

Bridging Disciplinary Boundaries: Integrating XR in Communication Sciences Master's Programs

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Abstract. Extended Reality (XR) is transforming sectors like education, healthcare, and construction. With its potential for simulating real-world scenarios, XR's role in digital transformation is increasingly recognized. This shift necessitates XR education expansion beyond STEM, addressing the needs of humanities and social sciences students to understand these technologies' applications, ethics, and societal implications. This paper investigates the integration of XR into three Master's courses in communication sciences. It emphasizes the importance of practical engagement with XR through user testing, hands-on projects, and developing a critical stance towards UX and related issues. The study utilizes an exploratory case study approach, leveraging participant observation, assignments analysis, and student feedback. Findings highlight the value of XR in enhancing student engagement, understanding, and the ability to propose inclusive design solutions. Despite challenges linked to large-scale implementation and the absence of advanced programming courses in social sciences and humanities programs, XR integration serves as a powerful tool in raising awareness about designing user-friendly, secure, and inclusive immersive systems.

Keywords: XR education · Augmented reality · Virtual reality · Storyboard · User experience · Case study

1 Introduction

Extended reality (XR), an umbrella term for technologies like augmented reality (AR), virtual reality (VR), and mixed reality (MR), has emerged as a transformative force, merging the digital and physical realms [15]. The immersive nature of XR technologies, exemplified by AR and VR, has already penetrated sectors such as education, healthcare, and construction. Notably, VR has made significant inroads in healthcare, particularly in surgical simulations, owing to its capacity to simulate real-world scenarios [9]. Immersive experiences simulation, and digital twins are recognized as pivotal drivers of digital transformation, with Gartner [8] asserting their more substantial role compared to other technologies.

Meanwhile, challenges in XR span user experience (UX), ethical considerations, inclusion, and cybersecurity, posing multifaceted issues in the scientific domain.

In this context, the imperative arises to extend XR education beyond traditional health sciences or STEM disciplines. Humanities and social sciences students, whose professions (e.g. anthropologist, economist, lawyer) are or will be affected by digital transformation, need to comprehend and study these technologies [6]. This involves identifying current and potential applications, analyzing user attitudes, formulating recommendations for improvement, and understanding associated issues such as data protection, ethics, and inclusion. Students in communication sciences are no exception to this imperative. Broadening educational scopes ensures a comprehensive understanding of XR technologies and their societal implications [6]. This raises the following research question: *How to seamlessly and efficiently integrate XR into humanities and social sciences educational programs while preparing students for challenges associated with XR?*

Using a multiple exploratory case study design, this paper delineates the integration of immersive technologies into three courses within the Master’s programs in communication sciences at Université catholique de Louvain (UCLouvain): design and evaluation of prototypes, user experience, and project management. Across these three courses, the pedagogical objectives aimed to provide students with a theoretical and practical foundation for appropriating XR technologies, identifying their key features, and fostering a critical stance toward them. The critical stance particularly concerned UX, user engagement, acceptance, or data protection. The common threads among the courses are:

1. Conducting user tests following an experimental protocol collaboratively defined by students during classes,
2. Using UX as cornerstone while defining the experimental protocol.

Additionally, students were tasked with hands-on projects, such as creating multimedia content for an AR prototype (case 1), describing interaction modalities and affordances of an existing VR prototype (case 2), and storyboarding optimistic and pessimistic VR experiences related to cybersecurity and data protection (case 3).

The paper explores the intricate ramifications of digital transformation, showcasing the viability and significance of equipping students in humanities and social sciences for the multifaceted challenges and opportunities presented by immersive technologies. Specifically, the paper delineates the instructional designs of the three courses, outlining requirements for technical and logistical support, and offering insights derived from the practical implementation of immersive technologies in these educational contexts. Subsequently, the paper examines student performance metrics, including attendance, participation, production quality, and grades, alongside solicited feedback pertaining to the instructional design of the courses. Finally, the discussion extends to the scalability of the course instructional designs, considering their applicability to larger student cohorts or undergraduate programs.

2 Background

Extended reality (XR) encompasses a broad spectrum of experiences that merge the virtual and real worlds, achieved through the integration of various immersive technologies (Figure 1). According to [19], VR is defined as a computer-generated simulation that transports the user to a different, computer-generated environment; AR uses digital devices to overlay additional sensory information (sounds, objects, avatars, graphics, labels, etc.) on the real world, which provides contextual information that enhances appearance, delivering an enriched interactive experience; MR combines elements of AR and VR, which allows for the interactive and real-time overlay of virtual elements within the real world, providing an environment in which virtual and physical objects coexist and interact.



Fig. 1. Examples of VR (left), MR (center), and AR (right) systems. Photos by Unknown Authors licensed under CC BY (left and center), CC BY-NC (right).

2.1 Challenges associated with XR

XR has integrated into various sectors, such as education, healthcare, marketing, pharmaceutical production, and construction, demonstrating their versatility and comprehensive applicability. Despite the transformative potential of XR, its widespread acceptance and seamless integration are challenged by a spectrum of issues spanning technical, societal, and ethical dimensions.

