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Designing Immersive Labs and Programs for Higher Education

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Abstract: Immersive learning tools and technologies such as augmented and virtual reality are set to disrupt learning technology support and learning lab design for educational institutions and campuses. Campus facilities such as computer labs may not be properly equipped to utilize these new technologies to support emerging technologies as the design of these spaces, the implementation strategies, and technology requirements can be very different from more traditional computer-aided learning. This paper outlines a strategic approach to design and implement immersive learning labs in higher education settings, with a focus on virtual and augmented reality-enhanced content. It begins with a clarification of design concepts and initial program suggestions and ends with a range of setup and management tools for these labs.

Keywords: Immersive Learning, Learning Laboratories, Collaborative Online International Learning, Virtual Reality, Augmented Reality

INTRODUCTION

Background

Immersive technology and its many forms such as virtual reality (VR) presents exciting opportunities across various domains, including education. Despite growing interest, there is a dearth of comprehensive research on the adoption of immersive VR in many educational contexts, considering both high-end and low-cost head-mounted displays (HMDs) in higher education. This study proposes a systematic mapping approach to identify design components in existing VR/AR/MR facilitation models and spaces for learning. The increased usage of digital tools for teaching and learning has been particularly evident from 1997 to 2016, showcasing a paradigm shift from networked computers for cooperative learning to digital learning platforms (Radianti et al., 2020).

The great differences in how immersive technology is used have caused higher education institutions to begin experiments with new designs and activities in new spaces. To better understand how to best facilitate these new technologies for students, a look at the trajectory of technology and usage for learning, the benefits and risks of these technologies, and some ways to get started into these new types of learning are needed to be explored further. This study tries to take a comprehensive look at these trends to help institutions better develop spaces and programs using emerging immersive technologies like AR and VR.

Defining Immersive Learning

The term immersive virtual learning began to take shape after at least ten years of research on these technologies in educational settings, as meta-studies revealed that the concept was becoming more popular (Freina & Ott, 2015). Virtual was used in this sense to refer more specifically to simulated multi-user settings like Second Life. In various learning situations, interactive CAVE (Cave Automatic Virtual Environment) was just beginning to be used at this point (Manjrekar et al., 2014). Immersive learning has become a more popular word as the research community has developed and expanded (Gaspar et al., 2020).

Virtual reality (VR) has been the most widely used immersive technology and has been shown to have advantages in a variety of educational contexts. VR has a lot of promise and has been increasingly interested in its use in education (Zawacki-Richter & Latchem, 2018). For learning and education, digital devices are being used more and more. This was especially evident between 1997 and 2006 when networked computers were heavily utilized for collaborative learning, and between 2007 and 2016, when so-called interactive online learning gained popularity (Boulton et al., 2018). People looked at the exploitation possibilities of new technologies throughout these two time periods, including mobile devices and virtual learning settings. Increasingly, virtual reality (VR) and less so, augmented reality (AR) technology has become more present in teaching, learning, and education across a range of application fields (Radianti et al., 2020).

Although VR and AR are not new, recent advancements in immersive technology, particularly in terms of visualization and interactivity, have made these technologies more alluring to academics. The most recent VR head-mounted screens (HMDs), like the HTC Vive Series or Oculus Quest Series, enable users to immerse themselves completely in their virtual worlds. Instead, define this term as "a perception of being present physically in a non-physical universe by enclosing the consumer of the VR system developed with images, sound, or other stimuli" so that a participant begins to feel he or she is actually "there". Immersion explains the interaction of a user in a virtual world in which his or her understanding of time and the real world frequently become disconnected (Freina & Ott, 2015).

