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Virtual, Augmented, and Mixed Realities in Education

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Chapter 1
Introduction: Virtual, Augmented, and Mixed Realities in Education

Christopher J. Dede, Jeffrey Jacobson and John Richards

Keywords Virtual reality · Augmented reality · Mixed reality · Augmented virtuality
Virtual environment · VR · AR · MR · VE · Cyberspace · Immersion
Presence · Haptics · Constructivism · Situated learning · Active learning
Constructionism · Education · Schools · Museums · Informal education
Conceptual change · Adaptive response · Metaverse · 360 video · HMD
CAVE · Dome · Cybersickness · Sensory conflict · Interactive · Interactivity
Multiuser virtual environment · MUVE · Massively multiple online roleplaying game
MMORPG · MMO · Avatar · Panoramic · Oculus rift · HTC vive
Google cardboard · GearVR · 3D

1.1 Origin of This Book

We live at a time of rapid advances in both the capabilities and the cost of virtual reality (VR), multi-user virtual environments (MUVEs), and various forms of mixed reality (e.g., augmented reality (AR), tangible interfaces). These new media potentially offer extraordinary opportunities for enhancing both motivation and learning across a range

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of subject areas, student developmental levels, and educational settings. However, past generations of learning technologies have seldom fulfilled the promise they offered, because of shortfalls in orchestrating research, development, policy, practice, and sustainable revenue to achieve transformational change in education.

With the sponsorship of NetDragon Websoft, a Chinese gaming and education company, in January, 2017 the Immersive Learning Group at the Harvard Graduate School of Education, and the Smart Learning Institute at Beijing Normal University co-convened an invitational research workshop of research experts in immersive learning. Its goal was to describe the leading edge of research in this field, as well as to push forward the evolution of next-generation immersive learning experiences. This volume is based on chapters these experts presented at that workshop and later refined based on feedback from rich discussions among participants. Overall, the goal of the workshop and book is to develop a strategic vision for educational VR and immersive learning. This will include evaluations of long term potential and opportunities, as well as current problems and barriers. Further, the ideas in the book can inform a research and development agenda for the field. Achieving this agenda will require understanding and surmounting issues with implementation, as well as the development of testbeds at scale.

The discussion at the workshop was scholarly and sophisticated, since we are a select group of researchers deeply familiar with this field. However, this book is written to be accessible to a broad audience, since we want to reach a much wider spectrum of stakeholders in immersive learning: teachers, administrators, scholars, policy makers, instructional designers, evaluators, industry leaders.

Also, even experts are still refining their definitions of terms in this field. For that reason, we include a glossary towards the end of this book that provides our definitions as used to frame the workshop. However, the authors of each chapter may use somewhat different definitions and will describe why in their discussions.

1.2 A Brief History of Immersive Media in Education

Virtual Reality (VR) was invented in the 60s or 70s with the flight simulators developed by military aerospace, although they might be better described as Mixed Reality (MR). [The next section of this chapter provides detailed definitions for all these terms.] The advance of research on educational applications of VR has been uneven, with empirical studies rare (Jacobson, 2008, pp. 62–75). VR was shown to be very effective for learning procedural tasks, in which students learns a sequence of steps to accomplish a task requiring maneuvers in three-dimensional space. Examples include as operating a vehicle, fixing on a complex piece of machinery, and finding your way around an otherwise unfamiliar landscape. The scientific literature on this is vast, but it never found significant use in K-12 education, which tends to emphasize declarative knowledge, primarily facts and concepts. Also, until 2015 equipment of usable quality was unaffordable at scale in classroom settings.

In the early 2000s multi-user virtual environments (MUVEs) and augmented realities (AR) came on the scene, and soon educational research established their effectiveness for learning. Further, these technologies were affordable at scale. But again they did not penetrate the K-12 market, for reasons discussed in Richards' chapter.

Today, VR AR and MR are all flourishing in the consumer market. Google, Samsung, SONY, and Facebook all have Head Mounted Devices (HMDs) and were joined by a half dozen new devices at the 2017 Consumer Electronics Show. Pokemon GO© had 100 million downloads from its launch on July 6, 2016 through December, 2016 and has been earning over $10M per day on IOS and Google Play combined. After twenty-five years of educational research, the consensus of the participants at the conference was that the time has come for these new technologies to have a substantial impact in education.