Technical challenges. Advancements in XR technology have been propelled by significant strides in object detection, motion tracking, gesture recognition, and the substantial growth of artificial intelligence. These advancements have profoundly enriched the understanding of human-machine interactions. Further technological progress in 3D rendering, such as hologram projection, has enabled more realistic and immersive virtual experiences [2]. However, the high cost of XR hardware, like VR headsets, constitutes a barrier to mass adoption. Moreover, the accessibility of these technologies is restricted, especially in settings with limited resources. Lastly, the management of sensitive biometric data and the risks of cyberattacks demand robust security protocols and stringent privacy safeguards to protect user data and foster trust in these technologies [22].

UX challenges. User experience (UX) goes beyond usability [14] and is defined as *user’s perceptions and responses that result from the use or anticipated use of a system, product or service* [26]. UX is pivotal in shaping the success of XR technologies, as a well-designed UX not only ensures usability but also enriches user engagement, fostering a deep and intuitive connection with the technology. In the context of XR, UX challenges are multifaceted [12], including the creation of immersive content that is both compelling and contextually relevant, designing interactions that feel natural and intuitive, and ensuring the system’s performance is seamlessly synchronized with user actions. The evolution of UX into a driver of innovation highlights its role in the deployment of XR technologies, where real-time responsiveness and adaptive interfaces are crucial for meeting user expectations and enhancing their immersive experience [17].

Societal and ethical challenges. While XR technologies offer immersive experiences, they bring significant societal and ethical challenges. Issues related to the collection and potential misuse of biometric data pose serious privacy risks [2]. Moreover, the immersive nature of XR technologies raises ethical considerations, particularly concerning vulnerable groups like children or individuals with mental disorders, who may be more susceptible to the psychological impacts of these technologies [25]. Furthermore, prolonged exposure to XR environments presents health concerns, while accessibility and inclusion remain pressing challenges, emphasizing the need for XR environments and interfaces that are universally accessible and non-discriminatory [3]. Addressing these societal and ethical challenges is crucial for fostering a responsible and inclusive evolution of XR technologies.

2.2 XR for education

XR technologies facilitate the creation of immersive educational experiences that substantially enhance academic performance [7], stimulate active participation, and ultimately cultivate a learning environment that is both enriched and engaging. By replicating real-world scenarios, XR provides learners with practical exposure within a secure and controlled setting. Moreover, such simulations bridge the gap between theoretical knowledge and its practical application, an integration that proves especially pivotal in fields such as architecture, engineering, and healthcare, where grasping the practical ramifications of theoretical knowledge is paramount. At this stage, proficiency in XR technologies is crucial, proving vital for industry professionals and for those orchestrating the deployment of these technological infrastructures. For these individuals, learning XR technologies involves not only mastering the tools but also gaining a deep understanding of technological, economic, and ethical issues. In this context, the ability to identify and skillfully address technical, ethical, or user experience (UX) challenges is crucial for these future professionals.

3 Methodology

3.1 Objective and related approach

The paper explores strategies for seamlessly and efficiently integrating XR into educational programs, ensuring the preparation of students in humanities and social sciences for challenges associated with XR. Specifically, the paper aims to provide insights into the how-tos of XR integration:

- How to align with course learning objectives;
- How to adapt to students' profile;
- How to maintain academic performance and student engagement, particularly when students may be unfamiliar with the technology;
- How to prompt students to critically reflect on XR, encouraging a forward-looking perspective on the evolving technological landscape.

To pursue this objective, we opted for a multiple exploratory case study design. First, case study designs are suitable to address how and why questions [1], or to explore situations involving multiple variables (i.e., students' engagement or familiarity with XR) that cannot be controlled [23]. Second, we chose an exploratory approach, as XR integration in humanities and social sciences programs has no clear, single set of outcomes [1, 23]. Finally, multiple cases allowed us to explore differences between cases [1].

3.2 Description of the three cases

We selected three case studies, each corresponding to a specific course taught in the communication sciences master's programs at UCLouvain (Table 1), based on both the relevance of XR integration in students' curriculum and the consistency of XR integration against each course' learning outcomes.

The selected cases focus on prototyping (case 1), user experience (case 2), and project management (case3). Distinguishing features emerge in the specifics of each case. Notably, the type of prototype utilized diverges across the cases, ranging from AR in case 1 to VR in case 2 and storyboard in case 3. Additionally, students carried out user tests individually in cases 1 and 3, and in group in case 2. Although evaluation methods exhibit slight diversity, all cases place a high emphasis on group assignment, reaching 60% in case 3. Finally, the hours allocated to each course vary significantly, with cases 2 and 3 requiring twice the time compared to case 1, demanding substantially fewer hours.

All three cases share common elements: each course carries a weight of 5 European Credit Transfer and Accumulation System (ECTS), suggesting a similar level of academic commitment; the class sizes are notably consistent across different cases; and the students exhibit homogeneity in terms of socio-demographic attributes. More importantly, all three cases rely on user experience as a cornerstone, and as such, they all involve user testing.

Figure 2 depicts the instructional design in cases. All three cases involved an acclimatization phase, user testing phase, and jury. The acclimatization phase

Table 1. Description of the three cases. ECTS stands for European Credit Transfer and Accumulation System.

