April 23, 2025

Metaverse and XR at California State University, Long Beach

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Executive Summary

Faculty at Cal State Long Beach have been involved with Immersive Technologies such as Augmented (AR), and Virtual Reality (VR) for several years. Like any other technology tool, the degree of usage, its success, and student experiences are varied. This white paper will cover the nuances of utilizing AR, and VR technologies in the classroom, the advantages, challenges, and limitations, the preparatory work involved, the collaboration and support needed, and tips and ideas for successfully utilizing these technologies to engage students, and enhance their learning outcomes. Issues related to access, and equity in the integration of AR and VR technologies will be discussed as well.

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Introduction

Extended Reality, or XR, is an umbrella term that encompasses virtual reality (VR), mixed reality (MR) and augmented reality (AR). XR technologies blend the digital and physical worlds to craft immersive experiences that either fully immerse users in a virtual world (VR), overlay digital elements onto the physical world (AR), or blend the physical and digital worlds as seamlessly as possible (MR).

The history of XR technology goes back further than some may realize, and universities have been at the forefront of development from the start. Building on earlier experiments in multi-sensory technologies, cinematographer Morton Heilig created Sensorama, the first VR machine, in 1956. The Sensorama combined stereoscopic vision (which already existed) with smells, audio and a vibrating chair – creating an immersive movie experience that presaged technologies to come (Marr 2021). Engineers at Philco – building on Heilig's ideas – created the first VR headset with motion tracking in the 1960s, the Headsight system. The Headsight, in turn, inspired

further developments, culminating in Harvard professor Ivan Sutherland's cumbersome "Sword of Democles" VR headset in 1968 and MIT's Aspen Movie Map, a more primitive version of today's Google Maps, soon after. As for AR, in 1998 Sportsvision broadcast the first live NFL game with graphics interlaced with live video – debuting the first down yellow line in real time, which proved a very effective proof of concept for the idea of overlaying graphics and information in real time over live video (AR).

The goals of immersive technology have not changed substantially since the 1960s, but the technology to achieve them has advanced at an alarming rate. But it wouldn't be until 2010 that this industry would produce its first relatively accessible product – teenager Palmer Lucky's Oculus Rift headset, which pulled VR into the realm of home entertainment and gaming and considerably boosted a technology sector that languished for most of the 1990s and 2000s. The Oculus Rift – and less expensive VR headsets like the Samsung Gear and later the Sony Playstation VR, and the super accessible Google Cardboard setup for mobile devices – inspired artists, creators, entertainers and game makers to create content to drive this heretofore practicality-based technology sector. At the close of the first quarter of the 21st century, major players include the Meta Quest 3 (formerly Oculus, but purchased by Facebook), the HTC Vive and the Apple Vision Pro. The world of immersive technology has become much more affordable and accessible with this latest generation of devices, and this provides an opportunity for users from many different sectors to employ and create content that leverages the advantages of what they can do. The so-called "Metaverse" - detailed below – is built on the infrastructure of these technologies. This White Paper is intended to advocate for their use in the university classroom – engaging the technologies and building the Metaverse with pedagogical and ethical considerations at the forefront.

Definition of Metaverse and Some Key Terms

The word Metaverse is a combination of two words, Meta, meaning beyond, and Verse meaning Universe. Gartner defines Metaverse as a collective virtual 3D shared space, created by the convergence of virtually enhanced physical and digital reality. It is persistent, and provides enhanced immersive experiences. Metaverse entails Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR), and Extended Reality (XR).

Each of these terms vary slightly in what they cover. VR consists of a computer-generated 3D environment which surrounds the user, responds to actions and where objects have a sense of spatial presence. AR includes real-time use of text, graphics, audio and other virtual enhancements integrated with real-world objects. MR is where the blend of physical and digital worlds, both co-exist, can interact with one another, real time. XR is the emerging umbrella term for all the immersive technologies.

Application of XR Technologies

Extended Reality (XR) brings together cutting-edge technologies such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). Extended reality provides mobility solutions as they are easily accessible via most electronic devices. XR is an umbrella term for all computer-generated environments to merge the virtual world with the physical world to deliver an immersive experience to users worldwide.

During the COVID-19 pandemic, companies around the world discovered methods to encourage their internally and geographically dispersed employees to connect, coordinate, and chart the way forward. This need drove the adoption of AR and VR Technologies during the pandemic.

Worldwide spending on XR products and services was estimated to be USD 18.8 billion in 2020. Implementing XR helps businesses with a platform that helps people to work efficiently. Rising usage of XR helps to lower the operational cost and helps to boost the productivity of the business by 10 to 20% by utilizing all the available resources. Increasing adoption of XR technique helps deliver real-world experience to customers worldwide with high engagement and interaction to improve sales and enhance brand awareness.

Virtual reality and alternate reality games represent a futuristic vision in the gaming world. The usage of XR allows users to experience data and analytical representations of current or past games as they prefer. Similarly, the growing usage of VR headsets in the entertainment industry helps to see 3D objects from different angles to deliver an immersive experience. VR headsets are increasingly used to build an emotional connection with the user. This propels the demand for VR headsets in gaming and entertainment applications, which helps to drive market growth.

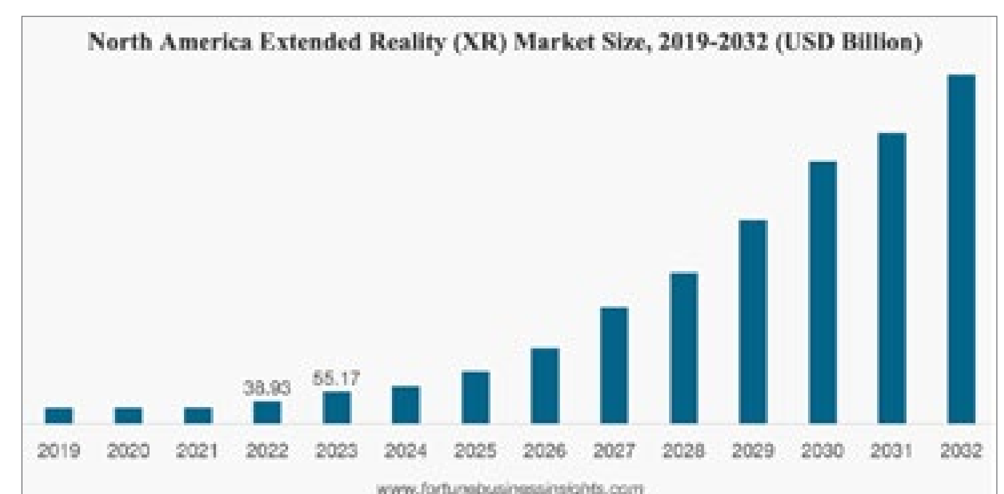
The global extended reality market was valued at USD 131.54 billion in 2023 and is projected to grow from USD 183.96 billion in 2024 to USD 1,706.96 billion by 2032, exhibiting a computed annual growth rate

(CAGR) of 32.1% during the forecast period. North America dominated the extended reality market with a share of 41.94% in 2023.