1.3 A Conceptual Framework for VR in Education

Learning experiences designed to teach complex knowledge and sophisticated skills are often based on "guided social constructivist" theories of learning. In this approach, learning involves mastering authentic tasks in personally relevant, realistic situations. Meaning is imposed by the individual rather than existing in the world independently, so people construct new knowledge and understandings based on what they already know and believe, which is shaped by their developmental level, their prior experiences, and their sociocultural background and context (Palincsar, 1998). Instruction can foster learning by providing rich, loosely structured experiences and guidance (such as apprenticeships, coaching, and mentoring) that encourage meaning-making without imposing a fixed set of knowledge and skills. This type of learning is usually social; students build personal interpretations of reality based on experiences and interactions with others.

Immersive media have affordances that enhance this type of learning. Psychological immersion is the mental state of being completely absorbed or engaged with something. For example, a well-designed game in a MUVE draws viewers into the world portrayed on the screen, and they feel caught up in that virtual environment. The use of narrative and symbolism creates credible, engaging situations (Dawley & Dede, 2013); each participant can influence what happens through their actions and can interact with others. Via richer stimuli, head-mounted or room-sized displays can create sensory immersion to deepen the effect of psychological immersion, as well as induce virtual presence (place illusion), the feeling that you are at a location in the virtual world (see Slater's chapter for more details).

Three types of immersive interfaces underlie a growing number of formal and informal learning experiences:

- *Virtual Reality* (VR) interfaces provide sensory immersion, at present focusing on visual and audio stimuli with some haptic (touch) interfaces. The participant can turn and move as they do in the real world, and the digital setting responds to maintain the illusion of presence of one's body in a simulated setting.

- *Multi-user Virtual Environment* (MUVE) interfaces offer students an engaging Alice-in-Wonderland experience, going “through the screen” to a simulated setting in which their digital avatars convey psychological immersion in a graphical, virtual context. The participant represented by the avatar feels remote presence inside the virtual environment: the equivalent of diving rather than riding in a glass-bottomed boat.
- *Mixed Reality* (MR) interfaces combine real and virtual settings in various ways, to enable psychological immersion in a setting that blends physical and digital phenomena. For example, an outdoor augmented reality (AR) experience using mobile devices can superimpose information, simulations, and videos on a through-the-camera-lens view of natural phenomena (Dunleavy & Dede, 2013).

The range of options is complex, because new sub-types of VR, MUVEs, and MR are constantly emerging. Each has unique strengths and limits for aiding learning, so understanding how to choose the right medium for a particular educational situation is an important next step in realizing the potential of immersive media in learning. However, some aspects of immersive learning apply across all these media.

1.3.1 How Immersive Presence Enhances Motivation and Learning

Immersion in a mediated, simulated experience (VR, MUVE, or AR) involves the willing suspension of disbelief. Inducing powerful immersion for learning depends on designs that utilize actional, social, and symbolic/narrative factors, as well as sensory stimuli (Dede, 2009):

- *Actional Immersion*: Empowering the participant in an experience to initiate actions that have novel, intriguing consequences. For example, when a baby is learning to walk, the degree of concentration this activity creates in the child is extraordinary. Discovering new capabilities to shape one’s environment is highly motivating and sharply focuses attention.
- *Symbolic/Narrative Immersion*: Triggering powerful semantic associations via the content of an experience. As an illustration, reading a horror novel at midnight in a strange house builds a mounting sense of terror, even though one’s physical context is unchanging and rationally safe. Narrative is an important motivational and intellectual component of all forms of learning. Invoking intellectual, emotional, and normative archetypes deepens the experience by imposing a complex overlay of associative mental models.
- *Sensory Immersion*: This occurs when the student employs an immersive display, like a head-mounted display, a CAVE, or a digital dome. The display presents a panoramic egocentric view of some virtual world, which the student leverages to imagine him or herself to be there. This type of immersion has been

used extensively for vehicle training and other procedural learning applications. There is also solid evidence that it can advantage students who need to learn the declarative knowledge connected to three-dimensional structures (Salzman, Dede, Loftin, & Chen, 1999; Jacobson, 2011, 2013).

- *Social Immersion*: As discussed in Gardner's and Kraemer's chapters, rich social interactions among participants in a shared virtual or mixed reality deepens their sense of immersion. In the real world, we participate in shared processes of reasoning between people who leverage their environment to make decisions and get things done. To the extent that a virtual or partially virtual environment supports this, it draws the user in, makes him or her feel more a part of it.

Psychological immersion is achievable in any of these interfaces by design strategies that combine actional, social, symbolic, and sensory factors.