	Case 1	Case 2	Case 3
Course	prototyping	user experience	project management
ECTS	5	5	5
Hours	15	30	30
Semester	Spring 2023	Spring 2023	Fall 2023
Students	27	30	33
Type of prototype	AR	VR	Storyboard
Experimental protocol	collaborative	collaborative	collaborative
User test	individual	in group (13 teams)	individual
Data analysis	collaborative	collaborative	collaborative
Students' evaluation modes			
Knowledge test	-	25%	40%
Individual assignment	50%	25%	-
Group assignment	50%	50%	60%

aimed to ensure that students acquire the fundamentals in each course. For example, it included an overview of prototyping techniques in case 1, exploration of methods, practices, and UX artifacts in case 2, and a combination of agile-UX methods and techniques for project management in case 3. Additionally, case 3 introduced role-play to put into practice the theory seen during the acclimatization and enhance social interactions during class. In cases 2 and 3, a demonstration session was incorporated to familiarize students with XR technology. The user testing phase presented students with a hands-on opportunity to directly engage with XR technologies, bridging the gap between theory and practice. This phase is dynamic and integral to the curriculum. User testing involved creating the experimental protocol, carrying out the user test, and analyzing collected data. In all three cases, both the creation of the experimental protocol and data analysis took place collaboratively during classes. Students performed user test data collection individually in both cases 1 and 3, and in groups in case 2. The jury evaluation served as a significant assessment of students' comprehension and practical application of XR principles. In all three cases, we tasked students with the consolidation of results and findings in one single presentation, so as to present an integrated perspective of the phenomenon investigated.

3.3 Methods for data collection

We used participant observation during face-to-face classes and screened the publications on the courses' MS Teams to collect data about attendance, participation, and engagement. We analyzed group and individual assignments to assess academic performance (quality of students production and grades). We tasked students with documenting their feedback about the system under investigation and their experience with the instructional design in a single document per working group.

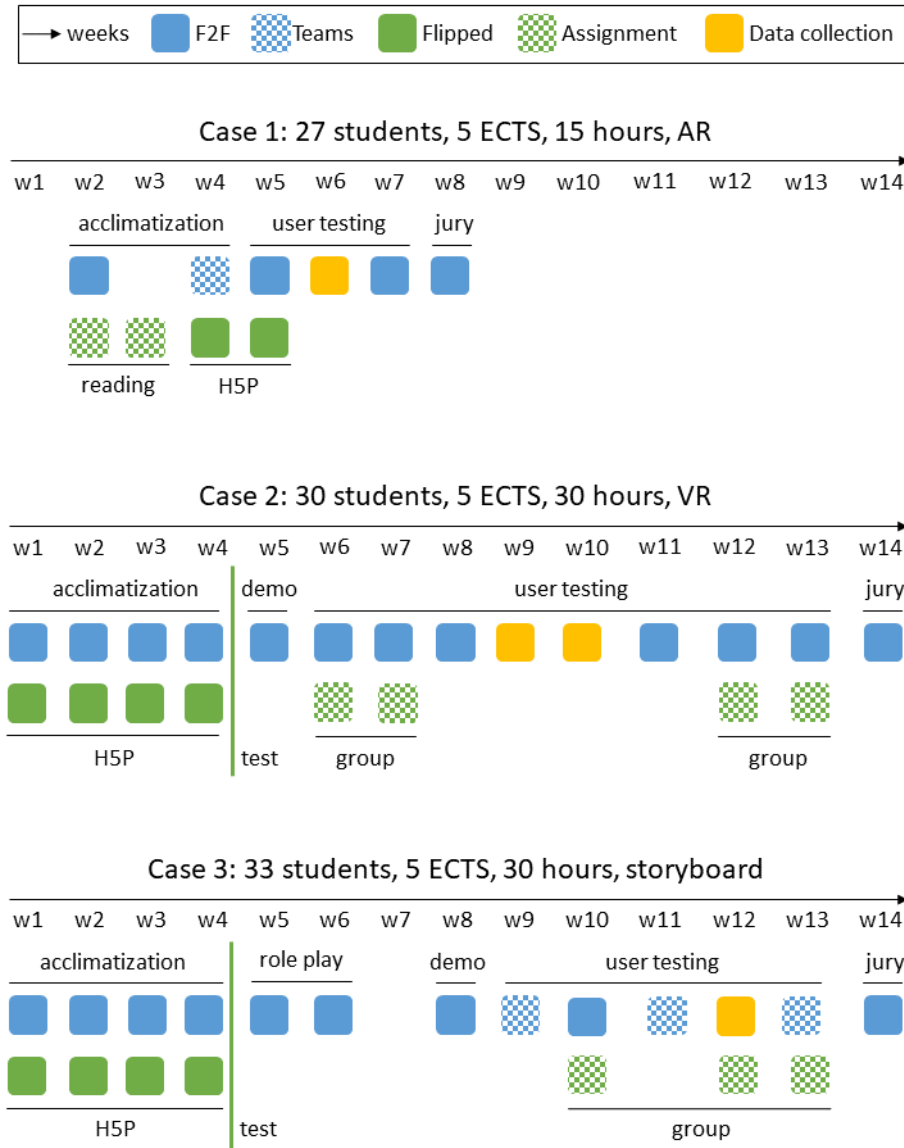


Fig. 2. Instructional design of each case. F2F stands for Face-to-Face, ECTS for European Credit Transfer and Accumulation System.

