



Reshaping the Online Interactive Teaching-Learning through VR for Sustainability – A Qualitative Study

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Abstract:

Online education has expanded access to learning opportunities, yet maintaining meaningful interaction and sustained learner engagement remains a persistent challenge. Virtual reality (VR) and other emerging immersive technologies provide new opportunities for making digital learning environments more engaging and participatory. This study investigates how virtual reality (VR) may help transform interactive online learning while promoting sustainable educational practices. The study investigates participant experiences and perceptions of VR use in online learning environments using a qualitative research methodology. An in-depth understanding of how immersive environments affect engagement, cooperation, and learning was made possible by the qualitative data collection methods, including reflective conversations and interviews. Interactivity, learner motivation, perceived efficacy, and VR's potential role in developing sustainable learning environments that lessen dependency on physical resources and allow for flexible involvement are the main themes of the investigation. Results show that VR-based learning environments may improve communication, produce immersive learning environments, and facilitate online collaborative learning. Participants emphasized how important shared virtual environments and realistic simulations are for increasing engagement and attention. However, the research also acknowledges pragmatic factors, such as technology preparedness, accessibility, and the necessity of pedagogically informed implementation. By offering qualitative insights into how VR might promote more engaging and long-lasting types of online interactive learning, this study adds to the expanding corpus of literature on immersive technology in education.

Keywords: *Virtual Reality (VR), Online Interactive Teaching-learning, Immersive Learning, Sustainability in Education, Qualitative Study.*

Introduction:

With flexibility and increased access to educational opportunities, the growth of online education has drastically changed the teaching and learning environment. Nevertheless, despite these benefits, online learning environments frequently encounter issues with low student engagement, little interaction, and limitations in developing realistic learning experiences. These drawbacks emphasise the need for creative strategies that can promote meaningful and long-lasting educational practices while improving interaction.

Recently, virtual reality (VR) has come to light as a promising technical tool that has the potential to transform online interactive education. Beyond the limitations of conventional digital platforms, VR allows students to actively connect with learning materials, communicate with peers, and experience realistic scenarios through the creation of immersive and virtual settings. Deeper comprehension, hands-on learning, and increased student motivation may all be fostered by such immersive encounters.

By encouraging resource-efficient learning settings and increasing access to experiential learning without the need for substantial physical infrastructure, VR integration in education also supports more general sustainability goals. In this regard, it becomes more crucial to comprehend how VR might support engaging and sustainable online learning.

This qualitative study investigates how virtual reality could change interactive online learning. The study aims to comprehend how immersive technologies might improve engagement, cooperation, and sustainable learning practices in digital educational environments through a thorough examination of participants' experiences and perspectives.

Objectives of the study

1. To investigate how virtual reality (VR) might improve interaction in online learning environments.
2. To comprehend how instructors and students see and use virtual reality in online learning environments.
3. To investigate the effects of immersive virtual reality settings on student involvement and engagement in online learning.
4. To look at how VR-based learning may help sustainable teaching methods, such as less reliance on tangible resources and more flexible learning options.
5. To determine the main obstacles and factors to be taken into account when integrating VR into online interactive education.

Review of recent related literatures

Here is a comprehensive chronological literature review to show the development of research in VR-based online/interactive education and sustainability themes, followed by a synthesis and research gaps.

• Early Consolidation of VR in Higher Education (2019–2020)

One of the most important early assessments examined many application sectors, including engineering, healthcare, and training, and emphasised the quick development of immersive VR in education. Many VR applications were still in the experimental stage and only partially incorporated into the standard curriculum, according to Radianti et al. (2020). The authors pointed out that studies lacked a foundation in learning theories and frequently focused on usability rather than learning results, indicating the necessity for more methodical design-based research.

In a similar vein, Hamilton et al. (2020) examined experimental research and came to the conclusion that while VR frequently increases engagement and information retention, many studies depend on brief treatments and neglect to assess long-term learning results. These drawbacks underscore the need for thorough approaches and long-term research in VR-assisted teaching.

Support for sustainability:

The absence of long-term and scalable integration, which is crucial for sustainable education systems, was brought to light by this fundamental research, which established VR as a viable tool for changing learning settings.

- **Growing Evidence of Engagement and Learning Benefits (2021)**

According to research presented in educational technology talks and related studies, VR and mixed-reality settings dramatically increase learners' engagement, pleasant feelings, and sense of presence while producing learning performance that is equivalent to traditional learning. During this time, it became more widely acknowledged that immersive technologies may improve engagement and motivation in online learning settings, which are essential components of long-term online education ecosystems.

- **Expansion into Specialised and Applied Domains (2022–2023)**

Research conducted during this time period increased the use of VR in a variety of fields, including professional training and construction instruction. For instance, a comprehensive assessment of virtual reality in construction education discovered that through interactive learning opportunities, immersive simulations enhance students' comprehension of intricate procedures.

This stage demonstrated the increasing use of virtual reality (VR) as a teaching technology that may enhance long-term learning goals related to sustainable development and job preparedness by bridging theoretical knowledge and practical skills.

- **Emergence of Sustainability and Metaverse-based Education (2024)**

VR is rapidly being connected to sustainability and social impact in education, according to recent studies. Immersion settings facilitate collaborative learning and digital engagement through avatars, promoting socially sustainable learning models, according to a study on immersive virtual technologies and the metaverse that looked at students' perspectives of sustainability in higher education.