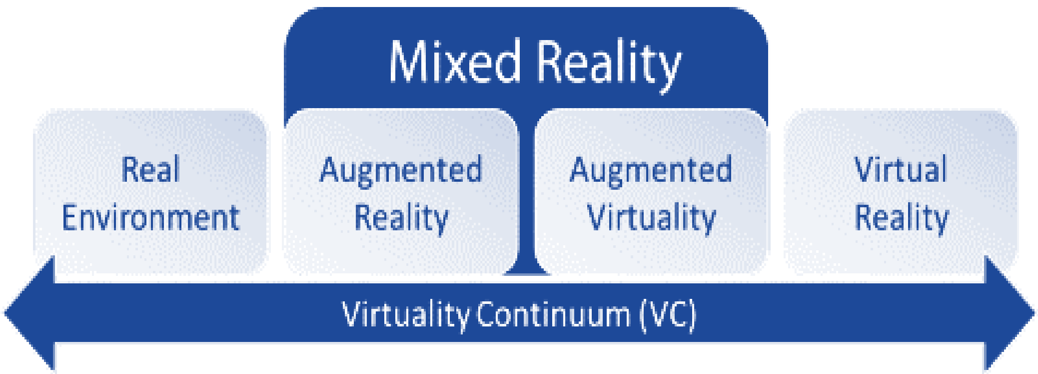

Figure 1. Reality-Virtuality Continuum

It is best to think about the reality-virtuality continuum described by Milgram, Takemura, Utsumi, and Kishino (Milgram et al., 1994), which is depicted in Figure 1, in order to differentiate VR from its sibling technology, augmented reality (AR). Think of a continuum where the real world is at one end and the virtual world is at the other. As the name implies, the real environment is the world in which people actually live, whereas the virtual world entirely submerges users inside a simulated reality full of artificial, synthetic items. Moving to the continuum's center, there exist environments that combine the actual with the virtual, which are referred to as mixed reality environments (MR).

Such settings can resemble augmented reality, where they contain a greater proportion of the real environment and digital things interact with real ones, or they might have a greater proportion of the virtual world with certain genuine objects present, creating augmented virtual (AV). The terms 'augmented reality', 'virtual reality', and 'mixed reality' describe different degrees of digital content integration into the real world. Although VR's inception is debatable, it began to take shape in the latter half of the 20th century, primarily for niche uses such as military training and aviation simulation. Flight simulators also enjoy a very early and high adoption in both professional and non-professional use (Aldrich, 2005; Valverde, 1968). It subsequently infiltrated various sectors, including gaming, entertainment, marketing, and advertising.

Benefits of Immersive Learning

Recent years have witnessed an increase in research on the advantages of VR headsets in particular for academic purposes contrasted to those of more traditional learning techniques due to technology improvement and better accessibility of virtual reality solutions. VR has brought about transformative changes in education sectors like science and medical education.

The use of interactive media, such as virtual reality, is supported by a number of pedagogical theories, including constructivism, situational learning, inquiry-based learning, game-based learning, and engagement theory. Constructivist learning is the first theory that is in line with VR integration in education. Constructivism encourages learners to develop their knowledge and understanding and to authenticate them through social negotiation, in contrast to earlier learning theories like behaviorism. It also views learning as an active, contextualized process of knowledge construction. The constructivist method of teaching and learning is supported by virtual reality because it enables students to build knowledge from rich and meaningful experiences (Ertmer & Newby, 2016). In understanding the role of Virtual Reality (VR) in education, revisiting Jonassen's (1994) interpretation of constructivism's implications for instructional design provides valuable insight into how VR fosters constructivist learning. Jonassen proposed that learning environments can facilitate knowledge construction by aligning with certain criteria:

Jonassen's Criteria for Knowledge Construction

- *Providing multiple representations of reality*
- *Representing the natural complexities of the real world*
- *Focusing on knowledge construction, not reproduction*
- *Presenting authentic tasks, thereby contextualizing rather than abstracting instruction*
- *Enabling reflective practice*
- *Encouraging context- and content-dependent knowledge construction*
- *Creating real-world, case-based learning environments*
- *Supporting collaborative knowledge construction through social negotiation, as opposed to competition among learners*

These guidelines reflect an approach where the emphasis is on facilitating learning through authentic experiences and collaboration, rather than fostering competition or rote learning. They underline the need for educational tools that offer learners the chance to interact with and reflect upon complex, real-world problems within a supportive, social context. VR technology, with its immersive, interactive nature, aligns well with these principles, promoting an engaging, constructivist approach to learning (Ertmer & Newby, 2016; Jonassen, 1994).

Immersive virtual reality with associated technologies enables instructional information to be presented all around the student, in contrast to traditional media like textbooks. Because it is virtual, the information is not constrained by the rules of physical reality or may thus be presented in creative ways that may be advantageous to students. For instance, readers of textbooks may find it difficult to grasp the visually and spatially complex field of neuroanatomy since there are only a limited amount of 2D representations of anatomical structures available. Although they contain a finite number of pieces and cannot be magnified to view certain aspects of interest, real anatomical models are not subject to this restriction.