Immersion is intrinsically helpful for motivation and learning in some ways, but not necessarily useful in others. In mastering complex knowledge and sophisticated skills, students learn well in a Plan, Act, Reflect cycle (PAR), in which first they prepare for an experience that involves doing something they want to master, then they attempt that performance, and finally they assess what went well, what did not, why, and what they need to learn in order to execute a more successful repetition of the cycle. Immersion is great for the Act part of the cycle, but unless used carefully can interfere with the Plan and the Reflect parts of the cycle. This—and numerous other factors—make effective instructional design for immersive learning complex.

1.3.2 Situated Learning and Transfer via Psychological Immersion

The capability of VR, MUVE, and MR interfaces to foster psychological immersion enables technology-intensive educational experiences that draw on a powerful pedagogy: situated learning.

Situated Learning: "Situated" learning takes place in the same or a similar context to that in which it is later applied, and the setting itself fosters tacit skills through experience and modeling. For example, in a medical internship, both the configuration and the coordinated team activities in a hospital surgical operating room provide embedded knowledge.

Situated learning requires authentic contexts, activities, and assessment coupled with guidance from expert modeling, mentoring, and "legitimate peripheral participation" (Wenger, 1998). As an example of legitimate peripheral participation, graduate students work within the laboratories of expert researchers, who model the practice of scholarship. These students interact with experts in research as well as with other members of the research team who understand the complex processes of scholarship to varying degrees. While in these laboratories, students gradually move from novice researchers to more advanced roles, with the skills and expectations for them evolving.

Related to situated learning is embodied cognition, an instructional strategy that posits retrieving a concept from memory and reasoning about it is enhanced by creating a mental perceptual simulation of it (Barsalou, 2008). For example, research shows that second grade students who acted out stories about farms using toy farmers, workers, animals, and objects increased their understanding and memory of the story they read. Steps involved in a grounded cognition approach to learning something include having an embodied experience (which could be created by immersive interfaces), learning to imagine that embodied experience as a mental perceptual simulation, and imagining that experience when learning from symbolic materials.

Potentially quite powerful, situated learning is seldom used in formal instruction because creating tacit, relatively unstructured learning in complex real-world settings is difficult. However, VR, MUVE, and MR experiences can draw on the power of situated learning by creating immersive, extended experiences with problems and contexts similar to the real world. In particular, all three types of immersive interfaces provide the capability to create problem-solving communities in which participants can gain knowledge and skills through interacting with other participants who have varied levels of skills, enabling legitimate peripheral participation driven by social and collaborative interactions.

Situated learning is important in part because of the crucial issue of transfer.

Transfer: Transfer is the application of knowledge learned in one situation to another situation, demonstrated if instruction on a learning task leads to improved performance on a transfer task, typically a skilled performance in a real-world setting. For example, statistical reasoning learned in a classroom can potentially aid with purchasing insurance, or with gambling.

A major criticism of instruction today is the low rate of transfer generated by conventional instruction. Even students who excel in schooling or training settings often are unable to apply what they have learned to similar real-world contexts. Situated learning addresses this challenge by making the setting in which learning takes place similar to the real-world context for performance in work or personal life. Learning in well-designed digital contexts can lead to the replication in the real world of behaviors successful in simulated environments (Fraser et al., 2012; Mayer, Dale, Fraccastoro, & Moss, 2011; Norman, Dore, & Grierson, 2012).

Moreover, the evolution of an individual's or group's identity is an important type of learning for which simulated experiences situated in immersive interfaces are well suited (Gee, 2003; Turkle, 1997). Reflecting on and refining an individual identity is often a significant issue for students of all ages, and learning to evolve group and organizational identity is a crucial skill in enabling innovation and in adapting to shifting contexts. Identity "play" through trying on various representations of the self and the group in virtual environments provides a means for different sides of a person or team to find common ground and the opportunity for synthesis and evolution (Laurel, 1993; Murray, 1998). As discussed in Slater's chapter, immersion is important in this process of identity exploration because virtual identity is unfettered by physical attributes such as gender, race, and disabilities.

Another attribute that makes immersive learning different, and potentially more powerful than real world learning, is the ability to create interactions and activities in mediated experience not possible in the real world. These include, for example, teleporting within a virtual environment, enabling a distant person to see a real-time image of your local environment, or interacting with a (simulated) chemical spill in a busy public setting. Slater's chapter categorizes opportunities for learning in simulations of settings not possible in the real world. Jacobson's chapter addresses how to develop representations that are authentic for learning.

All these capabilities suggest that, to maximize the power of immersive learning it's important not to present isolated moments in which VR, MUVEs, and AR are used to provide short-term engagement or fragmentary insight. Instead, extended experiences that immerse students in rich contexts with strong narratives, authentic practices, and links to real world outcomes are what truly unleash the transformational power of immersion. For example, while showing a 3-D model of a human heart illustrating blood flow is useful, immersing students in a virtual setting where they are applying knowledge of the heart to save the lives of computer-based agents is much more motivating, as well as effective in fostering a wide range of complex knowledge and sophisticated skills.