3.4 Case 1

We tasked students with generating content to be incorporated into a rapid prototyping tool for AR systems. Specifically, students created in groups (5 groups) a scannable poster that would redirect to a multimedia content such as a video, image, audio (Figure 3), therefore producing five prototypes in total, one per group. Then, students carried out user tests individually, which required them to recruit one participant who tested the five AR prototypes. Subsequently, students administered the recruited participant a questionnaire regarding user experience and engagement. At the end, the raw data was shared among all the groups, allowing them to conduct analyses based on the raw data. Students prepared the user test material in-class during week 5 and analyzed the data in-class during week 7 (Figure 2). The material included:

- An online consent form allowing us to use data for research purposes;
- A checklist for assessing participants' performance (errors and hesitations);
- Six scales of the UX questionnaire (UEQ+) [24], namely attractiveness, efficiency, intuitive use, aesthetics, quality of content, and trust;
- The user engagement scale (UES) short form [21];
- A form allowing students to collect participant feedback.

Students presented collaboratively the results during week 8 (Figure 2), discussing each component of the experimental design separately. For example, students emphasized the relatively mitigated results regarding both user experience and user engagement. They argued that these outcomes were "predictable" since the look and feel of the tested AR prototypes were perceived as low-fidelity by the participants. Furthermore, students highlighted the limitations of the content they created, which was evaluated as having limited engagement.

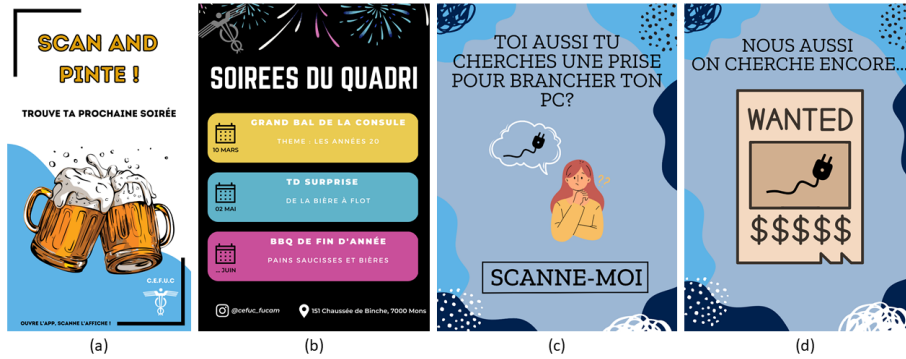


Fig. 3. AR prototypes. Example 1: users scan the poster (a), then information about next student parties appears (b). Example 2: users scan the poster (c), then a joke about the lack of electrical outlets appears (d).

3.5 Case 2

We tasked students with evaluating and formulating redesign proposals for an existing VR prototype. The VR prototype supports the arrangement of living spaces in a virtual world, including the selection of furniture and wall colors from a catalog. The immersive experience takes place under a VR headset with controllers that enable movement and interaction (Figure 4).

Similar to case 1, case 2 also included tasks such as developing the experimental protocol, conducting user tests, and sharing and analyzing data. However, students worked in groups throughout the process, and there were slight changes in the timeline, with the preparation of experimental material spanning weeks 6-8 and analysis occurring during weeks 11-13 (Figure 2). Like in case 1, the resulting material included a checklist for assessing participants' performance, eight scales of the UEQ+ (efficiency, dependability, intuitive use, haptics, stimulation, visual aesthetics, quality of content, acoustics), the UES short form, and a form allowing students to collect participant feedback. However, the material also included an onboarding kit for participants, and we added impression testing [12] to gather participants' initial impressions about the virtual world.

Students presented collaboratively the results during week 14 (Figure 2), discussing each component of the experimental design separately, as well as limitations in the VR prototype. For example, students identified several inclusion-related concerns (e.g. white male hands of the avatar), and also proposed a set of recommendations for improvement (e.g. integration of auditory elements to deepen participant immersion).

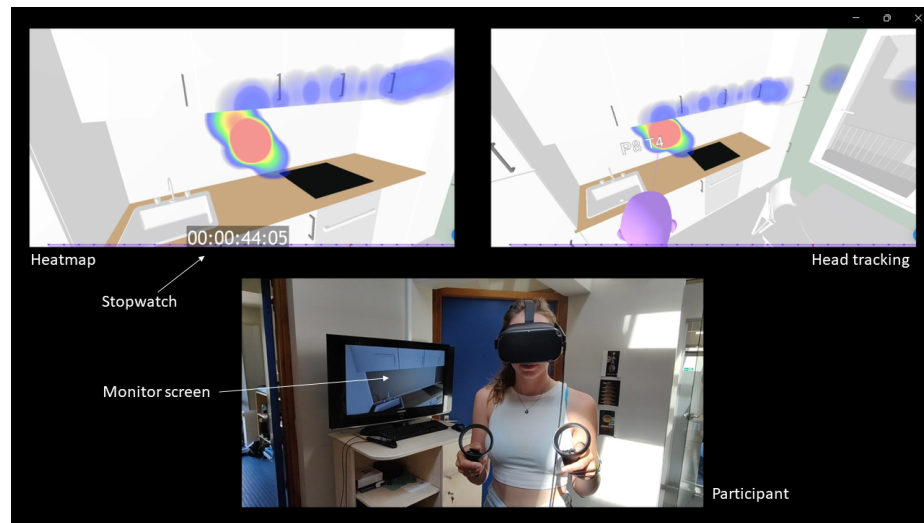


Fig. 4. VR prototype. Top: heatmap (left) and head tracking (right). Bottom: experimental setting.

