. However, it is not simply the IVR medium that results in improved learning outcomes but rather the instructional methods that effectively utilize the affordances of IVR—such as presence and agency [3]. Immersion, control over the virtual environment, realistic and smooth displays, and consistent object behaviors influence presence. On the other hand, Agency is shaped by users' ability to control and interact with the environment, modify objects, and experience high interaction fidelity, where users' movements align with the system's feedback [1]. The alignment of technological affordances with sound instructional design principles is critical for fostering student engagement and effective learning outcomes in IVR environments [4].

This study presents the development and evaluation of two immersive learning experiences designed as pre-training tools for professional practice in distinct fields of knowledge:

1. Plating MR: Developing aesthetic and functional skills in gastronomy using mixed reality.

2. Chain of Custody VR: Simulation of digital evidence collection in a forensic VR investigation setting.

The study investigated how these immersive experiences influenced students' perceptions of engagement, motivation, and learning while assessing usability and potential cybersickness symptoms. These findings contribute to a growing body of evidence supporting the potential of XR technologies to overcome traditional barriers in higher education while enhancing experiential learning opportunities [2, 4].

2 Design, Development, and Data Collection

The Plating MR (Fig. 1) and Chain of Custody VR (Fig.2) applications were developed following a structured pipeline. Initially, a detailed briefing was conducted with the respective conceivers of each experience to understand each project's specific demands and educational goals thoroughly. During the pre-production phase, the general parameters of the experiences were defined, and the sound and visual elements to be developed were analyzed. The Plating MR experience was designed to run in HoloLens 2, and the Chain of Custody VR experience in Meta Quest 2. Both applications were implemented using the Unity game engine, with visual assets modeled and textured using Blender and Substance Painter. Sound elements were created and mixed using Studio One to provide an auditory ambiance aligned with the specific requirements of each application. The user interfaces (UIs) were designed in Adobe Photoshop, where icons and other visual elements were developed.

The Plating MR experience was conceived as an educational tool to introduce Gastronomy students to the principles of plating in a controlled and sustainable manner, avoiding food waste. The application simulates a tabletop with various virtual ingredients, enabling students to practice proper restaurant plating. The experience dynamics were designed to accommodate two types of users: the active user, who interacts directly using the Microsoft HoloLens 2 mixed reality devices, and observers, who follow the activity mirrored on a screen. This dual-user setup allows observers to analyze the activity and gain inspiration for their future interactions. The HoloLens 2 was chosen for its suitability in simulating the typical environment of gastronomy laboratories while enabling a focused application scope that only required the development of elements necessary for direct interaction, without the need for extensive visual ambiance or scenery. During the experience, users begin by positioning a virtual plate at the height of the physical table where they will perform the activity. From there, they can access the application's features, including selecting different shapes and colors for the plate and choosing and applying sauces. All interactions utilize hand tracking rather than physical controllers, allowing for natural, intuitive movements while reinforcing the immersive nature of the activity.

The Chain of Custody VR application was developed as an assessment tool for postgraduate students in forensic science. This application evaluates students' knowledge of the chain of custody principles. To ensure the integrity of the assessment, the experience is designed for individual use, without screen mirroring, to prevent revealing the objectives or solutions to other students. In the virtual environment, students are immersed in a simulated apartment and tasked with locating and collecting seven pieces of digital evidence scattered randomly throughout the space. These tasks must be performed following proper chain-of-custody procedures. Upon completing the activity, the system generates a report detailing errors (if any), providing students with immediate feedback on their performance. The application utilizes a teleportation-based movement system to ensure the experience remains viable regardless of the user's physical space constraints. As with the Plating MR experience, hand tracking was employed for all interactions to provide natural, realistic actions. Users can perform tasks such as putting on gloves, photographing evidence, handling objects, opening and closing collection bags, inserting evidence into proper bags, and labeling the collected items. These interactions replicate real-life procedures, ensuring the application is an effective and technically accurate teaching tool.