Utilizing immersive technology wisely may eliminate these limitations and deliver student-centered education that is specifically designed and highly engaging, opening up new possibilities for learning assistance. However, there isn't much empirical research that has looked at how immersive learning differs from more traditional study approaches in terms of learning outcomes. Non-immersive virtual learning environments, like those seen on standard 2D desktop displays, have previously been shown to provide a variety of educational advantages. They may promote collaboration, spatial awareness, and contextual learning (Dalgarno & Lee, 2010) constructivist learning (Lee et al., 2010; Mikropoulos & Natsis, 2011), and learning transfer (Dede, 2009).

There is very little research on the use of virtual reality headsets for group learning. As a result, the promise of virtual reality headsets enabling group learning has not been fully realized, and it is suggested for further study as new spaces and laboratories are made to facilitate immersive learning in higher education.

One system that has been studied for group use in immersive environments is a CAVE. A CAVE is a space that submerges one or more people into a projected virtual environment. Using tiny see-through spectacles like those used in a movie theater and/or projection mapping in a physical room, the virtual world is often viewed in stereoscopic 3D. Space tracking can be done using special glasses and a 3D mouse. Users are now able to move their hands and heads naturally to explore and engage with the virtual world (Cruz-Neira et al., 1992).

CAVE**s** are ideally suited to immersive collaborative learning because of a number of features. CAVE**s** enable a blend of the virtual and the real by allowing users to concurrently observe their actual body, the bodies/faces of others, and the virtual world thanks to the use of see-through glasses, thus there is no requirement for an avatar that represents the user. This is different from modern virtual reality headset setups that cut the user off from their surroundings and often only track head and hand locations, which results in the loss or inference of the rest of the body's information. In contrast, groups of students may participate in immersive educational virtual environments whilst maintaining their body language, including their facial expressions, while utilizing CAVEs. As a result of the learners' ability to see and engage with one another as they usually would, this enables natural group interaction and fosters a clear understanding of co-presence (Back et al., 2020).

Dangers of Immersive Learning

Virtual reality and immersive virtual environments (VE) technology are being hailed as significant new tools for teaching and education. Communications, health, architecture, astronomy, data management, teleoperation, and entertainment are among further possible VE uses. Researchers in VR have already found that using VR can improve human sensory perception. This problem is comparable to the teleoperation of robots and machines where watching the environment using cameras and using artificial controls to do tasks alters our perception of it and how we behave. A smaller field of vision, various lighting conditions, and varied refresh rates are all imposed by these scenarios.

The best ways to address these issues are always being researched. Data gloves, various body trackers, and 3D displays with a broad field of vision are a few methods. All of these sensors, while helpful in creating immersion and providing feedback, are sensitive biometric data that could be dangerous if mistreated. One of the most significant issues with augmented and virtual reality is the loss of privacy. Privacy and secrecy are at risk since AR technology can monitor and gather far more information about a user and his or her environment. Compared to, say, social media platforms and potentially other technological tools, AR collects a great deal more data about the user and their behaviors (Kaspersky, 2021).

IMPLEMENTATIONS FOR FLEDGLING IMMERSIVE LABS

My Hometown Project

One project that was created for students of tourism as well as practical training for use in the tourist and hospitality industries has been now deployed in a number of other uses such as cultural exchange and immersive storytelling. Therefore this project could be a simple and flexible way to start immersive learning in a newer learning space. In this vein, it was envisioned that VR may be a useful tool to enable students to get experience in planning, curating, and leading English-language tours, possibly as a prelude to designing and leading tours with real visitors later in the program.

There were various steps leading up to the introduction, implementation, and evaluation of the usage of VR in this course, all of which were in line with the objectives and curricula of an elective course called New Media Lab. Given that it was the 1st time using VR as part of a departmental project called for caution, there was a lot of scaffolding put in place, as well as training for the necessary fundamental skills. In this context, scaffolding refers to the gradual deployment of supporting hardware and software prior to the release of the most cutting-edge technologies.

The course was divided into 7 distinct phases. VR in education is reliant on:

(a) Careful task design to ensure that technology supports learning and is not purely and simply an end in itself;
(b) Ease of administration and deployment, given that most institutions lack the financial and physical resources for complex hardware and software provision; and
(c) Careful task design. Researchers are becoming more interested in its application areas, and more studies should appear.