Teachers view VR as helpful for experiential learning, but they also identify obstacles, including infrastructure needs, pedagogical integration, and technological complexity, according to another qualitative study that examined instructors' opinions on VR adoption.

Conclusion:

Examining VR within sustainability frameworks (such as digital inclusion, access, and collaborative learning) is a change that is in line with the objectives of contemporary online education.

- **Mixed-Methods Evidence on VR Learning Environments (2024)**

Quantitative testing and qualitative comments from teachers and students were integrated into research assessing virtual reality learning environments (like Physics Playground VR). While qualitative findings highlighted user happiness and the benefits of immersion in VR settings, the results demonstrated increases in knowledge and confidence. However, traditional learning approaches occasionally outperformed VR in terms of information acquisition, suggesting that VR has to be properly included in more comprehensive educational approaches. For long-lasting learning effects, this study emphasises how crucial it is to integrate instructional design with immersive experiences.

- **Role of Presence and Immersion in Learning Outcomes (2025)**

Spatial, social, and cognitive presence have a significant impact on learning effectiveness, motivation, and engagement in immersive educational systems, according to a recent systematic study on "presence" in VR settings.

Designing long-lasting VR-based online learning platforms that foster meaningful engagement and teamwork requires an understanding of these psychological aspects.

- **Integration of VR and AR in Digital Education Systems (2026)**

Immersion technologies boost motivation and engagement, but they still have drawbacks, including cognitive overload, usability concerns, and infrastructure constraints, according to more recent research on VR and AR integration in public education. To facilitate successful integration in educational institutions, researchers advise better interface design, personalisation, and teacher preparation.

This implies that pedagogy and institutional preparedness are just as important to the sustainability of VR education as technology.

- **Systematic Reviews Connecting VR with Sustainable Development Goals (2025)**

VR supports multiple UN Sustainable Development Goals (SDGs), including Quality Education (SDG 4), and improves participation, conceptual comprehension, and digital capabilities, according to a new systematic review that included research from 2020 to 2025. The report also emphasised how VR might lower physical and geographic obstacles to learning, hence improving accessibility and inclusivity.

The study did, however, highlight persistent issues such as exorbitant expenses, restricted accessibility, inadequate teacher preparation, and the absence of standardised frameworks for long-term implementation.

Synthesis of the Literature

VR in online education has changed during the last ten years in several ways:

1. Phase of exploration (2019–2020): The majority of the research focused on engagement advantages and practicality, but it lacked a theoretical foundation.
2. Phase of Adoption and Application (2021–2023) : VR started to be used in a variety of fields, including engineering and training settings.
3. Integration of Sustainability and Education (2024 onwards): Research is increasingly concentrating on sustainability frameworks, metaverse settings, immersive learning design, and teacher perspectives.
4. Global Impact and Systematic Assessment (2025–2026) : Reviews link the long-term change of digital education systems and the SDGs with VR adoption.

All things considered, virtual reality is acknowledged as a revolutionary technology that may improve accessibility, motivation, and learning experience in online learning.

Determined Research Gaps

There are still some important gaps in the evaluated literature:

1. Insufficient Large-Scale and Extended Research: Numerous studies on VR education focus on short-term trials or pilot projects, which restricts knowledge about long-term learning results and institutional acceptance.
2. Inadequate Adherence to Learning Theories: There is a need for frameworks based on educational theory since many VR educational deployments are technology-driven rather than pedagogy-driven.
3. Inadequate Studies Connecting VR to Sustainability Results: Despite the fact that VR supports SDGs like inclusive and high-quality education, there are still few empirical studies that specifically link VR learning environments to sustainability metrics.

4. **Issues with the Digital Divide and Accessibility:** Widespread VR adoption in educational systems is still hampered by high implementation costs, hardware requirements, and technological obstacles.
5. **Insufficient Qualitative Research on the Experience of Learners:** Fewer research concentrate extensively on qualitative insights into learner experiences, perspectives, and socio-cultural influences, whereas many employ quantitative measures like surveys or pre-post exams.
6. **Integration with Interactive Online Learning Platforms is Required:** Instead of fully integrated online learning ecosystems that include VR, AI, and collaboration tools, research frequently focuses on discrete VR experiences.
7. **Training for Teachers and Institutional Preparedness:** Curriculum integration and teacher preparedness are still understudied elements influencing long-term VR adoption.

According to research, virtual reality (VR) has the potential to significantly change online interactive education by fostering immersive, hands-on learning environments that improve accessibility, engagement, and teamwork. Sustainability is being emphasised more and more in recent research, which connects VR adoption to more general educational development objectives and digital inclusivity. Future research must, however, concentrate on long-term empirical investigations, theoretical frameworks, fair access, and qualitative insights into learner experiences in order to fully realise its promise. Filling up these gaps will help create long-lasting virtual reality-based online learning platforms.

The Changing Face of Online Learning

Over the last twenty years, online education has changed in amazing ways. The path has been one of more interactivity and accessibility, going from static web pages and downloadable PDFs in the early 2000s to interactive learning management systems, MOOCs, and live video conferencing. Millions of students around the world now take classes, get certifications, and earn degrees completely online. The COVID-19 pandemic sped up this change by forcing schools of all sizes to adapt almost overnight.