The global revenue in the AR & VR market was forecast to continuously increase between 2024 and 2029 by in total 21.7 billion U.S. dollars (+53.74 percent). After the tenth consecutive increasing year, the indicator is estimated to reach 62.03 billion U.S. dollars and therefore a new peak in 2029. Notably, the revenue of the AR & VR market has continuously increased over the past years.

5G integrated with XR technology provides a wide range of application areas to boost communication capabilities. The penetration of 5G and XR techniques helps deliver remote control access, real-time experience, industrial control, and mobility automation applications. The surge in the advancement of 5G technology boosts its demand and is anticipated to drive the extended reality market growth during the forecast period.

Extended reality creates virtual replicas of datasets that can be tested and shared with other users. However, this process encounters challenges when capturing the intricate details of real-world images and specialized models. Providing a high-quality XR experience can be expensive, particularly when factoring in the expenses of headsets and tactile sensors. As a result, this factor hampers the overall implementation cost and may hinder the Extended Reality (XR) market growth.



XR Market Segmentation by Type

Based on type, the market is segmented into virtual reality, augmented reality, and mixed reality. The growing usage of Virtual Reality (VR) applications and headsets aims to immerse users in a computer-simulated reality. These VR headsets generate realistic sounds and images, engaging all five senses to create an interactive virtual world. The virtual reality segment dominates the market during the forecast period. Furthermore, augmented reality and mixed reality segments are projected to grow with a prominent share due to increasing implementation of AR and MR among different industry verticals to provide a comprehensive digital experience to users.

XR Market Segmentation by Industry

Based on industry, the market is divided into healthcare, education, retail & e-commerce, gaming, automotive, media & entertainment, and others. The gaming sector dominated the market in 2023 as most end users demand immersive experiences provided by XR. Companies that develop games are among the early adopters of XR solutions to create more memorable, immersive, and engaging customer experiences. The industry has transitioned from the creation of even more engaging and faster game consoles, smart chipsets and extraordinary graphics.

Increasing the use of XR technology in hospitals by surgeons helps to learn new skills or improve existing skills in a safe and secure environment. Innovations in the field of XR across the healthcare industry help to reduce the operating costs of clinics and hospitals, to make better diagnostics, and enable patient-to-patient communication. These innovations enhance the penetration of the XR technique in the healthcare industry.

North America holds the largest XR market share, owing to the presence of multiple market players. The region benefits from opportunities for exposure to high technology and the increasing use of smart devices leading to stronger demand for extended reality experiences. Additionally, the growing investments in infrastructure development facilitate the integration of XR, enabling unprecedented connectivity across the U.S. and Canada. Moreover, technological advancements, such as the emergence of Augmented Reality (AR), Artificial Intelligence (AI), Virtual Reality (VR), and Big Data technologies across several industries, including retail, e-commerce, and entertainment industries, contribute to building fully virtual environments for users.

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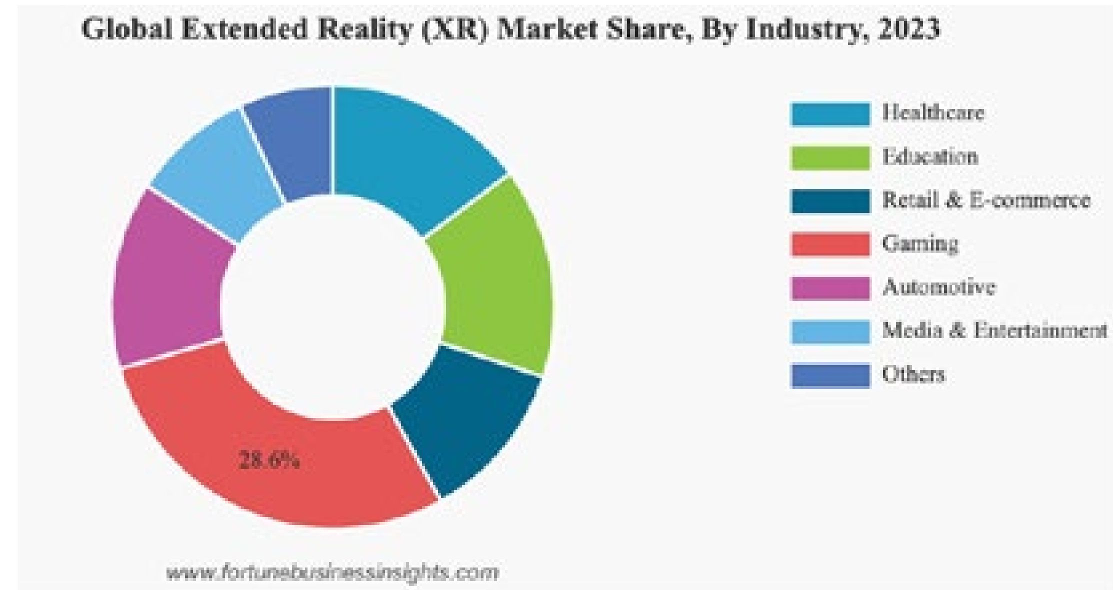

Pedagogy of XR and Immersive Technologies

In academic terms Metaverse could mean students and faculty participating in any of the XR technologies. Faculty could convert their entire class to XR, or they could implement XR into specific modules, activities, or assessments. Colleges and universities have fully developed virtual XR campuses, referred to as a digital twin of their actual campus. Morehouse College has implemented this strategy and has successfully created a digital twin, where students can take classes, and browse around the campus virtually. They have reported highly favorable response from students, and have used XR to engage at-risk students, and have used this technology to help with student retention.

Studies across the academic world have shown that implementing XR into the curriculum helps engage students, beyond passive online learning. It adds social interaction and presence to students, who may otherwise be disengaged. Engaging in a Metaverse, using avatars instead of their video, or picture, students feel more confident, and less conscious of their appearance.

Implications of using XR Technologies

Post-secondary education is entering a critical period vis-à-vis the technologies available for teaching our students. As with the advent of audio-visual technologies in the early to mid-20th century - and their associated capabilities in terms of active learning strategies in the classroom - we are now presented with technologies and platforms that can combine the best elements of Edgar Dale's classic construction of the "cone of experience" for student learners. By moving educational activities beyond "verbal symbols" (reading, lectures) at the more passive end of the spectrum, audio-visual technologies expanded the repertoire of teaching to include materials that aid in the development of knowledge retention (audio, photographs, film, video) (Kaplan-Rakowsi, & Meseberg, 2019; Washington & Shaw, 2019). VR, AR and MR simulations and experiences can expand on the strengths of audio-visual materials, and allow for pedagogical practices that integrate the totality of strategies for teaching students. Students can engage themselves in course content that not only includes texts, sound, and video, but can also include immersive and interactive simulations that replicate three dimensional objects, social situations, clinical interactions, historical reconstructions, cultural performances, rituals, and geographic locations that would be completely inaccessible to students otherwise (Bailenson, 2018; Washington, & Shaw, 2019; Wilson, 2019).