3.6 Case 3

We tasked students with designing and evaluating VR scenarios through a storyboard representation system. They crafted four scenarios, categorized along two dimensions: utopian versus dystopian scenarios, and the inclusion or exclusion of details about cybersecurity risks in the consent form.

Similar to cases 1 and 2, case 3 also included tasks such as developing the experimental protocol, conducting user tests, and analyzing data. In addition to the consent form, the material included scales of the technology acceptance model (TAM) questionnaire (usefulness, perceived ease of use, attitude, behavioral intention, enjoyment) adapted to VR technology [16], scales for assessing perceived cybersecurity risks [10], and a form allowing students to collect participant feedback. The students collaborated in groups, with each group producing storyboards and consent forms. Following a peer review of these works, the instructor selected one group’s output. Subsequently, this chosen material was utilized uniformly by all students for user testing.

During week 14, students collaboratively presented the results (Figure 2), delving into each aspect of the experimental design. They discussed both the advantages, such as resource efficiency, and the limitations, such as low-fidelity, associated with using storyboards for user testing. Additionally, they emphasized the significance of designing experimental materials that closely match the situations one intends to generalize the results to.

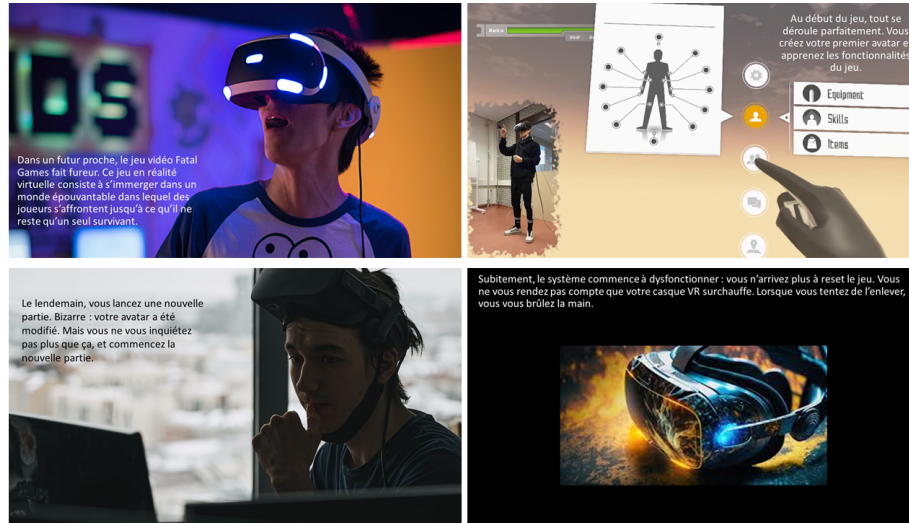


Fig. 5. Top - Utopian scenario (left: introducing VR technology; right: illustrating a positive user experience). Bottom - Dystopian scenario (left: introducing a security breach; right: suggesting user’s death after the headset exploded).

4 Findings

The pedagogical approach involving user testing and (re)design activities contributed to a comprehensive understanding of XR technologies and their applications. For example, students were able to grasp the advantages (e.g. capacity of simulation) and limitations (i.e. lack of inclusion) of XR technologies.

The collaborative nature of the learning experience implemented in these cases yielded positive outcomes. Table 2 presents for each case the number of students, dropouts, and mean grades. The number of students is similar among each case, with no dropouts in case 1, but a slight increase in dropout rates in cases 2 and 3 (7% and 9%, respectively). Despite broad ranges of grades, academic performance was above average, with high attendance to courses and implication in F2F and distant activities. For example, all students conducted user tests and delivered complete user data collection.

Table 2. Students' academic performances per case.

	Case 1	Case 2	Case 3
Course	prototyping	user experience	project management
Type of prototype	AR	VR	Storyboard
Experimental protocol	collaborative	collaborative	collaborative
User test	individual	collaborative	individual
Data analysis	collaborative	collaborative	collaborative
Students	27	30	33
Dropouts	0	2 (7%)	3 (9%)
Mean grades (%)	77	73	70
Range grades (%)	60-82	55-87	64-85
Course attendance	high	high	high
Students' implication	high	high	high
Critical thinking	medium	high	high

4.1 Case 1

Students identified several issues with the fast prototyping tool for AR. Key problems included the application's incompatibility with various operating systems, including some Android smartphones, and malfunctioning when attempting to scan a poster more than once or different posters in succession, necessitating an application restart. Additionally, the placement of posters in high-traffic areas posed challenges. Students' notable errors involved administrative oversights, such as two students failing to have the consent form signed.