But even though it has come a long way, online education still has to deal with some basic problems. Completion rates for MOOCs stay below 15%, and student surveys show that students often feel alone, disengaged, and like they don't get enough hands-on experience. Collaborative projects, lab experiments, and immersive field experiences are all great ways to teach in physical classrooms, but they have been hard to copy in a digital medium that is mostly made up of video and text.

In this situation, immersive technologies, especially Virtual Reality, come in as a real game-changer. Instead of having students watch a simulation or read about a procedure, VR puts them in the experience. The change from being an observer to a participant isn't just for show; it's backed up by decades of research in learning science that shows that being actively involved and physically present leads to deeper understanding and longer-term memory. This article explains why VR is more than just another small improvement to the e-learning toolkit; it's a real change in how we think about digital education.

In the early 2000s

Web pages that don't change and course materials that one can download

2008–2012

The growth of MOOCs and interactive LMS platforms

From *2015 to 2019*

Video conferencing and blended learning have become popular.

2020 to 2023

The pandemic makes everyone use digital technology, which leads to a crisis of engagement.

From 2024 to now

Immersive VR is the next big thing in online learning.

The Difficulty of Getting People to Participate in Digital Learning

One of the most common and well-known problems with online education is keeping students interested in what they're learning. In a real classroom, social dynamics, peer pressure, and the teacher's physical presence all help students pay attention. But in an online classroom, it's up to each student to stay motivated. The result, as decades of research and institutional data show, is widespread disengagement: students who start courses but never finish, who passively watch lecture videos without processing the content, and who have trouble connecting abstract information to real-life meaning.

During the pandemic, the term "Zoom fatigue" became well-known. It showed that video-based remote learning is not good for people because they are not wired to sit still and take in information through a screen for hours at a time. It takes a lot of mental and emotional energy to stay focused on a flat, two-dimensional video interface, but the amount of environmental cues that naturally hold our attention in person is very low. Students say they don't feel connected to their teachers, classmates, or even the subject matter itself.

In STEM fields, healthcare, engineering, and the natural sciences, the lack of hands-on experience is especially bad. These are fields where learning by doing is not a luxury but a requirement for deep understanding. A chemistry student who has never used a pipette, a medical student who has never practised a suture, or an engineering student who has never worked with a control system in real life is at a huge disadvantage. In the past, online education has not been able to fill this gap in a satisfying way, leaving lab work to optional "virtual simulations" that often feel like games and don't seem real.

The Main Issue

Passive consumption, Zoom fatigue, and a lack of hands-on experience make a "learning gap" that traditional online tools can't fill.

Important Signs of Disengagement

1. Less than 15% of people who sign up for MOOCs finish them.
2. Watching videos passively without thinking about them
3. Not being able to connect theory to practice
4. Being alone and not working with others
5. "Zoom fatigue" that doesn't go away in live sessions

The Promise of Technologies That Immerse human being

Virtual reality gives a real sense of presence that no other digital medium has been able to do on a large scale. When a student puts on a VR headset and sees themselves in a virtual chemistry lab, on the moon, or inside a living cell going through mitosis, their brain reacts to that environment in ways that are very different from watching a video of the same scene. Researchers call this neurological change the "presence response," which is a feeling of being in a real place. This change has big effects on learning.

The change that VR makes possible is going from passive consumption to active participation. Instead of seeing a teacher put together a mechanical part, a student in VR can pick up virtual parts, try to put them together themselves, make mistakes in a safe space, and keep trying until they get it right. This “learning by doing” model fits with constructivist learning theory, which says that the best way to learn is through direct experience and actively building your understanding, not by taking in information that has already been packaged.

Also, VR can recreate places and experiences that would be impossible, dangerous, or too expensive to do in real life. Students can walk through ancient Rome, watch chemical reactions happen at the molecular level, practise emergency medical procedures, or do experiments in zero gravity, all in a safe, controlled, and repeatable virtual space. One of the most exciting things about VR as an educational tool is that it can give every student, no matter where they are or what resources their school has, access to experiences that were only available to the most privileged before.

Being Present

VR really makes the brain respond to “presence,” making it feel like the virtual world is real.

Learning through Action

Students interact with virtual objects and perform experiments, consistent with constructivist learning theory.

Access for Everyone

VR can make rare, expensive, or dangerous situations happen, so all students can learn in world-class settings.

What makes VR special for education

It goes deeper into what makes Virtual Reality a unique and powerful way to learn. It looks at more than just its novelty; it also looks at the specific teaching benefits that make it different from all other digital learning tools. VR’s abilities are in line with the basic conditions that learning science says are necessary for deep, lasting understanding. These include experiential learning, spatial cognition, emotional engagement, and multimodal interaction.

Experiential Learning in VR: Beyond the Screen

John Dewey came up with the idea of experiential learning in the early 1900s. This idea, which means learning through direct experience and reflection, has been a big part of educational philosophy ever since. The Experiential Learning Cycle by David Kolb is one of the most well-known frameworks in educational psychology. It says that learning happens in four stages: concrete experience, reflective observation, abstract conceptualisation, and active experimentation. Virtual Reality is the only technology that can support all four stages of this cycle in one clear learning environment.