The DICE Framework

VR pioneer Jeremy Bailensen (2018) further outlines the utility of virtual reality in facilitating access to locations and experiences that would be unavailable to students otherwise. VR and AR technologies allow students to explore a range of phenomena and processes in environments that are dangerous, impossible, counterproductive, or expensive, and rare. His "D.I.C.E." framework is a useful rubric for designing VR experiences, as well as for planning how to integrate them into the classroom. Dangerous environments could range from flight simulators to disaster areas, as well as natural disasters and battlefields. Impossible experiences could include historical reconstructions and other places that would not be accessible under normal circumstances. Counterproductive simulations involve socio-cultural situations that could be awkward or dangerous for participants. And finally, Expensive experiences could include virtual excursions to places that would be prohibitively expensive for most people to visit. Overall, the DICE principle can be a useful rubric for determining which immersive learning modules could be productive in an

educational setting.
Experience-based Learning Modules
Authors of this white paper propose to create four distinct kinds of experience-based learning modules for students in our general education courses. These use cases have proven to be the most effective in delivering active learning experiences in a range of different settings:

3D Models

VR-based simulations that feature interactive 3D objects and structures give students the opportunity to have a virtually real interaction with the objects under study - such as the structures of blood cells and antibodies, or the design, manipulation and deployment of complex machinery, for example. Saunders and Bennet (2019) reported that 94% of their students felt that the VR component of the course enhanced their learning experience in their cell biology course. This could also prove useful in other courses that involve inaccessible objects, such as archaeology, anatomy, physics, engineering, geology and history.

Social Interactions

Social science and humanities courses could also benefit from creating immersive, interactive simulations that immerse students in socio-cultural phenomena beyond reading about them or hearing about them in lectures. Schulze, et al. (2019), found that having a group of students embody (virtually inhabit) an avatar of a different gender in virtual reality and interact with a range of "characters" was an effective means to test the ability of VR to facilitate changes in implicit gender bias. Those students who participated in the VR experience showed a remarkable reduction in implicit bias, as evidenced in the subsequent Implicit Association Test. This use case has also recently been applied to implicit bias in terms of race and ethnicity, with similarly positive results (Banakou, Hanumanthu, & Slater 2016; Chen, Chan, & Tan 2021; Martingano, Brown, & Persky 2023). Though research in this field is still emergent, it is already apparent that immersive experiences in VR can be a powerful tool for assessing and improving understanding and empathy across racial, ethnic, generational and gendered barriers (Washington, & Shaw, 2019). This could be an invaluable resource for general education courses in departments such as anthropology, psychology, sociology, human development and women's, gender and sexuality studies at Cal State Long Beach.

Virtual Field Trips

One of the most impactful uses of VR production technologies has always been for virtual field trips to inaccessible places.

These can take the form of either computer-generated content or documentaries created from live action 360° video. Some of the more famous examples of VR documentaries take place in locations such as refugee camps, war zones, inaccessible places (like Chernobyl, for example), or places that most people cannot afford to visit (such as World Heritage sites). While not the same as actually "being there" and experiencing these locations in person, VR documentaries can provide a reasonable, accessible facsimile of the places in question, with all of the sights, sounds and spatial dimensions that make these projects so immersive.

Simulations

XR technologies can be a powerful way to realistically re-create immersive real-world environments and systems. This is one of the most popular uses of immersive media, as it allows for virtual dissections, industrial training, or anatomical explorations in non-destructive ways. Immersive simulations allow educators to expose students to complex structures and systems – structures and systems that can be manipulated, taken apart and rebuilt in a repetitive fashion. These understandings and skills have been found to be readily transferable to real world situations – as immersive simulations enable the embodiment of knowledge and skills.

Challenges of Using XR Technologies

Although extended reality has many potential benefits, including improved learning and collaboration, it also faces challenges like high costs and hardware limitations. Below is the list of main challenges faced by both developers and users of the XR technology.

High Cost and Hardware Limitations

XR headsets and development tools can be expensive, limiting widespread adoption, particularly in consumer markets. Such technologies are expensive to develop and manufacture. In addition, XR depends on many technologies, software, and components, making it difficult to create the necessary hardware (sources: AI Multiple, Etelligens Technologies) Hardware limitations include system latency, resolution constraints, and short battery life which can impact the user experience, and usability in extended sessions.

Technical Complexity

Developing high-quality XR experiences requires specialized skills in 3D modeling,

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programming, and interaction design. The technical complexity arises due to the need to integrate multiple hardware, software, and network components, often requiring specialized expertise to develop and implement high-quality experiences, including challenges with device configuration, content creation, user interaction, and seamless integration with existing systems, particularly in enterprise environments.

Initial Setup Issues

A significant challenge in implementing an effective Metaverse initiative are the initial teething technical issues – from acquisition, and set up of the hardware, like the VR headsets, having them properly adjusted, set up and apps installed, to ongoing maintenance and troubleshooting. It is recommended that faculty and students receive support from trained technicians in setting up and running of the VR headsets – at least initially. At Cal State Long Beach, faculty and students are supported in the ISPACE which offers a carefully set up XR lab, and ISPACE technicians are available to help faculty set up VR devices in classrooms.

Physical Limitations and Accessibility

Physical constraints related to user comfort and ergonomics may limit the use of XR (source: HQ SoftwareLab) In particular, wearing XR headsets for long periods can cause discomfort due to weight and pressure points. Some users may experience nausea or visual strain when using XR devices, especially with rapid movement within virtual environments. In addition, some key ADA concerns include the over reliance on motion controls, requiring specific physical positions like standing or sitting, difficulty with precise interactions, challenges for users in wheelchairs, and potential issues with visual and auditory cues, all of which can significantly limit users with disabilities from fully engaging with XR experiences.

User Experience

XR users may experience confusion or have a steep learning curve. This is caused by the spatial awareness of the user being challenged by the immersive and dynamic environments, which can potentially result in cognitive overload (Deshpande, 2024) The term "cognitive load" refers to the amount of mental effort required to understand and process any given type of information. In XR environments, users are bombarded with visual, auditory, and sometimes tactile stimuli, which can lead to cognitive overload, where the brain struggles with processing and navigating intricate virtual spaces (Gupta et al, 2022). When cognitive overload occurs, users may experience confusion, finding it difficult to understand how to interact with the XR environment. They may also experience disorientation, struggling with navigation, or feeling spatially disoriented. Additionally, cognitive overload can lead to reduced engagement from users, causing a decrease in immersion and enjoyment due to frustration or confusion (Deshpande, 2024).

Privacy Concerns

XR devices collect large amounts of personal and environmental data that can be used to identify users and infer sensitive information about them (source: AI Multiple). This raises concerns about data security and privacy violations. Among the data collected by XR devices are biometric (i.e., eye tracking, iris identification), location (i.e., GPS), movement (i.e., tracking of head, hand, and body movements), audio (i.e., recordings of voice and other sounds) and environmental (i.e., spatial data about a user's surroundings). This data can be used to discriminate against users and/or create targeted advertising, posing potential privacy risks including digital fingerprinting, data misuse, cyberattacks, and deepfakes.

Standardization Issues

Lack of industry standards for development and compatibility between different XR platforms can hinder widespread adoption and limit the potential of XR technology in various industries. These issues primarily relate to the lack of consistent protocols for hardware, software, including device specifications, content formats, interaction methods, network protocols, privacy and security, and user interaction across different XR devices and platforms. The standardization issues lead to challenges in developing cross-platform applications, ensuring compatibility, and creating a cohesive user experience across diverse devices.