Schnieder references *constructivism* explicitly in his chapter, and the term is used widely in the educational VR literature. Constructivism is nearly the same thing as Situated Learning, because it revolves around a managed ecosystem within which students build their own learning experience.

1.3.3 Approaches to Designing Immersive Educational Media

1.3.3.1 Simulation

In this approach, the learning experience is an immersive simulation of an artifact, environment, or situation that exists in real life. For example, the phenomenon modeled at an appropriate level of fidelity for the instructional goals could be a virtual garden, or a simulated first-responder crisis with a building on fire, or a representation of some industrial process. Importantly, the simulation allows learners to do a few things they could not do in real life (National Research Council, 2011). For example, they could change the season of a virtual forest with the touch of a button, or move along a timeline for historical change, or operate dangerous machinery that would be too risky to learn how to use (at first) in real life.

In classroom settings, the instructional design is built around the simulation, with students often using a PAR cycle to interact with the simulation, complemented by the instructor teaching with knowledge and skills outside the simulation to aid in developing effective performances. The design of the curriculum in which the simulation is embedded is important, as is professional development for effective use of simulations in classrooms.

Some advantages of simulations are that they are quick to deploy, compared to developing more complex experiential environments, and relatively straightforward to understand. They are well suited for teaching students procedural knowledge, using skills to help them accomplish tasks that require some sequence of actions.

1.3.3.2 Constructionist Activities

In his chapter, Schneider discusses constructivism, the educational learning theory of which constructionism is one approach. Constructionist learning theory is based on the assumption that developing knowledge occurs best through building artifacts (physical or digital) that can be experienced and shared (Papert, 1991). In this type of learning, participants are given tools to build their own immersive environments, or provided an immersive environment and told to build something within it. In a classroom setting, an illustration would be a learning project where each student designs a "monster truck" for each one of the planets in our solar system, and then attempts to drive their truck on the surface of that planet. To be successful, they have to learn about that planet's characteristics (e.g., gravity, temperature) and about the process of engineering a vehicle.

This approach can be very effective, because it empowers the learners to create something in which they have an emotional investment. Further, participants learn how to author in the immersive technology. As discussed later, all of the immersive technology manufacturers go to great lengths to develop tutorials and educational materials for people who want to informally create experiences that use their products. In formal education, all those materials can be leveraged in a constructionist curriculum. Further, research suggests that children can handle this approach at an earlier age than parents and teachers might expect.

As with simulations, in classroom settings the teacher must manage the learning process. She will need guidance in the technology itself and in instructional strategies, as well as a curriculum surrounding the building experience that is linked to academic objectives (Laurillard, 2009).

1.3.3.3 Embodied Cognition

As discussed earlier, embodied cognition learning experiences involving creating a mental perceptual simulation useful when retrieving a concept or reasoning about it (Barsalou, 2008). An embodied immersive experience via VR, MUVE, or MR can develop such a mental perceptual simulation, especially when facilitated by curricular and instructional support.

Embodied experience with academically important situations and phenomena is often limited, both by personal circumstances and by limitations of the real world. For example, an impoverished inner city student may never visit a farm, and no one now can have a physically embodied experience of living in the 17th century, or seeing relativistic effects when moving close to the speed of light. Digitally immersive learning experiences can bridge these gaps.

This approach to learning is not new; Montessori used analog artifacts as an important part of her pedagogical method. With the emergence of multi-modal interfaces that include gestures and similar physical movements, new forms of digitally enhanced embodied cognition are now possible and practical. Research on effective designs for immersive embodied learning is an exciting frontier for formal and informal education.

1.3.3.4 Directed Immersive Narrative

In this type of instructional design, learners participate in—and shape—a narrative. Participants are guided from beginning to end, but also choose their own path, with meaningful choices along the way to help them learn. In gaming, this type of immersive learning is usually a MUVE, although VR games are emerging. As discussed in Klopfer's chapter, the MUVE *The Radix Endeavor* is an example. However, such a learning experience could also include MR, if the phenomenon studied is some kind of activity that would make sense in a readily accessible type of physical environment, like an ecosystem. As discussed in Dede's chapter, *EcoMOBILE* is an augmented reality that illustrates this.

Directed narratives provide a superstructure within which the other types of immersive learning designs can be placed: simulations, constructionism (in part through the participant's choices), and embedded cognition. The story that emerges is the vehicle for identity and transfer that makes the whole more than the sum of its parts.