In a VR setting, students learn by doing things in the real world, like touching and moving virtual objects and places. They can stop and look from different angles, which helps with reflective observation. The system can give you feedback in real time and add layers of information to help you understand abstract ideas. Students can immediately start experimenting again in virtual environments because they can be reset and changed an unlimited number of times. They can test hypotheses, try different approaches, and improve their understanding over time. It’s very hard to recreate this tight loop between experience, reflection, and action in any other digital medium.

VR also helps people develop their spatial thinking in ways that two-dimensional screens can't. Molecular geometry, architectural proportion, geological stratigraphy, and the mechanics of fluid dynamics are all examples of three-dimensional concepts that are very hard to understand in STEM education. Students who have trouble seeing these structures in textbook diagrams or flat animations often find that a short VR experience helps them understand right away and for a long time. For spatial learners, being able to walk around, inside, or through a virtual version of a concept can be life-changing.

Experience in Real Life

Students physically engage with virtual objects—manipulating lab instruments, constructing systems, or traversing environments—thereby generating direct, embodied memories.

Looking Back

VR lets students pause, rewind, and look at things from any angle, which helps them think deeply about what they just saw.

Experimentation in Action

Students can test new ideas and keep changing them right away in virtual environments, which is what real scientific thinking is all about.

Case Study: A New Way of Teaching Control Engineering

Bai et al. (2026) created an immersive virtual experimental teaching platform just for control engineering education. This is one of the most interesting recent examples of how VR could be used in higher education. Control engineering is a field that requires both theoretical knowledge and practical skills. For example, students need to know how feedback systems work mathematically and be able to design, build, test, and fix real control circuits. This practical aspect has been almost impossible to provide in traditional online education.

The platform that Bai et al. made puts students in a photorealistic virtual lab that has all the tools, parts, and systems they would find in a real control engineering lab. Students can create control systems from the ground up, use virtual instrumentation to put their designs into action, watch how the system behaves in real time, and improve their methods based on what they see. The environment accurately models the physics of real control systems. This means that design mistakes lead to realistic and educational failures, while successful designs work exactly as the theory says they will.

The empirical validation aspect of the study is notably important. Bai et al. didn't just rely on anecdotal evidence or surveys of student satisfaction. Instead, they put the platform through rigorous experimental testing, comparing the learning outcomes of students who used the VR platform to those of control groups who used traditional online instruction. The findings indicated statistically significant enhancements in both conceptual comprehension and practical skill development among VR users. Students said they were more engaged, more confident in their skills, and more motivated to learn about the subject on their own. These are exactly the results that online engineering education has been trying to achieve for decades.

“The immersive virtual experimental platform enabled students to achieve practical competency outcomes previously only attainable in physical laboratory settings — representing a fundamental advance in the possibilities of online engineering education.” — Bai et al. (2026)

Case Study: Improving Biology Learning in High School

Using VR in high school has its own unique set of problems and challenges. Adolescents have unique motivational profiles, social sensitivities, and cognitive developmental traits that good educational design must take into account. The research conducted by Mohamed Mokmin et al. (2026) presents a comprehensive and theoretically advanced illustration of the application of virtual reality to tackle these attributes within the realm of secondary biology, a subject noted for its conceptual complexity at that educational tier.

The study's main topic was cell division, which is a basic concept in biology but is very hard for high school students to understand. At the molecular and cellular levels, cell division involves complex three-dimensional choreography that happens over several stages and timescales that are too slow and too fast to see directly. Textbook diagrams, 2D animations, and microscope slides are all examples of traditional teaching methods that only show a small and often distorted part of the process. The VR environment created for this study immersed students within a cell, enabling them to observe mitosis and meiosis from any scale and perspective.

The Mohamed Mokmin et al. study is especially interesting because it has a lot of theoretical depth. The researchers based their design on several complementary learning frameworks, such as Self-Determination Theory (SDT), which focuses on how autonomy, competence, and relatedness affect intrinsic motivation; Flow Theory, which describes the best mental state of deep engagement that happens when challenge and skill are in balance; and established models of inquiry-based and problem-based learning. AI-powered avatars acted as virtual teachers and lab partners, giving each student personalised help, asking Socratic questions, and changing the difficulty of challenges in real time based on how well each student was doing.

DVR + GIBL

Desktop Virtual Reality, combined with Guided Inquiry-Based Learning for a structured way to learn about how cells work.

Learning by Doing

Students solve real biological problems in the VR world, which helps them understand the concepts better.

Support for AI-Avatars

Self-Determination Theory says that intelligent virtual teachers give students personalised, real-time support.

Design of Flow Theory

Challenge levels change on the fly to keep the best level of engagement, as Flow Theory says they should.

Case Study: Physics Education Through Immersive Learning

Ioannou, Tsivitanidou, and Georgiou (2021) created and tested an immersive VR learning experience based on Einstein's Special Theory of Relativity for high school physics students. This is one of the most intellectually ambitious uses of educational VR. The Special Theory of Relativity is one of the hardest ideas to understand in the high school physics curriculum, no matter how you look at it. Its main ideas—like that the speed of light is the same for everyone, that time and space are relative instead of absolute, and that mass and energy can be changed into each other—are so different from what most people think that even very smart students often leave traditional classes with wrong ideas that are hard to fix.