Ethical Considerations

There are several ethical considerations around the use of XR (source: AI Multiple) These include concerns about user privacy, the potential for mental health impacts, the potential for misuse in criminal activity, issues of equity and access, manipulation of users through virtual environments, and the ethical implications of developing immersive experiences that could blur the lines between reality and virtuality.

While technical challenges like hardware limitations and user experience remain, extended reality market opportunities abound in sectors such as industrial training, virtual events, and immersive storytelling, driving innovation and growth in the extended reality market recent developments.

Integrating XR into the Classroom

Cal State Long Beach has invested in multiple ways to enhance the usage of XR in the classroom. A dedicated Innovation Space (ISPACE) was established which provides the faculty, and students, along with many other technologies, full access to AR, VR, and XR technologies and tools. Established fully through donor funding, the ISPACE is centrally located in the University Library building, it offers an Extended Reality (XR) lab for students and faculty to engage in, and develop AR/VR projects and experiences. VR headsets are also available to use in the XR lab, or for check-out to faculty to use in their classrooms. The ISPACE also offers a sophisticated 360 theater which provides an immersive experience to students and faculty without having to wear a VR headset. To extend the VR experience, two podcasting studios have been set up in the ISPACE. These podcasting studios provide a well-equipped, and reliable space for students to be able to add audio and video to their AR/VR projects.

Over the past two years, the University has encouraged and funded various Metaverse projects. Cal State Long Beach's Metaverse initiative has funded faculty usage and implementation of XR technologies across the entire campus. Funds have been allocated and provided to develop content through XR content development vendors such as VictoryXR, and Curio XR. Faculty also receive pedagogical and technical support from instructional designers and techs in developing and implementing their XR projects.

To support faculty and students on the hardware and technology front, here are a total of 75 Meta (previously Oculus) headsets in the ISPACE inventory, which are used within the facility and are checked out to faculty, and students. In addition, the XR lab has a sophisticated Powerwall and Motion Tracking System, which enables faculty and students to use real-time motion capture, tracking speed, and angles, and target groups placed on body. The XR lab's motion capture technology has been most effective for specific usage in departments including dance, kinesiology, film, and bioengineering.

In addition to the XR lab, and 360 theater, the most important function of ISPACE is to provide technical and instructional design support to the faculty. At Cal State Long Beach, Academic Technology Services (ATS) instructional designers provide pedagogical consultation and support to faculty and assist in the integration of AR and VR into the curriculum. Instructional designers work with faculty in developing VR projects and assessments for their classes. Tech support in usage of hardware and XR devices, including support in using software and XR apps is provided by the ISPACE staff who are resident experts in using and troubleshooting the otherwise complex XR devices.

For a metaverse, or XR initiative to succeed at an educational institution, the baseline is to have an effective technical infrastructure. This includes hardware, VR devices, headsets, high-end computers, as well as software, and apps to effectively run XR projects. In addition to the technology, it is imperative that (XR) content development, and instructional design support is provided to faculty, along with prompt tech support for both faculty and students.

Content Development

For XR to be effective, the content must be developed or selected to align with specific learning goals. There are three major pathways to XR content development: custom in-house, third-party off-the-shelf solutions, and custom content commissioned from XR vendors.

In-house XR Content Development

In-house XR content development offers institutions full control over creating tailored experiences for their curriculum. Key tools for XR development include game engines like Unity and Unreal Engine. Low programming platforms, such as EON-XR, allow educators to create XR content with minimal programming, offering drag-and-drop interfaces and easy updates. An emerging solution, Curio XR streamlines development by providing pre-built infrastructure. All of these tools require faculty to invest time in learning the platform and preparing assets. In-house XR development provides flexibility and ownership but demands technical skills and can be time-consuming. At Cal State Long Beach, instructional designers work in partnership with faculty, and their students in assisting them with in-house XR content development.

Third-party XR Platforms and Content

Third-party XR platforms and content solutions offer a quicker way to integrate XR into education by providing ready-made experiences and tools for teaching and training. Companies like VictoryXR provide a library of VR content across various subjects and enable virtual classrooms

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through platforms like ENGAGE. Labster offers virtual science lab simulations for subjects like biology and chemistry, enhancing student engagement and skills through risk-free, interactive experiments. Companies like GigXR and Osso VR offer AR and VR applications for healthcare and surgical training. While third-party XR content offers immediate availability and lower development overhead, it may not perfectly align with unique curriculum requirements. Additionally, there may be ongoing licensing costs. Cal State Long Beach has partnered with content vendors including VictoryXR, and Curio XR in acquiring XR content for various Metaverse projects.

Custom XR by Vendor

Custom XR by vendor is a popular middle ground. In this model, universities hire a third-party XR vendor to develop customized content. The institution provides subject expertise, learning goals, and specific requirements, while the vendor handles the content creation. This approach allows institutions to access high-quality, tailored XR experiences without the need for in-house development. When working with a vendor, there are several important considerations to keep in mind: (i) contracts should clearly define ownership of intellectual property, licensing rights (exclusive vs. shared), and responsibilities for updates and maintenance; (ii) pricing will vary based on the scope and complexity of the project; and (iii) timelines will depend on the size and scale of the project. Cal State Long Beach has developed a relationship with content providers such as VictoryXR, and Curio XR, with numerous Metaverse projects already developed and underway.

XR Content Development Comparison Table

	In-House Build	Custom By Builder	Third Party (Off shelf)
Customization	Full Control	High: Tailored to Your Course	Limited
Speed to Deploy	Slow (weeks/months)	Medium	Immediate
Technical Skills Needed	High (Unity, Unreal, etc.)	Low- Vendor Manages	Minimum
Cost	-High upfront for learning -Low long-term	Very high upfront	Moderate licensing fees
Pedagogical Fit	Precise alignment	Strong alignment if collaboration is strong	General purpose
Ownership	Yours	Negotiable	Vendor-owned
Maintenance	Your responsibility	Often included in contract	Vendor-managed

Instructor Training
Training for faculty in XR technologies is essential for ensuring successful integration into education. A comprehensive training program will help users understand XR tools, optimize learning experiences, and navigate potential challenges.

Technical Training
Instructors should learn how to operate XR devices, launch applications, and trouble-shoot basic issues to ensure smooth class-room experiences.

Pedagogical Integration
Faculty need guidance on aligning XR expe-riences with learning objectives and creating supporting materials such as assignments, and assessments.

Classroom Management
Instructors should be trained to organize physical space, schedule headset use, and ensure accessibility and comfort for all stu-dents during XR activities.

Collaboration with XR Support Teams
Instructors benefit from working with in-structional designers, IT staff, or XR labs to co-design content and receive ongoing tech-nical support.

Student Training
Student training is just as essential as faculty training. The following are some pointers on student training.

Device Orientation
Students should be introduced to XR hard-ware through hands-on tutorials or demo sessions that cover controls, navigation, and safety.

Comfort and Safety Guidelines
Guide students on safe XR usage, how to identify signs of physical discomfort (such as motion sickness or eye strain), and what to do if they need an alternative learning op-tion.