The course was perceived as innovative, offering students a unique opportunity to explore AR within their curriculum. Highlights include the practical, hands-on experience that allowed for real-world application of classroom knowledge, conducting user tests outside the course, and learning about tools (observation grid, UEQ+, UES) beneficial for future careers in communication. The

approach facilitated team-building skills, adherence to deadlines, and an ethical understanding of data collection, including the development of a confidentiality charter. Additionally, students appreciated the creative freedom to design visuals and select poster themes, enhancing their learning experience and engagement with the course material.

Within this innovative setting, the fast prototyping tool for AR has the potential to support larger student groups effectively, offering expansive educational benefits when aforementioned issues are systematically addressed.

4.2 Case 2

During user tests, students encountered several technical difficulties that impacted data collection. These challenges included poor Wi-Fi connectivity that significantly degraded image quality and caused latency in immersive sessions, as well as frequent or prolonged system crashes. The premature activation of the sleep mode on the VR headset before the commencement of user tests also contributed to stress among participants.

Errors committed by students involved deviations from the experimental protocol, such as unnecessarily prolonging the duration of impression tests beyond the specified time, a failure to accurately log encountered errors, and an omission in the collection of vital data segments. Furthermore, survey administration was compromised by translation inaccuracies and imprecise instructions, undermining the reliability of the collected data.

The course was perceived as innovative, offering students an opportunity to explore VR within their curriculum. Students proposed redesign solutions toward more equality and inclusion in the VR prototype, which is in line with the major challenges associated with immersive technologies [4, 5]. From the jury's perspective, the instructional initiative provided a detailed exploration of the advantages and current challenges in incorporating immersive technologies into educational settings. Emphasis was placed on the need to develop a UX maturity model tailored to the specific demands and challenges faced by immersive technologies and their development teams. The analysis pointed out that while certain immersive experiences offer significant benefits, the complexity of human-machine interactions, especially those involving gestures and movements, requires in-depth study, modeling, and improvement.

The feasibility of conducting user tests of the VR prototype in synchronous mode was supported by the availability of four VR headsets operating simultaneously. However, accommodating a larger cohort would necessitate asynchronous testing, introducing more complex logistical considerations.

4.3 Case 3

The analysis of data collected during user tests indicated that the scenarios depicted in the storyboards did not adequately reflect the intended themes, particularly with the "utopian" scenario's inappropriate solicitation of personal information, which diverged from the project's thematic objectives. However,

insights from cases 1 and 2 led to an improvement in the data collection process, specifically through the encoding of consent form and questionnaire via Moodle’s feedback activity, which significantly reduced student error.

Students praised the course for its innovative approach, in particular the possibility to engage with both VR technology and related cybersecurity risks. Their feedback focused on refining the experimental protocol, notably to enhance administration of questionnaire and ensuring consistent data collection. For example, their collective input advocated for a meticulous enhancement of testing protocols, emphasizing preparatory work was deemed essential for effectively addressing participant queries, allowing participants to elaborate on their answers was suggested to deepen insights into user experiences, and streamlining questionnaires and expanding the participant pool beyond familiar circles were advised to improve data diversity and authenticity.

Storyboards emerge as a critical tool in this context, serving not just to visualize and communicate user experiences and foster creativity, but also to anchor a user-centered design approach. Importantly, they provide a pragmatic solution to the logistical challenge of equipment limitations, exemplified by the impracticality of supplying 30 headsets for 30 students. This innovative use of storyboards underscores the course’s commitment to overcoming practical constraints while maintaining high educational standards and meeting learning objectives in the realm of immersive technologies.

5 Discussion

5.1 Analyzing challenges in XR education

Cases 1 and 2 encountered technical issues, such as operating system incompatibility (case 1 with AR) and system crashes affecting the user experience and data collection process (case 2 with VR). To facilitate effective large-scale implementation, these technical hurdles must be systematically addressed. This entails acquiring a sufficient number of smartphones or developing a system compatible with iOS for AR applications. For VR applications, it necessitates purchasing a substantial quantity of headsets and providing suitable spaces for conducting tests. By contrast, students encountered no such technical hurdles in case 3 with storyboards, demonstrating that storyboard prototypes effectively mitigate scalability challenges and technological problems and limitations associated with XR. However, storyboarding introduces considerations regarding the construction of scenarios, which must be perceived as credible by testing participants. This necessitates a careful and deliberate design process to ensure the authenticity of the content and user engagement [13].

Students consistently acknowledged the courses for their innovation, valuing the opportunity to explore XR technologies within their academic programs. This sentiment highlights the educational value seen in integrating cutting-edge technologies into the curriculum. Furthermore, the projects facilitated not only technical skills development but also soft skills, such as team building, adherence to deadlines, and an ethical understanding of data collection.