Ioannou and his team made a VR world that let students see relativistic effects for themselves. They could “travel” at speeds close to the speed of light and see time dilation and length contraction as they really happen, not just as abstract equations on a whiteboard. They could see them as real, first-person experiences. The environment was set up based on the principles of inquiry-based learning. Students were encouraged to come up with hypotheses, make predictions, and do virtual “experiments” by changing their speed in relation to different reference frames. They were also encouraged to compare their observations with theoretical explanations.

The study’s evaluation methodology was equally stringent. Pre- and post-tests measured how much students learned about relativistic physics, while validated tools measured how students felt about the VR experience, how present and immersed they felt, and how engaged they were with the inquiry-based learning process. The results showed that students made big gains in their understanding of concepts, especially when it came to things that are hard to understand from a Newtonian point of view. It’s important to note that students who had previously said they were anxious about physics reported feeling much more confident and curious after the VR experience. This has important implications for fairness and inclusion in STEM education (Ioannou, Tsivitanidou, & Georgiou, 2021).

VR for Different Subjects and Learning Styles

The focus is to explore the potential of VR to benefit students across diverse subjects, motivational profiles, and learning requirements. The case studies and research results shown here suggest that VR’s benefits aren’t limited to a small group of learners or subjects. Instead, the technology is very flexible and open to everyone, and it has a lot of potential to help students who have not been well served by traditional teaching methods.

Getting Students Who are not Motivated at Work

One of the biggest problems with fairness in education is that students are often not motivated to learn. This problem is even worse in online learning environments, where social accountability and outside pressure are at their weakest. Students who have trouble engaging with traditional teaching methods often get stuck in a cycle where low engagement leads to bad results, which lowers their self-efficacy, which makes them less motivated. To break this cycle, we need to use methods that are not only easier or better looking, but also more deeply interesting on a psychological level.

Fu et al. (2024) looked into this problem in a very thorough study that looked at how to use VR in scaffolded game-based learning environments for students who were already not very interested in science. The study used a comparative design to look at immersive VR modes and non-immersive desktop game-based learning experiences that covered the same science content. The immersive VR condition resulted in significantly enhanced advancements in targeted science knowledge acquisition; however, more crucially, it elicited substantial transformations in students’ motivational states and self-reported interest in science as a discipline.

The mechanisms underlying these motivational enhancements seem to be diverse and mutually reinforcing. Self-Determination Theory says that autonomy, competence, and relatedness are the three basic psychological needs that drive intrinsic motivation. Immersive VR gives people a sense of presence and agency, making them feel like they are really there and doing something meaningful. Students who might lose interest in a regular lesson or even a desktop game are drawn into the immersive environment by how new and interesting it is. They stay there because they enjoy having real control over their actions and getting better at the game. The game-based learning framework provides a structure for this engagement so that it leads to structured knowledge acquisition instead of random play (Fu et al., 2024).

Identified Low Motivation

The VR intervention is for students who don't pay attention in regular science classes.

VR that puts one in the game

Scaffolded VR game environments offer structured but very interesting ways to learn about science.

Independence, skill, and connection

VR meets SDT's most important psychological needs, which leads to real intrinsic motivation.

Significant Knowledge Gains

For low-motivation learners, immersive VR is better than desktop games for learning about science (Fu et al., 2024).

Learning Historical Events Through Exploration

History education is a unique challenge for immersive technology because the events, places, and things of the past can't be seen directly anymore. However, the best and most lasting understanding of history is usually built on strong, concrete, and emotionally resonant engagement with specific events, people, and places. The work of Peng et al. (2023) shows how VR can fill this gap in a very creative and educational way by using the Apollo lunar roving missions as the historical setting for an educational VR game.

The Apollo lunar rover missions are a great topic for an educational VR experience because they are important in history, look and feel different from other things, have a lot of scientific and engineering content, and are related to themes of exploration, human achievement, and international competition that appeal to people of all ages. Peng et al. made the VR experience using a three-phase method that combined strict historical and scientific research with game design rules and VR-specific production methods. The first step, "Modelling & Simulation," was to make very accurate virtual copies of the lunar surface, the rover vehicles, and the mission equipment using old NASA documents. The second phase, Gamification & Euducation, turned this information into structured gameplay mechanics that were meant to help students learn specific things in the areas of spatial, factual, and operational knowledge. The third phase, VRization, changed the experience so that it could be fully immersive in VR.

One very thoughtful design choice was to include two different learning modes: an active mode where players control the rover, navigate the lunar surface, and interact with mission equipment, and a passive mode where players watch a scripted walkthrough of important mission events. This design choice shows that the designer has a deep understanding of the different needs and preferences of learners. They know that not all students benefit equally from having the same level of direct control over a virtual environment, and that giving students structured choice can be a powerful way to motivate them. The experience led to big improvements in all three areas of knowledge that were targeted. The active mode led to bigger gains in spatial and operational knowledge, while the passive mode helped people learn more reliable facts (Peng et al., 2023).