Ongoing Assistance
Provide students with access to XR help resources, such as quick-start guides, lab as-sistants, or peer mentors for extra support. Academic Technology Services (ATS) at CSU Long Beach provides training, professional development, and tech support for faculty and students on XR tools. The Academic Affairs- funded Metaverse Initiative has been pivotal in supporting faculty in the imple-mentation of XR technologies, by funding content development, and offering incentiv-ized professional development.

Guidelines For Educators on Integration of XR Technologies

Extended reality (XR) technologies like virtual reality (VR) and augmented reality (AR) can be used in the classroom to create immersive learning experiences (sources: Old Dominion University, CDW, Binmile) making education more interactive and engaging. These technologies integrated with curriculum immerses students in multisensory experiences, enhance student engagement and retention, and allow for safe exploration of complex environments. Even before the pandemic, K-12 schools and universities were experimenting with XR as a new teaching modality. Some uses for extended reality in education include but are not limited to virtual field trips, visualizing conceptual subjects, technical training, and tools for learning disabilities. The following section provides guidelines for educators to develop content and integrate XR technologies in their curriculum.

Identifying Learning Objectives

Key step for integrating XR into the classroom is to determine what content and learning outcomes would benefit from XR. The learning objectives include enhancing engagement and retention through immersive experiences, developing critical thinking and problem-solving skills by simulating real-world scenarios, fostering creativity and innovation through exploration within virtual environments, improving collaboration and communication skills through shared XR experiences, as well as building digital literacy and technological competence by interacting with digital content in a hands-on way. In addition, XR education facilitates practical training in safe, controlled environments by providing realistic simulations across various fields like healthcare, engineering, and manufacturing.

Assessing Technology

The content developers should also consider the affordability, ease of use, and compatibility with existing technology. A challenge to implementing XR technologies is the cost of the equipment used to experience immersive content. While VR headsets are becoming more affordable, many still require a computer with a high-powered graphics processing unit (GPU) and the software required to build and run the applications. It is key for institutions to create XR or VR labs that provide access to these devices in a centralized location. Proper administrative controls should also be in place to prevent malicious software from being installed but still allow these XR applications to update regularly. In addition, the ease of use of XR technology strongly influences its effectiveness for learning. User-friendly interfaces allow for better engagement and comprehension, especially for learners who might be unfamiliar with complex technology, ultimately leading to more positive learning outcomes.

Providing Professional Development and Training

Another key aspect is to ensure teachers are trained in how to use XR technologies. Professional development should focus on introducing the teachers and educator to Extended Reality (XR) technologies like Virtual Reality (VR) and Augmented Reality (AR), teaching them how to integrate these tools into their curriculum, and providing practical skills to design engaging and effective XR learning experiences for their students, covering aspects like content creation, accessibility, and assessment and evaluation strategies within the XR environment. Potential professional development activities include hands-on workshops, case studies and demonstrations, mentorship and collaboration, online learning modules, and campus-wide implementation projects and symposiums.

Creating Content and Integrating it with the Existing Curriculum

This component of content creation starts with developing teaching materials that align with XR and the existing curriculum. This requires learning basic 3D modeling and design tools; developing interactive 3D environments and simulations relevant to the subject matter; and incorporating audio, video, and text elements into XR experiences. The final step is to integrate the developed modules with the existing course or lab component. This includes: (i) identifying appropriate learning objectives for XR experiences; (ii) strategies for aligning XR activities with existing curriculum standards; and (iii) developing engaging XR lessons across different subjects (science, history, math, art, etc.).

Considering Accessibility

Equitable access is one major benefit, and a challenge for extended reality in education. Through XR, pricey experiences like field trips to other countries and complex science experiments could be accessible to many more students in a virtual world. But educational institutions should ensure that XR experience is accessible to all learners. Creating and maintaining centralized locations on campus that provide access, and support is

a major step toward accessibility. In addition, interface development is critical for accessibility, such as captioning for users who are deaf or hard of hearing, and for controllers that are usable for those with mobility impairments. Generally standardized interfaces make a technology easier to use, as the interface is likely to be familiar even to a newcomer (Everett M. Rogers, 2003; J.R.R. Tolkien, 2019; Means et al., 2009).

In addition to the guidelines described above, educators and teachers should also consider the ethical and physical implications of XR technologies when integrating in their curriculum. These aspects are discussed in the next section.

Ethical Concerns in XR

As XR technology becomes more widespread across industries such as education, entertainment, and social networking, it introduces ethical challenges that must be addressed. Key concerns revolve around privacy, psychological effects, and social interactions. Below is a summary of these concerns and recommended solutions.

Privacy and Data Security

VR systems collect vast amounts of user data, including biometric information, movement tracking, and behavioral patterns. Without proper regulations, this data can be misused for unauthorized surveillance, targeted manipulation, or identity theft (Skulmowski, 2023).

Recommendations:

- Develop strong data policies that ensure transparency on how VR platforms collect, store, and use personal data.
- Use deidentification algorithms to anonymize sensitive user data and prevent exploitation
- Implement clear user consent mechanisms for data collection to ensure ethical compliance.

Psychological and Behavioral Effects

The immersive nature of VR can alter users' emotions, behaviors, and cognitive states, potentially leading to desensitization, behavioral manipulation, and addiction (Madary & Metzinger, 2016). Research suggests that embodied experiences in VR can shape attitudes and behaviors beyond the virtual environment, reinforcing both prosocial and antisocial tendencies.

Recommendations:

- Limit session duration to prevent over-immersion and psychological detachment from reality.
- Incorporate ethical design features that allow users to adjust their VR experience and maintain autonomy.
- Encourage reflective interactions by designing VR environments that promote awareness and critical thinking rather than passive engagement

Social Interaction and Harassment in Virtual Spaces

VR enables embodied interactions, making social experiences more immersive, but also more susceptible to harassment, manipulation, and exclusion. The lack of clear governance in VR platforms can lead to misuse of anonymity, cyberbullying, and inappropriate behaviors (Blackwell et al., 2019).

Recommendations:

- Develop strong governance models to regulate user behavior and provide clear guidelines for ethical interaction.
- Educate users on ethical conduct and introduce built-in reporting tools to address harassment in real time.

Participation Etiquette

While policies and design safeguards address ethical challenges in VR, responsible user behavior is equally crucial. Research on communication in embodied VR underscores the role of nonverbal cues and spatial awareness in shaping positive interactions (Smith & Neff, 2018). The following are some guidelines to help ensure a safe and respectful experience:

1. Respectful Participation:

- Be Aware of Personal Space: Maintain appropriate distance in multiplayer VR or shared environments.
- Present Yourself Professionally: Choose avatars and behaviors that align with the setting.
- Minimize Disruptions: Mute your microphone when not speaking to reduce background noise.
- Protect Privacy: Avoid recording, taking screenshots, or sharing VR content without consent.
- Report Concerns: Inform instructors or moderators about technical issues or inappropriate behavior.