5.2 How-tos of XR integration

Aligning XR introduction with course learning objectives necessitates a strategic approach where XR technologies are integrated into courses that naturally support their application. This alignment implies selecting courses with learning objectives that are seamlessly complemented by XR's capabilities, such as design-oriented activities including immersive scenario prototyping or empirical data collection and analysis through XR system testing. The integration of XR should enhance the pedagogical framework, enabling students to directly apply XR technologies to solve real-world problems, thereby fostering a deeper understanding of the subject matter.

Adapting to students' profiles is crucial for the effective delivery of XR-based education. Providing students with a uniform baseline of knowledge and practical experience with XR technologies is essential. This can be achieved through targeted demonstrations and immersive experiences, considering that a significant portion of students may not have prior experience with VR technologies (30% in cases 1 and 3, 50% in case 2). Incorporating guest lectures from XR experts can demystify the technology and provide students with accessible, expert insights into XR applications, enhancing their learning experience. Moreover, master programs in social sciences and humanities do not include advanced programming courses that would allow students to develop high-fidelity prototypes. This once again positions the storyboard as a prototype facilitating the integration of XR in humanities and social sciences

Maintaining academic performance and engagement with XR involves integrating hands-on activities like user testing and prototyping. Collaborative exercises not only solidify theoretical knowledge but also cultivate teamwork and creativity, essential in XR's dynamic field. Direct application of XR keeps students motivated and academically focused, despite new tech introductions.

Encouraging critical reflection on XR requires involving students in material creation for testing and initiating discussions on design and protocol improvements. This active involvement deepens their understanding of XR's challenges and opportunities, pushing them to think ahead about technological progress and their role in shaping future innovations.

5.3 Future work

We delved into the variances among cases, bearing in mind the hurdles linked to large-scale implementation and the absence of advanced programming courses in social sciences and humanities programs. This enabled us to pinpoint storyboard prototypes as a solution that tackles both of these challenges simultaneously, as they simplify the introduction of XR concepts, bypassing the need for extensive programming skills and reducing reliance on expensive equipment.

Therefore, our future work will delve deeper into leveraging storyboard prototypes for XR education, with the aim of showcasing their efficacy in crafting scalable XR learning experiences accessible to students in social sciences and humanities. To enrich our understanding and validate the effectiveness of this

approach, we plan to replicate case 3, aiming to produce cumulative findings and facilitate comparative analyses [1]. This endeavor will not only strengthen the evidence base but also allow for nuanced insights into the pedagogical value of storyboarding in XR education. Furthermore, we intend to broaden our research scope to include other low-fidelity prototyping methods, such as video or paper mockups, as suggested by [18]. By exploring these varied prototyping techniques, we aspire to develop a comprehensive, integrative model that enhances the adaptability and robustness of XR educational frameworks [27]. This model will ideally support educators in effectively incorporating XR technologies into their curricula, thereby democratizing access to immersive learning experiences across diverse academic disciplines.

6 Conclusion

In conclusion, the successful integration of XR technologies into educational settings requires careful consideration of course alignment, student adaptation, engagement maintenance, and the cultivation of critical thinking. By addressing these aspects, educators can not only enhance the learning experience but also prepare students to contribute meaningfully to the future of XR technology. A significant revelation of our work is the efficacy of storyboarding as an innovative approach to circumvent the dual hurdles of scalability and technical expertise in XR education. This method not only facilitates broader student involvement in XR development projects, sidestepping the necessity for advanced programming skills, but also significantly enhances collaborative processes. Finally, the integration of these technologies as learning tools enabled us to raise students' awareness of the need to design immersive systems offering a good UX [17], to integrate cybersecurity and data protection [11] and inclusion [20] into the development of these technologies.

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References

1. Baxter, P., Jack, S.: Qualitative case study methodology: Study design and implementation for novice researchers. *The qualitative report* **13**(4), 544–559 (2008). <https://doi.org/10.46743/2160-3715/2008.1573>