According to the current research, virtual reality (VR) might be a beneficial tool for creating context for language acquisition, therefore possibly a follow-up study concentrating more on language use is necessary. In conclusion, this specific case study demonstrates an obvious and useful application of VR in second-language vocational training. This is due to the fact that students not only develop and lead tours in English but also gain knowledge of the tools and concepts used to make VR tours that may be more helpful and necessary in the future (Alizadeh & Hawkinson, 2021). Since this study, students have taken this platform and used it in a variety of student projects, research, and campus events. This shows how both a flexible platform and a planned training program go a long way in realizing the benefits of immersive learning.

Reality Labo

This research describes the design iterations for mobile immersive augmented reality (MAR) applications in various informal learning contexts. With the aim of developing a MAR infrastructure that would make it easier for non-technical people to create augmented reality content and surroundings, numerous cycles of development to implementation were examined and improved upon using a design-based research paradigm. The project went through numerous stages, and throughout that time, a basic framework was built that may guide the creation and implementation of MAR applications in tourism-related situations.

These development phases led to the creation of a platform that enables even non-technical people to rapidly prototype augmented reality media, content, games, and more. The study's exploration of this MAR platform and its design components, which have consequences for tourist contexts, come to a conclusion. The report also identifies potential design strategies and case studies for enhanced tourism. Mobile augmented experiences are influenced by a variety of elements, many of which are tied to the actual location in which the experience will take place. This is because the physical space(s) as well as the functions they fulfill are so diverse. Internet speed, wireless signal quality, illumination, mobility, and accessibility are features of the environment that can have a significant influence on MAR design.

The users also have a significant role in design decisions. Users may have varying degrees of AR experience, varying degrees of technological expectation, and varying degrees of technical proficiency. All of them have varied effects on people's willingness to participate in augmented reality upgrades for tourist scenarios. The degree of digital augmentation is a further idea crucial to design decisions (Hawkinson & Artemciukas, 2018). Examples from the past, like geocaching, have a very low level of digital improvement since, in its most basic form, all that contributes to the user's experience is a sequence of GPS coordinates. As machine learning and other sensors, which are connected to augmented reality, advance, they will collect and aggregate further data and add more material to the experience.

These concepts, which have been investigated in classroom settings for learning environments, are impacted by the gadgets that are being used and their capabilities. Some capabilities might include cameras with depth sensors and powerful image processing power.

Combining these platforms with lessons learned from the research produced using them, could be a valid way to introduce AR and VR in any space on campus to help iterate and design a dedicated space later.

EVALUATING SOFTWARE

The projects mentioned and suggested in the previous passage are introduced not only because they are flexible and require little effort to get started, but they show some attributes that pass some simple evaluations that are forming around immersive technology adoption for institutions. There are some considerations, which may not have been present for universities to consider when looking to procure immersive learning hardware and software, which could inform the design of programs and spaces heavily.

Content Validity

The reason for listing this concept first is because typically when consulting with universities, a common focus is first is what gadget(s) to price, what area is required, and what budgets are required, and it is more important to consider the use, the content, and the implementation first. It has been seen in a few instances that a purchase of devices comes first and then begins to test how to use those devices. This can hinder flexibility and could get stuck with devices that were presumed or imagined to do less than planned. So it is recommended to consider software, programs, and learning objectives first and match those platforms/software/programs with appropriate hardware.

Accessibility and Universal Design

Immersive tools can sometimes rely more closely on the physicality of the user and surroundings. It is because this accessibility and universal design take on new challenges and issues. These principles ensure that learning environments are inclusive and accessible to all learners, regardless of their abilities or disabilities.

In the context of VR, developers must consider features such as closed captions for the hearing impaired, voice commands for those who have motor impairments, and adjustable settings for individuals sensitive to intense movement or graphics. Universal Design involves creating educational experiences in such a way that they can be accessed, understood, and used to the greatest extent possible by all students. In the context of immersive learning, this means designing experiences that are flexible, equitable, and intuitive, minimizing the potential barriers for all learners.