Participation Etiquette (cont'd)

2. Communication and Interaction:

- **Speak Respectfully:** Use polite and professional language in voice and text communication.
- **Actively Participate:** Engage in discussions and activities as you would in a real-world setting.
- **Acknowledge Others**: Use gestures or verbal cues to recognize and interact with others.
- **Be Patient with Connectivity Issues:** If someone appears unresponsive, they may be experiencing technical difficulties rather than ignoring you.

Assessment

Virtual Reality (VR) is increasingly recognized as a powerful tool for improving student learning in higher education. To effectively measure student progress, VR assessments must align with specific learning objectives, ensuring they provide meaningful insights into student performance.

These assessments generally fall into two categories:

1. **Formative Assessments** provide real-time feedback, allowing students to adjust and improve their learning throughout the process.
2. **Summative Assessments** evaluate overall knowledge and skill acquisition at the end of a module, measuring final learning outcomes.

VR-based assessments take different forms depending on the skills and knowledge being evaluated:

- **Skill-Based Evaluations** focus on practical, hands-on learning through simulations and interactive virtual tools.
- **Concept Understanding** assesses theoretical knowledge using VR quizzes, 3D models, and interactive experiences that test comprehension.
- **Collaboration Assessments** measure teamwork, communication, and problem-solving in shared virtual environments, allowing students to engage in real-time decision-making and cooperative tasks.

To assess student performance effectively, key performance indicators such as task completion rates, accuracy levels, engagement metrics, and problem-solving abilities help quantify learning outcomes in VR environments. Task completion rates measure how efficiently students complete assigned VR tasks, while accuracy levels assess their precision when interacting with virtual tools and environments. Engagement metrics track participation, time spent in VR, and interaction levels, whereas problem-solving abilities evaluate decision-making and critical thinking within VR scenarios. These indicators provide a structured framework for evaluating students' ability to interact with and navigate VR-based learning experiences.

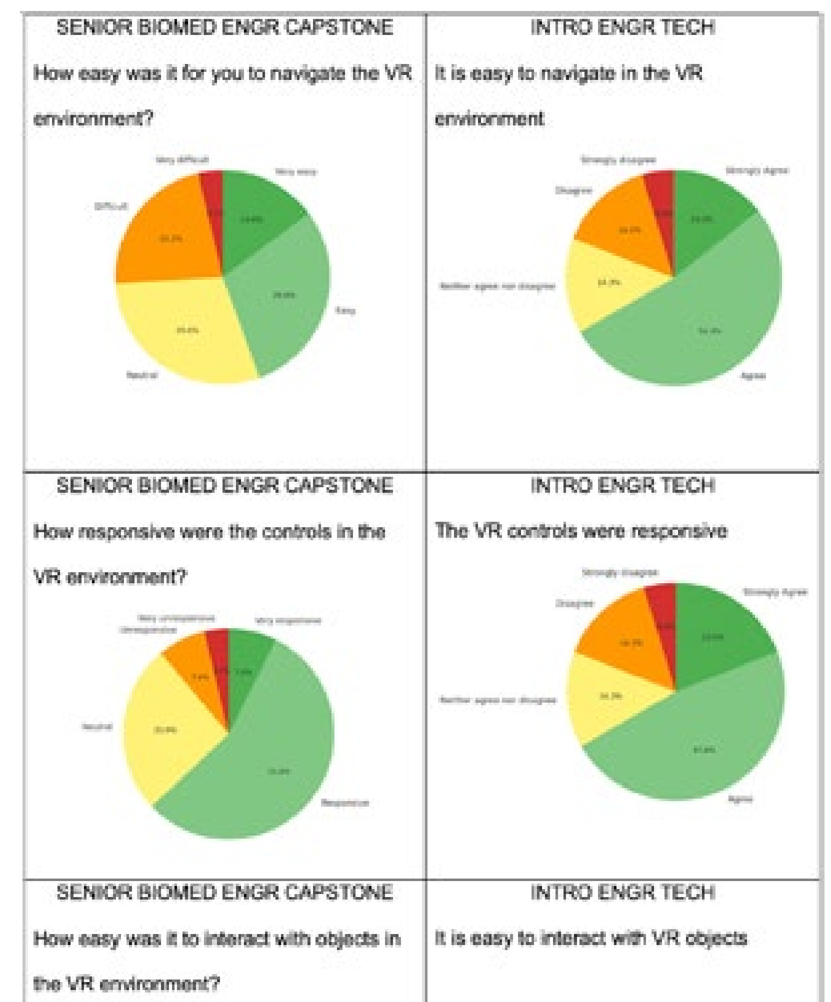
Assessment of VR Presentation Skills in Introductory Engineering Class

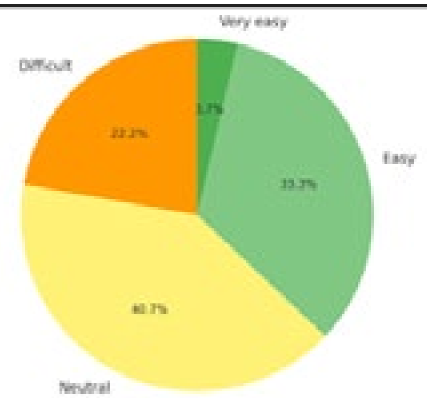
Using these performance indicators, a VR presentation assessment was conducted for the Intro to Engineering Technology class to evaluate students' ability to create and deliver content within a virtual environment. Before preparing their presentations, students participated in two 50-minute VR sessions to familiarize themselves with the tools and environment. The results indicate strong proficiency in core VR tasks, with students achieving an average score above 90% in importing environments, spawning and moving models, creating notes, and recording their VR presentations. These high scores suggest that students effectively utilized VR tools to construct and document their presentations, demonstrating their ability to engage with the platform in a meaningful way. Some challenges, however, were observed in rotating models and avatar movement/teleportation, where students scored an average of 85%, indicating minor difficulties in precise object manipulation and navigation. Nonetheless, the assessment demonstrates that students adapted quickly to VR technology, developing a solid foundation in VR-based presentation skills within a short time.

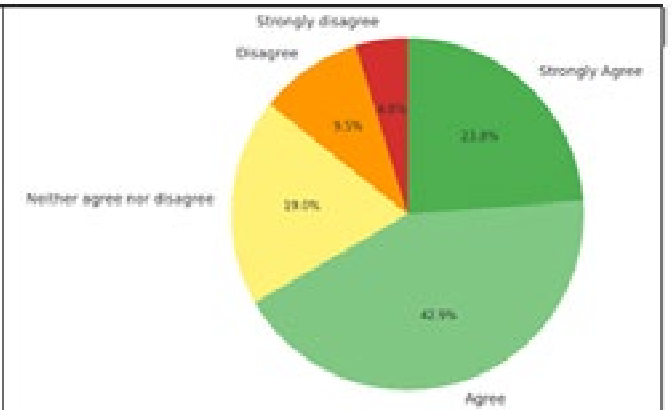
While performance metrics provide valuable insights into technical proficiency, the overall user VR experience is equally crucial in determining their effectiveness. A well-designed VR environment must be intuitive, engaging, and accessible to enhance student interaction, ensuring that users can focus on learning rather than struggling with the interface. The way students interact with VR tools across different educational levels offers critical insights into usability, engagement, and the impact of VR as a learning platform. Understanding these factors can help refine VR-based assessments, making them more effective for students with varying levels of expertise.