The Effect of VR on Learning Outcomes

Putting together all the research that this article looks at, a complex but mostly positive picture of how VR affects learning outcomes starts to take shape. The evidence is most robust and consistent for affective outcomes: nearly all studies investigating them indicate that immersive VR experiences lead to substantial enhancements in student interest, motivation, engagement, and self-reported satisfaction with the learning experience. These are not small results. In an online education world where students often lose interest and

drop out, any intervention that reliably and significantly increases student motivation and interest should be taken very seriously.

The evidence for direct effects on learning and skill development is also good, but it depends more on the situation. According to Mohamed Mokmin et al. (2026), students' interest and focus have gone up a lot, and their biology test scores have also gone up. Bai et al. (2026) show that students in control engineering make progress in both understanding concepts and using them in real life. Ioannou et al. (2021) report substantial conceptual learning advancements in relativistic physics. Fu et al. (2024) demonstrate enhanced science knowledge acquisition in virtual reality compared to desktop game environments for students with low motivation. Peng et al. (2023) discovered significant improvements in spatial, factual, and operational knowledge domains within historical learning.

However, it is important to be careful. A review published in ERIC (2021) found that VR consistently makes students "like" learning experiences more and feel more involved in simulations. However, this increased engagement doesn't always lead to measurable learning gains; it depends on how well the VR is integrated into the classroom. VR experiences that focus mostly on novelty and immersion, without paying close attention to instructional scaffolding, learning goals, and evidence-based teaching methods, may get a lot of people interested but not teach them anything useful. The message is clear: VR is a great way to make good teaching even better, not a replacement for it.

Boosting Engagement

Studies show that immersive VR consistently makes students more interested and motivated.

Gains in Knowledge

Most well-designed VR studies show that learning outcomes are much better than in control groups.

Skills Retention

Practical skills learned through VR last longer than those learned through passive instruction.

Designing Effective VR Learning Experiences

It moves away from the empirical record and asks a practical question about design: what rules and guidelines should be followed when making VR educational experiences that work? The research looked at in earlier chapters comes together to form a clear set of ideas that make up a new framework for designing VR lessons. This framework puts good teaching at the centre and uses the unique features of immersive technology to improve learning outcomes.

The Key is Pedagogical Integration

The most important thing that has come out of the research on educational VR is that VR is a tool, not a way of teaching. A well-designed, technically advanced virtual world with accurate scientific data and interactive elements won't be enough to make learning meaningful on its own. The quality of its pedagogical integration—how well its design reflects, supports, and amplifies evidence-based teaching principles—is what turns a VR experience from a fun novelty into a real learning environment.

The research consistently shows that VR works best when it is used with established teaching methods rather than on its own. Inquiry-based learning (IBL) is a method of teaching that helps students come up with and test hypotheses through structured investigation. It fits well with VR's interactive features and has been shown to work well in studies by Ioannou et al. (2021) and Mohamed Mokmin et al. (2026). Problem-based learning (PBL) uses VR's ability to create realistic problem situations in ways that text or video can't. This is

because PBL organises lessons around the challenge of solving real, hard problems. Fu et al. (2024) and Peng et al. (2023) show that game-based learning uses VR's ability to immerse people to make motivational structures that keep people interested over long periods of learning.

Two ideas from cognitive science are very important for making VR content. Richard Mayer's Multimedia Learning Principles are a set of research-based rules for making learning materials that make it easier for people to learn while still getting the most information across. These rules can help you decide how dense, fast, and multimodal to make content in VR environments. Cognitive Load Theory, created by John Sweller, is just as important. If VR environments aren't carefully designed, their rich visual detail and interactive options can easily overload learners' limited working memory. So, good VR educational design needs to find a balance between how rich the immersive experience is and how much the students can handle mentally.

Inquiry-Based Learning

Help students come up with hypotheses and look into them in a virtual setting; this has worked well in VR studies in physics and biology.

Learning Through Problem-Solving

There needs to be set up VR experiences that are based on real, difficult problems that need people to actively solve them.

Principles of Learning with Multimedia

There is a need to use Mayer's rules to manage cognitive load and improve how information is shown in rich VR environments.

Frameworks Based on Games

It is recommended to use VR's immersive qualities with structured game mechanics that keep players interested and help them learn.

Support for AI and scaffolding

Instructional scaffolding is one of the most powerful and well-supported ideas in educational psychology. It means giving students temporary, flexible help so they can do things they couldn't do on their own, with the goal of slowly taking that help away as they become more competent. Scaffolding comes from Vygotsky's Zone of Proximal Development. Decades of research have shown that it is especially helpful for learning tasks that are complicated and require the use of declarative knowledge, procedural skill, and metacognitive awareness. VR learning environments, characterised by their potential for complexity and cognitive demand, represent the contexts in which effectively designed scaffolding can distinguish between transformative and overwhelming experiences.

The work of Mohamed Mokmin et al. (2026) gives a strong picture of how AI-powered scaffolding can be used in VR classrooms. Their use of AI-driven avatars—virtual teachers that talk to students in natural language, react to what they do and say, ask Socratic questions, and change the difficulty and speed of challenges in real time—is a big step up from the static, scripted hint systems that were common in older educational software. These smart virtual teachers can tell when a student is having trouble, when they are ready for a harder task, and when they need encouragement instead of instruction. They can then respond appropriately to each situation.