2. Bye, K., Hosfelt, D., Chase, S., Miesnieks, M., Beck, T.: The ethical and privacy implications of mixed reality. In: ACM SIGGRAPH 2019 Panels. SIGGRAPH '19, Association for Computing Machinery, New York, NY, USA (2019). <https://doi.org/10.1145/3306212.3328138>, <https://doi.org/10.1145/3306212.3328138>
3. Carter, M., Egliston, B.: What are the risks of virtual reality data? learning analytics, algorithmic bias and a fantasy of perfect data. *New Media & Society* p. 146144482110127 (2021). <https://doi.org/10.1177/14614448211012794>
4. Dick, E.: Current and potential uses of ar/vr for equity and inclusion. Tech. rep., Information Technology and Innovation Foundation (2021)
5. Djamasbi, S., Strong, D.: User experience-driven innovation in smart and connected worlds. *AIS Transactions on Human-Computer Interaction* **11**(4), 215–231 (2019). <https://doi.org/10.17705/1thci.00121>
6. Dong, W., Zhou, M., Zhou, M., Jiang, B., Lu, J.: An overview of applications and trends in the use of extended reality for teaching effectiveness: an umbrella review based on 20 meta-analysis studies. *The Electronic Library* (2023)
7. Fonseca, D., Martí, N., Redondo, E., Navarro, I., Sánchez, A.: Relationship between student profile, tool use, participation, and academic performance with the use of augmented reality technology for visualized architecture models. *Computers in human behavior* **31**, 434–445 (2014)
8. Gartner: What's new in the 2022 gartner hype cycle for emerging technologies (2022), <https://www.gartner.com/en/articles/what-s-new-in-the-2022-gartner-hype-cycle-for-emerging-technologies>
9. Guo, X., Guo, Y., Liu, Y.: The Development of Extended Reality in Education: Inspiration from the Research Literature. *Sustainability* **13**(24), 1–20 (December 2021), <https://ideas.repec.org/a/gam/jsusta/v13y2021i24p13776-d701728.html>
10. Heierhoff, S., Choun, I.H.: The impact of cybersecurity and innovation on mobility technology acceptance. In: PACIS 2023 Proceedings. No. 53 (2023), <https://aisel.aisnet.org/pacis2023/53>
11. Hernández-Ramos, J.L., Geneiatakis, D., Kounelis, I., Steri, G., Fovino, I.N.: Toward a data-driven society: A technological perspective on the development of cybersecurity and data-protection policies. *IEEE Security & Privacy* **18**(1), 28–38 (2019)
12. Hillmann, C.: UX for XR: User Experience Design and Strategies for Immersive Technologies. Springer (2021)
13. Hoffart, N., Doumit, R., Nasser, S.C.: Use of storyboards as an active learning strategy in pharmacy and nursing education. *Currents in pharmacy teaching and learning* **8**(6), 876–884 (2016)
14. Kieffer, S., Rukonić, L., Kervyn de Meerendré, V., Vanderdonckt, J.: A process reference model for ux. In: Cláudio, A.P., Bouatouch, K., Chessa, M., Paljic, A., Keren, A., Hurter, C., Tremeau, A., Farinella, G.M. (eds.) *Computer Vision, Imaging and Computer Graphics Theory and Applications*. pp. 128–152. Springer International Publishing, Cham (2020)
15. Kosko, K.W., Ferdig, R.E.: Conceptualizing a shared definition and future directions for extended reality (xr) in teacher education. *Journal of Technology and Teacher Education* **29**(3), 257–277 (2021), <https://par.nsf.gov/biblio/10340467>
16. Lee, J., Kim, J., Choi, J.Y.: The adoption of virtual reality devices: The technology acceptance model integrating enjoyment, social interaction, and strength of the social ties. *Telematics and Informatics* **39**, 37–48 (2019)

17. MacDonald, C.M., Sosebee, J., Srp, A.: A framework for assessing organizational user experience (ux) capacity. *International Journal of Human–Computer Interaction* **38**(11), 1064–1080 (2022)
18. Maguire, M.: An exploration of low-fidelity prototyping methods for augmented and virtual reality. In: *Design, User Experience, and Usability. Design for Contemporary Interactive Environments: 9th International Conference, DUXU 2020, Held as Part of the 22nd HCI International Conference, HCII 2020, Copenhagen, Denmark, July 19–24, 2020, Proceedings, Part II* 22. pp. 470–481. Springer (2020)
19. Milgram, P., Kishino, F.: A taxonomy of mixed reality visual displays. *IEICE TRANSACTIONS on Information and Systems* **77**(12), 1321–1329 (1994)
20. Naudé, W., Nagler, P.: *Industrialisation, Innovation, Inclusion*, vol. 43. UNU-MERIT (2015)
21. O’Brien, H.L., Cairns, P., Hall, M.: A practical approach to measuring user engagement with the refined user engagement scale (ues) and new ues short form. *International Journal of Human-Computer Studies* **112**, 28–39 (2018)
22. Odeleye, B., Loukas, G., Heartfield, R., Sakellari, G., Panaousis, E., Spyridonis, F.: Virtually secure: A taxonomic assessment of cybersecurity challenges in virtual reality environments. *Computers & Security* **124**, 102951 (2023). <https://doi.org/10.1016/j.cose.2022.102951>, <https://www.sciencedirect.com/science/article/pii/S0167404822003431>
23. Quintão, C., Andrade, P., Almeida, F.: How to improve the validity and reliability of a case study approach? *Journal of Interdisciplinary Studies in Education* **9**(2), 264–275 (Feb 2021). <https://doi.org/10.32674/jise.v9i2.2026>, <https://www.ojed.org/index.php/jise/article/view/2026>
24. Schrepp, M., Thomaschewski, J.: Design and validation of a framework for the creation of user experience questionnaires. *International Journal of Interactive Multimedia and Artificial Intelligence* (2019)
25. Slater, M., Gonzalez-Liencre, C., Haggard, P., Vinkers, C., Gregory-Clarke, R., Jelley, S., et al.: The ethics of realism in virtual and augmented reality. *Frontiers in Virtual Reality* **1**, 1 (2020). <https://doi.org/10.3389/frvir.2020.00001>
26. for Standardization (ISO), I.O.: *Ergonomics of human-system interaction — part 210: Human-centred design for interactive systems*. Tech. Rep. ISO 9241-210:2019, ISO, Geneva, Switzerland (2019), <https://www.iso.org/standard/77520.html>, accessed: January 30, 2024
27. Yin, R.K.: *Case Study Research: Design and Methods*. Sage, Thousand Oaks, CA (2003)