Survey of User VR Experience

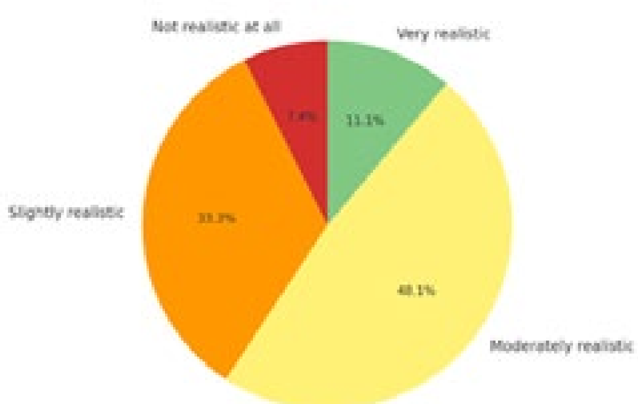
To assess the effectiveness of VR as a platform for collaboration, presentation, and demonstration, a user experience survey was conducted in 2024 across two engineering classes: Introduction to Engineering Technology, and Senior Biomedical Engineering Capstone. The survey examined user experience, engagement, and the applicability of VR across different levels of engineering expertise. The introductory class included students with less advanced technical skills, while the senior class comprised students working on specialized, field-specific projects. Both groups utilized the VictoryXR platform and Meta Quest 2 headsets, providing a controlled environment for evaluating the usability and effectiveness of VR-based learning experiences.

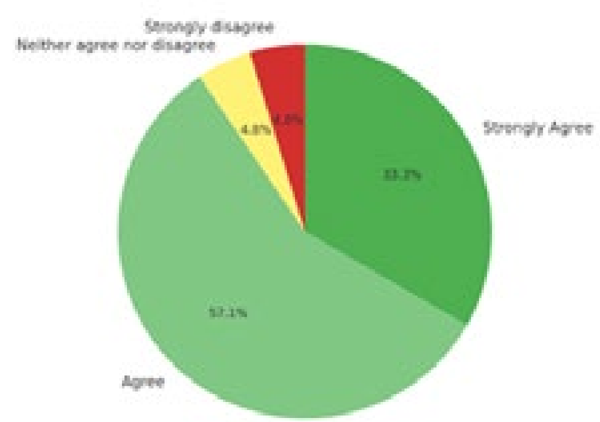






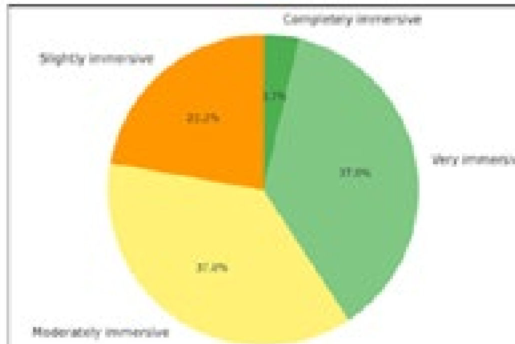
SENIOR BIOMED ENGR CAPSTONE	INTRO ENGR TECH
How realistic did the visuals and graphics appear in the VR environment?	The way that objects and spaces look and feel made sense to me

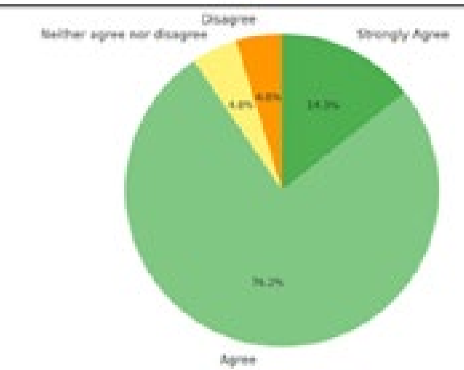


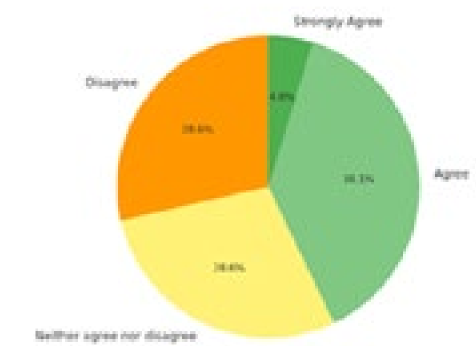


SENIOR BIOMED ENGR CAPSTONE	INTRO ENGR TECH
How immersive did you find the VR experience?	I felt like the objects in the room surrounded me I lost track of time

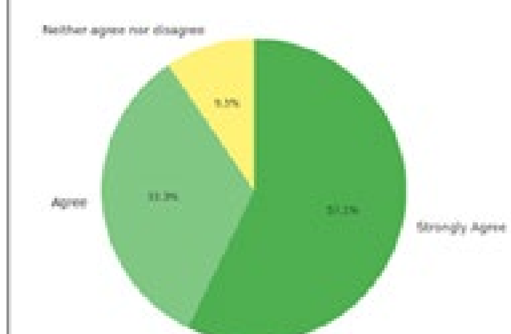
Metaverse and XR at CSULB





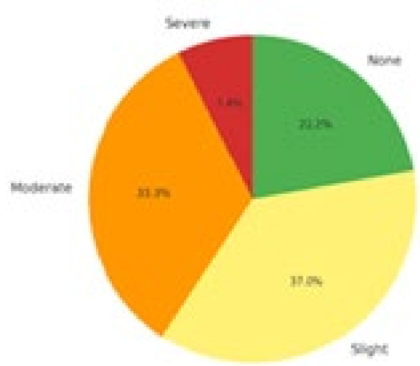


I could examine objects from multiple angles



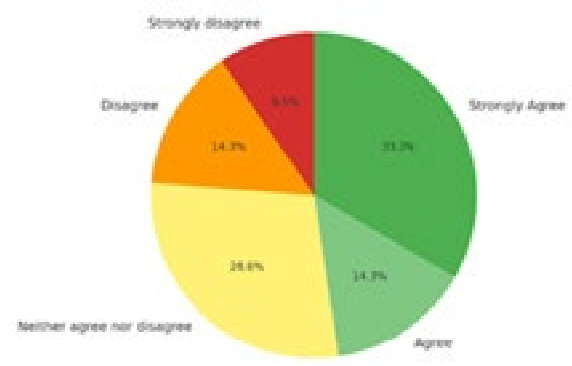
SENIOR BIOMED ENGR CAPSTONE

Did you experience any discomfort or motion sickness while using VR?



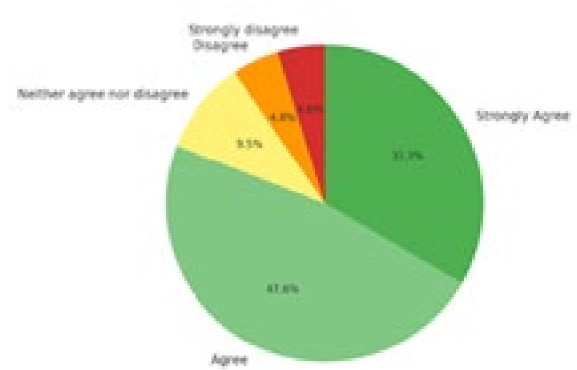
INTRO ENGR TECH

The VR experience felt comfortable (e.g., no motion sickness or headaches).