Scaffolding in VR is especially important for students who learn in different ways, such as those who have less prior knowledge, learning disabilities or differences, are learning English as a second language, or are

trying to learn new subject matter while also figuring out how to use the VR interface. Research consistently shows that these learners benefit disproportionately from well-designed scaffolding, and that VR without adequate support structures can actually widen rather than narrow achievement gaps. The design implication is that scaffolding should not be seen as an optional extra for students who are having trouble, but as a necessary part of any VR educational experience that is meant to work for a wide range of students.

Avatars with AI

Smart virtual teachers that change in real time based on how well each student is doing, giving them personalized help and adjusting the level of difficulty (Mohamed Mokmin et al., 2026).

Who Gains the Most from VR Scaffolding?

1. Students who have not yet acquired extensive knowledge
2. Students with disabilities or who learn differently
3. English language learners managing two sets of mental demands
4. First-time VR users are responsible for both the interface and the content simultaneously
5. Students in STEM subjects are facing high complexity

Designing for Performance and Engagement

To make VR educational experiences that are both very interesting and very useful for learning, you need to keep two sets of concerns in productive tension. When it comes to engagement, the literature is clear that the quality and realism of the virtual environment matter: photorealistic graphics, physics simulations that are accurate in space, convincing audio environments, and smooth, responsive interactive mechanics all add to the sense of presence that is VR's most unique and educationally important feature. Students who use VR environments that are low-fidelity, glitchy, or not visually convincing say they feel less present, less engaged, and ultimately less able to learn—exactly the opposite of what the goal is.

At the same time, the quest for photorealism and technical advancement shouldn't get in the way of the basics of education. Ioannou et al. (2021) found that the best VR physics environments were those that struck a careful balance between showing students the specific physical phenomena they were meant to observe and understand in a clear and unambiguous way and making the environment look as real as possible. Peng et al. (2023) similarly discovered that the most pedagogically effective design features of their lunar rover VR game were not the most visually impressive; rather, they were the interactive components that provided students with authentic agency over their learning path: the option to select between active and passive modes, to traverse the lunar surface at their own pace, and to repeatedly access and scrutinise essential mission equipment as required.

It is important to stress how important whole-body movement and multimodal interaction are in VR learning. Fu et al. (2024) found that immersive VR led to better learning outcomes than desktop games. This was at least partly because the VR experience was multimodal, meaning that it involved physical movement and gestures as part of the learning process. This finding is related to a growing body of research on embodied cognition, which says that interacting with the learning environment in a physical way is not only a way to motivate students, but also a key way to help them understand concepts and remember things. So, one of the best design choices VR teachers can make may be to create VR experiences that use whole-body movement instead of just copying the mouse-and-keyboard interaction model in a three-dimensional space.

Visual Realism

High-quality graphics and realistic physics simulations make the sense of presence stronger, which is the most important part of VR's educational effect (Ioannou et al., 2021).

Interaction with multiple modes

Whole-body movements and physical gestures in VR use embodied cognition to improve memory formation and understanding of concepts (Fu et al., 2024).

Learner Power

Giving real choices, like active vs. passive modes, self-paced navigation, and content that can be revisited, boosts motivation and helps different kinds of learners (Peng et al., 2023).

The Future of VR in Online Education

It looks to the future and talks about the future of VR technology, the factors that will affect how quickly and widely it is used in education, and the changes that could happen if immersive online education becomes common. The picture that comes out is one of cautious but real hope: the problems that make it hard for VR to be used in schools are real, but they are getting better. The possible benefits of a world where every student has access to high-quality immersive learning experiences are huge.

For a future that is more interactive and open to everyone

Historically, the biggest obstacle to widespread use of VR in schools has been its high cost. Early consumer VR headsets were too big, too expensive, and needed powerful desktop computers to work well. This made them too expensive for most schools, especially those in under-resourced areas and developing economies. The picture is changing quickly. The price of standalone VR headsets, which don't need a computer and can be used wirelessly anywhere, has dropped a lot. The current generation of headsets is now available for prices similar to those of mid-range laptops. Predictions for the future say that this trend will continue, and that VR hardware for schools will probably cost the same as tablets and Chromebooks within the next five years.

The growth of strong VR content libraries and standard educational platforms will also be very important for widespread use. Right now, most of the high-quality educational VR content is made by individual research teams or specialised companies for specific courses or schools. This model doesn't work well on a large scale. Open-standard VR content platforms, similar to current learning management systems like Canvas or Moodle, would let teachers access, change, and use VR learning experiences without needing to know a lot about technology or have a lot of money to spend on development. Several big companies that make educational technology are putting a lot of money into this infrastructure right now, and the pace of development is picking up.

Perhaps the most exciting thing about VR is that it could make high-quality experiential education available to everyone around the world. A student in a rural area of sub-Saharan Africa who has a cheap VR headset and a good internet connection could, in theory, use the same virtual chemistry lab, go on the same immersive history trips, and get the same AI-powered tutoring help as a student at a well-funded university in North America or Europe. This potential to make things more equal isn't automatic; it needs careful design choices, fair distribution policies, and ongoing investment in infrastructure. However, it is real, and it is one of the strongest moral arguments for speeding up the development and use of VR in education.