Creative Control and Platform Agnosticism

Utilizing universally accepted software foundations such as Open XR can simplify the creation of digital, virtual, or augmented environments, enhancing their accessibility in diverse contexts. This refers to the concept of platform neutrality or agnosticism, a principle that emphasizes universal compatibility across different systems. Large companies typically integrate their virtual reality (VR) or augmented reality (AR) products into their existing ecosystems, aiming for seamless cross-platform usability. This incentive to create a ‘walled garden’ to keep users in ecosystems can conflict with the need for visibility on open internet platforms, such as search engines, to reach a broader audience.

Open educational resources are an area that could be focused on. Although this strategy has been acknowledged by various global institutions, including open universities, it has not been universally adopted. Apple, for example, may take a distinctive approach with their upcoming AR and VR products. These devices are expected to be deeply integrated into Apple's proprietary ecosystem, demonstrating a significant departure from the platform neutrality paradigm.

Data Collection

The very nature of immersive technology requires the collection and processing of a large amount of data about the user and environment from a variety of sensors. Data about how the user’s head, eyes, and body moves is taken in and used to create immersive environments. When evaluating software, it will be important to consider who is collecting data and for what purposes. One example is the Quest VR headset, which is a popular choice because of its price. Data that is collected with the Quest VR could be sold to another corporation or used for Facebook's many product lines for advertising.

DESIGN PRINCIPLES

When considering an upgrade or re-design of a more conventional computer laboratory on campus. There are some design considerations and affordances to consider to gain the most learning benefit from the space and technology.

Flexible Space

Keyboards are still the dominant method of computer-human interface, and PC skills are still in high demand. However, with most immersive technology, the interface is completely different, as you may want to be able to place digital objects in that actual environment and move about it whether you're utilizing virtual reality or even augmented reality. Therefore, you don't want anyone to get hurt when they are swinging their arms or moving around in virtual space since they are unable to view their immediate surroundings. So the environment, layout, and physical space can appear extremely different between facilitating immersive technology.

You sometimes need freedom to move about and not be locked into a specific layout in the area. One of the advantages of creating a virtual lab or immersive lab the way I'm developing it is that it opens up the opportunity for participation for those who are unable to physically attend. So design of space could need consideration of how digital environments meld with physical spaces.

Future-Proofing Immersive Technology

The landscape of immersive technology is advancing at a breakneck pace, which can pose challenges for launching and sustaining initiatives. With hardware and software versions being updated regularly, it's essential to employ iterative and flexible budgeting strategies. As this technology becomes more ubiquitous and versatile, it's expected to permeate further into diverse fields of study. Therefore, it's prudent to plan for its continued growth and evolving use over time. While embarking on new projects, it's equally important to maintain support for existing ones. By adopting a future-proof approach, we can effectively navigate the continuous changes and maximize the potential of immersive technology in the long term.

Expanding and Sustaining Projects: The Function of Immersive Labs

As understanding of the application of immersive technology broadens among faculty, staff, and students, its support for diverse programs and learning contexts will likely increase. It is crucial to maintain flexible and iterative

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budgets for the long term to accommodate this growth. As the utilization of technology becomes more frequent, diverse, and accessible, it's essential to manage ongoing projects effectively. Our goal is to maintain existing initiatives, encouraging them to collaborate and synergize with new projects as they emerge. In these pursuits, the creation of unique educational spaces is vital.

Experiences that deviate from the traditional classroom or studio space can add a new dimension to learning. This could be in the form of an immersive lab, incorporating certain design principles to foster and enhance teaching and learning through immersive technology. Experiences may range from viewing digital objects in your physical environment through an AR tablet or glasses to immersing oneself in a virtual reality environment on a curved screen. These are all elements that can add richness and depth to educational interactions.

The ability to create and participate in unique experiences beyond the typical confines of classroom or studio spaces is vital. In this context, an activity could involve engaging with digital objects in your physical environment via an AR tablet or glasses, or even experiencing a full immersion through a virtual reality curved screen. One example is the concept of group virtual reality experiences. This concept is a catalyst for designing spaces where individuals can gather and exchange ideas within 360-degree virtual reality environments. The possibilities are endless with this approach, and the current applications within this specific lab show that there's still much potential for further exploration. Creating flexible spaces is crucial for fostering a collaborative environment. This can be as simple as rearranging a room with movable tables, allowing small groups to gather and engage in discussions. This kind of dynamic, adaptable space invites creativity, innovation, and collaboration, making it an essential feature of immersive learning environments.