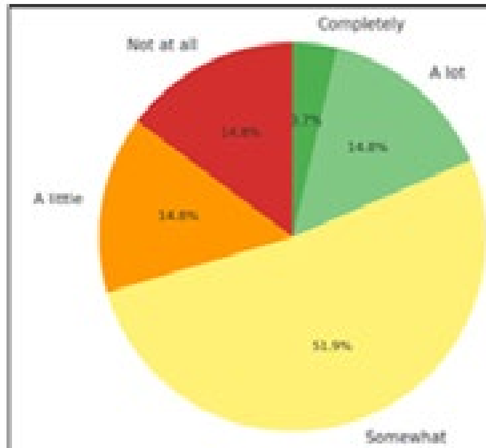
INTRO ENGR TECH

I easily got my tasks done



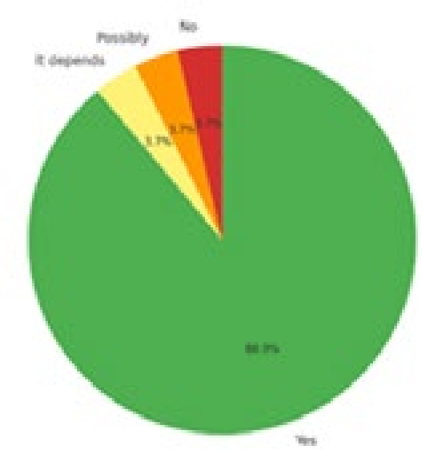
SENIOR BIOMED ENGR CAPSTONE

Did you feel the VR experience enhanced your understanding of a subject or task?



SENIOR BIOMED ENGR CAPSTONE

Do you think VR can be useful in learning or solving problems in your field?



Key Findings:

- More than half of the students in both groups had prior experience with VR.
- Introductory students found the VR experience to be more realistic.
- Senior students expressed greater confidence in VR's potential for real-world applications within their field.
- Both groups reported generally positive experiences in:
  - Ease of navigation within the VR environment.
  - Comfort during use.
  - Responsiveness of VR controls.
  - Ease of interacting with virtual objects.
  - Immersion, with a strong sense of presence in the virtual environment
- Memorable Aspects:
  - Both groups highlighted interacting with classmates in shared virtual spaces as the most memorable part of the experience.
  - The senior design students frequently mentioned enjoying activities like group presentations, collaborative content creation, and brainstorming sessions.

Conclusion

Overall, the survey highlighted a strong similarity in user experiences across both groups, with students sharing positive perceptions of VR. At the same time, senior students expressed greater confidence in VR's potential for real-world applications, showcasing its relevance for advanced field-specific projects.

Measuring the Success of Immersive Education Initiatives

Adopting the guidelines to develop content and integrate XR technologies in the curriculum, and following recommendations for creating effective immersive learning environments, along with continuous evaluation will unlock the full potential of immersive education and prepare students for success. To measure the success of XR education, educators can analyze various factors including student engagement and performance metrics like test scores, completion rates, time spent in the XR environment, qualitative feedback through surveys, observations of student behavior within the XR experience, and comparisons between XR learning outcomes and traditional methods; all while considering the specific learning objectives and context of the XR application.

More specifically, the following tools can help the educators to assess their XR teaching initiatives (IXRLabs). Learning

- Outcomes:
  Educators can assess students' learning

outcomes to determine the effectiveness of XR integration. Comparing the performance of students who experienced immersive education with those in traditional learning settings is a good practice.

- Student Feedback:
  Educators can gather feedback from students about their experiences with XR technologies. This includes using surveys or interviews to understand their perspectives on engagement, comprehension, and enjoyment of the immersive learning activities.
- Educator Observations:
  Educators can be encouraged to observe students' behaviors and interactions during immersive experiences. Some examples include collecting qualitative data on student engagement, collaboration, and critical thinking.
- Long-Term Impact:
  Educators can monitor the long-term impact of immersive education on students' attitudes toward learning and academic performance.

Future Goals and Implications

For Metaverse and XR initiatives to succeed at a campus, support from senior leadership is very important. This includes strategic initiatives that encourage, facilitate, and incentivize faculty to adopt these technologies and tools. At Cal State Long Beach, the President, and the Provost have highly supported the Metaverse initiative over the past several years. One such initiative that has garnered participation from several colleges is titled the Metaverse Initiative, and is spearheaded by Academic Initiative, and is spearheaded by Academic Technology Services, in partnership with key academic stakeholders including Deans, and senior administrators across the campus. This initiative is funded by Academic Affairs, and offers specific monetary incentives to faculty for participating in XR initiatives, and specifically incorporating XR into their curriculum. The Metaverse Initiative also is a means of funding internal and external content development efforts that have previously been discussed in this paper.

XR is the new medium in which courses can be taught, in an engaging and rich environment which enriches student learning. It may not be for every student, every faculty, or even every course or discipline - the same as online, or hybrid learning is not for everyone. Teaching in the metaverse can help elevate student retention, and engagement, but it comes with its challenges. Technical issues are common when adopting any new technology – XR is no different. In fact, it requires more training and getting used to, by the faculty, and as mentioned earlier in this paper, and requires ongoing technical, and instructional design support. Faculty professional development is necessary, and it must be provided in advance to prepare faculty to use these technologies in the classroom.

While it may be ideal to bring XR technologies into the classroom, at CSULB we have experienced that faculty and students have the most conducive XR experience when they use these technologies in the XR Lab in ISPACE. While ISPACE provides VR devices for checkout for faculty and students, however, it is recommended that faculty conduct their classes in the XR Lab, which has the most favorable technology setup, and offers skilled staff at hand to help students and faculty.

From an institutional standpoint, a centralized Metaverse support infrastructure works most effectively. It creates an environment which is well supported technically, and from the instructional design perspective, and it ensures that departmental implementation of XR technologies align with central and campus-wide hardware and software standards. Having standardized XR hardware and software helps provide effective support to all units, and also works well when negotiating bulk pricing of hardware and devices. XR content also becomes shareable on similar devices. At Cal State Long Beach, a significant investment has been made on Meta headsets, with approximately 75 headsets available for use at the ISPACE. Departments and colleges across the campus have followed suit, and have acquired Meta headsets.

Recommendations for Creating an Effective Immersive Learning Environment

Although each XR experience is unique, the following guidelines can benefit educators for creating effective immersive learning modules.

1. Educators should focus on creating immersive experiences that actively engage students and encourage interactivity. They should design experiences that allow students to interact with virtual objects and make decisions that impact the learning process.
2. Educators should incorporate storytelling and narration in XR experiences to provide context and create compelling narratives that draw students into the virtual environment.
3. Designing XR activities that promote collaboration and communication among students creates a sense of shared learning and teamwork within the immersive environment.

Finally, ensuring that XR experiences are relevant to real-world applications and showcasing the practical implications of the concepts being taught are key to an effective immersive learning environment (IXRLabs)

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