Conclusion: Making the Most of Virtual Learning

The evidence in this article makes a strong case: Virtual Reality is not just a gimmick, a fad, or a luxury for schools with a lot of money. It is a truly revolutionary technology that solves the biggest and most persistent problems with online education—engagement, interactivity, experiential learning, and fair access to high-quality educational experiences—in a principled and empirically validated way. The case studies by Bai et al. (2026), Mohamed Mokmin et al. (2026), Ioannou et al. (2021), Fu et al. (2024), and Peng et al. (2023) all show that well-designed VR educational experiences can lead to big and meaningful improvements in learning outcomes across a wide range of subjects, age groups, and types of learners.

The most important word in this article is “well-designed.” The research record is also clear that poorly designed VR experiences—those that put technical spectacle ahead of pedagogical purpose, don’t provide enough support for different types of learners, or don’t follow the rules of cognitive load management and evidence-based instructional design—can fail to help people learn, even though they are immersive. The future of educational VR depends not only on hardware and content development continuing to improve, but also on the growth of a professional community of VR instructional designers who know both the unique benefits of the medium and the best ways to teach and learn.

In the future, the combination of lower hardware costs, larger content ecosystems, better AI capabilities, and more schools realising the educational potential of VR will create the right conditions for a real turning point in the use of immersive technologies in education. The idea of a future where every student, no matter where they live, what school they go to, or how much money they have, can have rich, personalised, and immersive learning experiences is no longer just a dream. This article looks at research that shows that this goal is possible and gives a strong theoretical and empirical basis for the work that needs to be done to make it happen.

Bai et al. (2026)

An immersive virtual experimental teaching platform for control engineering showed big improvements in both understanding concepts and practical skills.

Mohamed Mokmin and others (2026)

DVR, GIBL, and PBL were used to teach secondary biology cell division. AI avatars and Flow Theory design helped students stay motivated and do better.

Ioannou, Tsivitanidou, and Georgiou (2021)

Immersive VR for Special Theory of Relativity in high school physics; big improvements in understanding and less anxiety about physics.

Fu et al. (2024)

VR-based scaffolded game-based learning for science students who aren’t very motivated; immersive VR was much better than desktop games.

Peng et al. (2023)

An educational VR game for the Apollo lunar missions; a three-phase method led to improvements in spatial, factual, and operational knowledge.

Review of ERIC (2021)

A broader review warns that VR reliably increases “liking,” but learning gains need to be carefully integrated into lessons and the use of generative learning strategies.

References

- Bai, Y., Jia, X., Yue, X., Zhang, X., & Jin, Z. (2026). An Immersive Virtual Experimental Teaching Platform for Control Engineering: Design, Implementation, and Empirical Validation. *Computer Applications in Engineering Education*.
- ERIC. (2021). *Immersive Virtual Reality Increases Liking but Not Learning with a Science Simulation, and Generative Learning Strategies Promote Learning in Immersive Virtual Reality*. *Journal of Educational Psychology*.
- Fu, H., Dubois, J., & Huang, K.-T. T. (2024). Integrating immersive virtual reality technology in scaffolded game-based learning to enhance low motivation students’ multimodal science learning. *Educational technology research and development*, 72(5), 2083–2102.
- Ioannou, A., Tsivitanidou, O., & Georgiou, Y. (2021). Learning experience design with immersive virtual reality in physics education. *Educational technology research and development*, 69(6), 3051–3080.
- Mohamed Mokmin, N. A., Mohd Hamizi, M. A., & Nur Azlina Mohamed Mokmin. (2026). Enhancing secondary biology learning through guided and problem-based virtual reality: effects on interest, concentration, and performance. *Education and Information Technologies*, 31(1), 755–785.
- Peng, C., Schwartz, D., Howell, G., Cao, L., & Zhang, H. (2023). An educational virtual reality game for learning historical events. *Virtual Reality*, 27(4), 2895–2909.
- Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). Immersive virtual reality as a pedagogical tool in education: A systematic literature review of quantitative learning outcomes and experimental design. *Educational Technology Research and Development*, 69(1), 1–32. <https://doi.org/10.1007/s11423-020-09879-7>
- Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2020). A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda. *Computers & Education*, 147, 103778. <https://doi.org/10.1016/j.compedu.2019.103778>
- Makransky, G., & Petersen, G. B. (2021). Immersive virtual reality and learning: A meta-analysis. *Educational Psychology Review*, 33(3), 937–959. <https://doi.org/10.1007/s10648-020-09569-6>
- Jensen, L., & Konradsen, F. (2018). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies*, 23(4), 1515–1529. <https://doi.org/10.1007/s10639-017-9676-0>
- Makransky, G., Terkildsen, T. S., & Mayer, R. E. (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. *Learning and Instruction*, 60, 225–236. <https://doi.org/10.1016/j.learninstruc.2017.12.007>

- Mystakidis, S. (2022). Metaverse. *Encyclopedia*, 2(1), 486–497. <https://doi.org/10.3390/encyclopedia2010031>
- Dede, C., Jacobson, J., & Richards, J. (2017). Immersive interfaces for engagement and learning. In M. Spector et al. (Eds.), *Handbook of research on educational communications and technology* (pp. 735–745). Springer. <https://doi.org/10.1007/978-3-319-17727-4>

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