LAB COMPONENTS

There are some common components that can be found in many examples of immersive labs and programs in higher education around the world. From these examples, we can infer some ideas of the kinds of lab components that might be suitable for different situations and deployed in a suitable timeline.

Shared Immersive VR Media

The experience of VR is often individualized, usually facilitated through devices like glasses or tablets, where the user's movements guide the visuals. While this can sometimes be mirrored onto a screen for others to see, it doesn't truly allow for a shared experience. However, the advent of immersive shared VR spaces addresses this limitation. Through the innovative use of software and multiple projectors, we can create a virtual reality experience projected onto a curved screen that can be collectively viewed. This enables a group of 5 to 20 people to simultaneously engage with 360-degree video content in one room. We are currently developing a similar setup in our mixed-reality studio. This shared VR space allows us to facilitate educational programs or seminars between physical locations, enhancing the learning experience. An example of this could be seen earlier when manipulating virtual swords. Various versions of this immersive setup exist, differing in size and design, but for most, a portable option could be recommended. One of the key elements of this setup is the use of chroma key green screening. This time-tested technique allows for the removal of background imagery, which can then be replaced with the desired visuals, leading to a truly immersive experience.

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AR/VR Development Workstations

These stations provide the ability to delve into more intricate virtual engagements. By connecting PC VR, creations, tests, and works-in-progress can be displayed and moved around. This facilitates real-time demonstrations of VR and AR projects to individuals or small groups of students. These development stations are equipped with high-end hardware that boasts advanced graphic capabilities and robust data processing power. Such features make these workstations ideal for the tasks of development and research in the realm of immersive technology.

Storage and Equipment Rental

Consider having a dedicated storage space for rental equipment such as standalone VR devices like Oculus Quest or Pico Neo, 3D scanners, and Augmented Reality (AR) glasses. There is a variety of equipment that can significantly contribute to experimenting with different VR and AR experiences, perspectives, and techniques. Tablets, for instance, provide a useful platform for VR and AR. The immediate value of interacting with AR and VR content on a tablet, while simultaneously engaging with the real world, is often overlooked. Many are drawn towards cutting-edge technologies, however, tablets continue to be an effective tool for designing, curating, and experiencing immersive content.

Photogrammetry Studio

The subsequent feature worth discussing is the photogrammetry workspace, fundamentally a photography studio aimed at digitizing real-world objects and individuals in high resolution. Examples can be seen in other institutions where numerous state-of-the-art digital cameras are used to capture a single subject from various angles.

These captured images can later be utilized to create volumetric videos or digital holograms, enabling users to interact with these objects in virtual reality environments.

DISCUSSION

The Cruciality of an Iterative Approach: Prioritizing Software Over Hardware

In the initial phase of prototype development, where features and functions are still being defined, the iterative method is key. It allows for swift alterations and improvements to a product, thereby affording room for necessary modifications. Unlike the waterfall model, which frequently necessitates comprehensive documentation, an iterative approach prioritizes project design, reducing time spent on paperwork.

By generating functional software early and swiftly in the software development cycle, the process is not only more cost-effective but also more flexible when adapting to changes in requirements and scope. Additionally, it simplifies testing and bug fixing within shorter iterations, while facilitating risk management by promptly identifying and addressing potential issues during each iterative phase.

Faculty Engagement and Forming Partnerships

New initiatives, be they outcome, technology, or infrastructure-based, may meet with resistance from faculty members. When faced with this challenge, the impulse might be to dismiss their concerns and proceed directly with the planned course of action, banking on success as the ultimate convincer. However, this approach risks a costly mistake. Without faculty support, the initiative may falter, or at the very least, become less effective. Achieving faculty buy-in, which refers to gaining the support or at least the understanding of faculty and students for the changes being implemented, is vital. This is why an iterative approach that seeks to demonstrate the affordances of the technology for various purposes in a low-cost, approachable way initially may be more successful.

The adoption of immersive technologies in education calls for an iterative approach prioritizing software over hardware, an understanding of the evolution and adaptation of immersive technologies, and importantly, the buy-in and engagement of faculty and students. These elements combined ensure a sustainable and efficient implementation of VR and AR tools, supporting an innovative learning environment that adapts to the ever-evolving technological landscape.

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