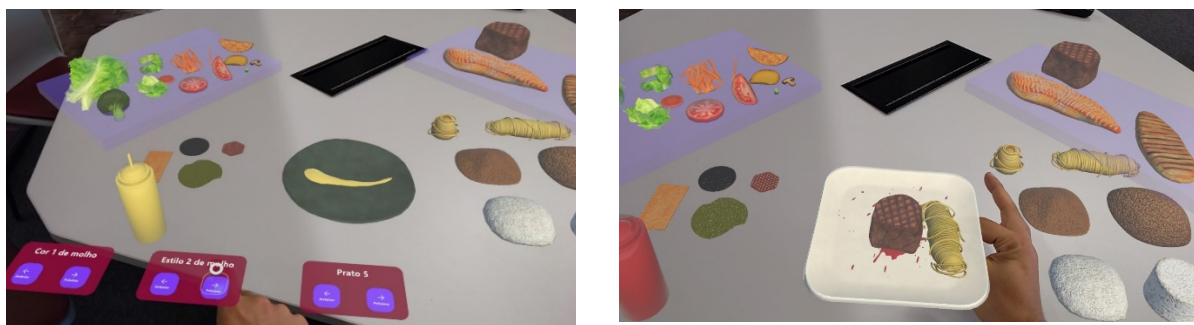


Fig. 1. Elements of Plating MR.



Fig. 2. Scenes of Chain of Custody VR.

The referred immersive experiences were implemented during regular classes in the undergraduate Gastronomy course (Plating MR) and the postgraduate Forensic Science course (Chain of Custody VR), following the professor's explanations on the related study topics. In the Gastronomy class, 14 out of the 30 students present had the opportunity to use the immersive experience, which was broadcast on a screen for the rest of the class. In the Forensic Science course, all seven students could use the experience; however, screen mirroring was not used to maintain confidentiality of the challenges. A few minutes before the end of each class, students voluntarily completed a perception questionnaire assessing situational interest, intrinsic motivation, cognitive load, learning, and usability. For the Chain of Custody VR experience, two additional questions on self-efficacy perception were included. The questionnaire was based on the CAMIL framework [3] and was administered online, anonymously, and voluntarily. It consisted of closed-ended questions, answered on a 5-point Likert scale (5 = Totally Agree, ... 1 = Totally Disagree), and one open-ended question for free opinions (criticisms or suggestions). Students also completed the SSQ questionnaire to assess cybersickness [5]. The university's Research Ethics Committee approved the study, and participants were required to be over 18 years old and to agree to an Informed Consent Form before responding to the questionnaires.

3 Findings and Discussion

3.1 Plating MR

Fourteen students participated in the Plating MR experience, with nine aged between 18 and 20, four between 21 and 26, and one student aged between 45 and 60. The responses of the users to the questionnaire (Fig. 3) will be discussed next.

The perception of the experience as real (Question 1) was high, with 71.5% of the users answering 4 or 5. In the open-ended question, some users suggested making the plating more realistic, reducing the size of virtual elements, or enabling features like cutting, with one commenting that the designs were "simple and did not reflect reality." Questions 2 ("The experience was interesting") and 3 ("I felt motivated by the experience") revealed highly positive results, with 92.9% of participants selecting 5 on the Likert scale. Interest is essential in initial engagement and a gateway to intrinsic motivation [6]. These evaluations suggest that the experience's design effectively created a stimulating environment that captured the interest and motivation of all participants. Participants described the experience as "super interesting," "dynamic," and "a great tool for developing perception."

Regarding learning perception, an analysis of responses to Question 4 ("I was able to learn about plating through the experience") revealed that 50% of participants were neutral or disagreed. In the open-ended questions, some students noted its potential to improve learning, with one stating it "helps in the creative process" and another adding it "helps to put plating concepts into practice." Feedback also highlighted the experience's role in fostering interaction; as one user mentioned, it "generates more interaction between the professor and the student and helps retain information." Most participants (78.6%) did not perceive information overload during the experience (Question 5, answers 1 and 2). However, when asked about performing actions in the experience (Question 6), 50% of participants indicated no or slight difficulty, whereas the other half agreed to some extent that it was difficult to handle the mixed reality device. The researchers observed that students had difficulties with hand-tracking movements, which generated some frustration and may have hindered perceived learning. Some users need more time than others to get used to the right way to select, pick up, and move objects with Hololens, since

this device uses pinch movement combined with a cursor, which needs to connect to the object to be moved by the user.

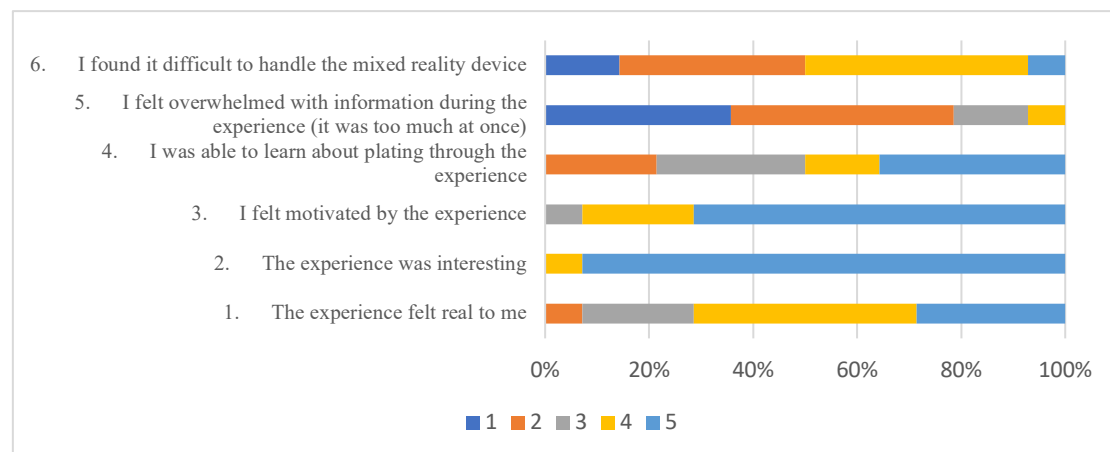


Fig. 3. Percentage of Answers on a 5-Point Likert Scale (5 = Totally Agree, ... 1 = Totally Disagree) – Plating MR.

The feedback regarding cybersickness during the immersive experience showed that 10 out of 17 participants (approximately 59%) reported "not feeling anything different," indicating a generally comfortable experience for the majority. However, 7 participants (approximately 41%) reported symptoms such as "nausea," "eye strain," "disorientation," "postural instability," and "mental fatigue," highlighting the need for ergonomic adjustments and interface optimizations to reduce discomfort for a significant minority. The Chi-Square test was conducted to examine whether there was a significant association between age group and cybersickness symptoms (binary symptom presence). The results ($\chi^2 = 3.0$, $p = 0.223$) indicate no statistically significant relationship. The reported symptoms of cybersickness, particularly given that most users spent at least 10 minutes in the experience and one participant used the device for an hour, are likely associated with the limited field of view in the HoloLens. This constraint required frequent head movements to select and place items, which, over time, could lead to eye strain, disorientation, and postural instability, especially during prolonged sessions. Also, the field of view and responsiveness are essential in fostering physical presence [1].

3.2 Chain of Custody VR

The Chain of Custody VR experience was applied to seven postgraduate students, six of whom completed the questionnaire. Their responses are presented in Fig. 4 and discussed next.

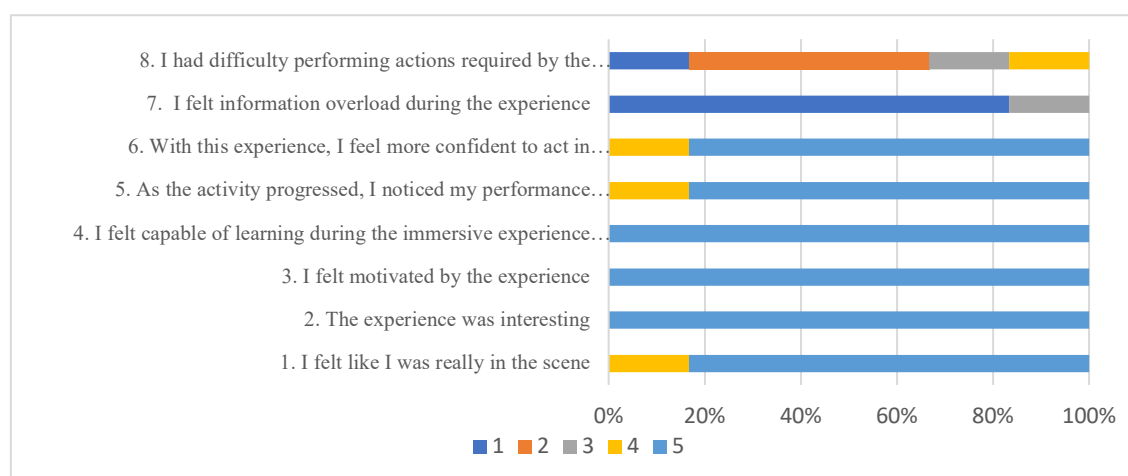


Fig. 4. Percentage of Answers on a 5-Point Likert Scale (5 = Totally Agree, ... 1 = Totally Disagree) – Chain of Custody VR.

The results of the Virtual Reality (VR) experience for investigating digital evidence at a crime scene revealed highly positive outcomes across most dimensions. Participants reported a strong sense of presence, with 83.3% of

respondents selecting 5 and 16.7% selecting 4 for the statement "I felt like I was really in the scene" (Question 1). Similarly, all participants rated the experience as "interesting" and "motivating," with both statements receiving 100% agreement at level 5 (Questions 2 and 3). The open-ended question had only three answers, stating that the experience was (1) incredible, (2) excellent and (3) congratulating the development team.

The statement of Question 4, "I felt capable of learning during the immersive experience (self-efficacy)", also received a unanimous response at level 5, indicating a universally perceived educational benefit from the VR application. Additionally, participants strongly agreed that they noted an improvement in their performance as the activity progressed (Question 5) and that the experience boosted their confidence in acting in similar real-life scenarios (Question 6), suggesting that the VR experience was not only engaging but could also be effective in fostering skill development.

Regarding Question 7, the perception of information overload was minimal, suggesting that the VR experience was well-designed to avoid overwhelming participants. The statement of Question 8, "I had difficulty performing actions required by the experience", received 66.7% disagreement, reflecting slight variability in participants' ease of interaction with the virtual environment, though no significant difficulties were reported. Some users take a little longer to get used to hand tracking, so they report task difficulties.

4 Final Remarks

This study's findings align with the Cognitive Affective Model of Immersive Learning (CAMIL), emphasizing the importance of presence, agency, and cognitive load management in immersive learning environments. Both the Chain of Custody VR and Plating MR experiences engaged participants and demonstrated educational value, with the VR experience consistently outperforming in realism, self-efficacy, and absence of cybersickness. The MR experience, while fostering interest and motivation, faced more usability challenges than the VR experience, including higher information overload and hand-tracking issues, impacting learning outcomes. Hand tracking with Meta Quest 2 simulates the real hand movement of the user, including precision movements of the fingers when they take the objects, what results in a more user-friendly experience than the MR experience with Microsoft HoloLens.

Despite the promising results, the small sample size limits the generalizability of these findings. Future research should involve more significant, diverse participant groups and focus on improving usability and realism in mixed reality applications. Usability of the MR application could be tested in another device, such as Meta Quest 3, which has more precise hand tracking features. Incorporating multiplayer functionalities could further enhance educational impact by fostering collaboration and simulating real-world teamwork scenarios, leveraging the social affordances of immersive technologies.

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