Transmedia narratives are emerging as a new form of entertainment and learning. Such a narrative can span immersive and non-immersive media, creating "alternate realities" that interweave fact and fiction to form myth. In education, the challenge is to immerse participants in the alternate reality for learning, but then fade its attraction so they return to the real world empowered through what they now know and can do.

1.3.3.5 Learning Simpler Material

This discussion has focused on learning complex knowledge and sophisticated skills, but what is the role of immersion in learning simpler, foundational material? It may seem counterintuitive given prevalent educational practice for centuries, but basic ideas are best learned in the context of attempting a relatively complicated task that is engaging and has relevance to the real world. Learning involving rote performances and low-level retention (e.g., math facts, vocabulary words) is not intrinsically interesting, and many students quickly tire of music, animations, simple games, and other forms of extrinsic rewards (the chocolate-covered broccoli problem). This leads to apathy about mastering foundational content and skills, especially when they have no perceived relevance to the learner's life. This motivational problem is exacerbated by a fundamental assumption of behaviorist instructional design that no complex knowledge or skill is learnable until the student has mastered every simple, underlying sub-skill. This tenet leads to long initial sequences of low-level teaching by telling and learning by listening, followed by rote practice with extrinsic bribery to keep going. In this common situation, students often lose sight of why they should care about learning the material, which may seem to them remote from the eventual goal-state of an engaging, complex knowledge or skill with real-world utility.

Substantial theory, research, and experience documents that—in contradiction to behaviorist theories of learning—students can master simple skills in the context of learning a complex task that is engaging and relevant to them (Dede, 2008). In contrast to conventional practice now, even when learning foundational material, students will experience higher motivation and longer retention of simple skills learned via the types of simulations, constructionist experiences, and directed immersive narratives discussed above. While learning by guided social constructivism seems inefficient compared to direct instruction, because more time is required, in the long run this approach is more effective, because less re-teaching is required due to problems with retention as un-engaging material is memorized, immediately tested, then forgotten.

So, if one is using such an approach to foundational learning, what is the role of immersion for the parts of instruction that involve simple skills and knowledge? While the psychological aspects of immersion are always useful in learning, sensory immersion in VR is necessary only for material that is intrinsically 3-dimensional (e.g., understanding the role of the ecliptic plane in the solar system) or where embodied cognition is useful (e.g., becoming an animal to experience its relationship to an ecological niche). 2-D simulations, non-immersive constructionism, and non-digital narratives—even rote teaching and learning—may be as effective and more efficient than immersive media if used for foundational learning in the context of a guided social constructivist experience.

1.4 Overview of the Chapters

The book begins with this introductory chapter introducing terms and conceptual frameworks, as well as providing a quick summary for the contents of each chapter, grouped into two types of discussions. *Frameworks* for the design and implementation of immersive learning are delineated in chapters by Slater; Jacobson;

Kraemer; Shute, Rahimi, and Emihovich; Richards; and Liu and Huang. Then, *Case Studies* of immersive learning are described in chapters by Dede, Grotzer, Kamarainen, and Metcalf; Gardner and Sheaffer; Klopfer; Johnson-Glenberg; and Schneider. Finally, a concluding chapter summarizes cross-cutting themes and advances a proposed research agenda.

1.4.1 Frameworks for the Design and Implementation of Immersive Learning

Slater's chapter, Implicit Learning through Embodiment in Immersive Virtual Reality, presents a framework for understanding how VR results in the illusion of presence. The participant in a VR scenario typically has the illusion of being in the virtual place and, under the right conditions, the further illusion that events there are really occurring. Slater also describes a further illusion that can be triggered in VR, referred to as body ownership. This can occur when the participant sees a life-sized virtual body substituting her or his own, from first person perspective. This virtual body can be programmed to move synchronously with the participant's real body movements, thus leading to the perceptual illusion that the virtual body is her or his actual body. Slater surveys various experiments showing that the form of the virtual body can result in implicit changes in attitudes, perception and cognition, as well as changes in behavior. He compares this with the process of implicit learning and concludes that virtual body ownership and its consequences may be used as a form of implicit learning. He concludes by suggesting how the study of the relationship between body ownership and implicit learning might be taken forward.

Jacobson's chapter, Authenticity in Immersive Design, describes authenticity a concept found in both media design and educational design, usually as a quality needed for success. He develops a theory of authenticity for educational experiences with immersive media (VR, MR, MUVEs) to help educators and designers in this new field. In this framework, authenticity refers to the relationship between a truth and its representation, guided by a purpose; A representation or an experience is said to be authentic, when it successfully captures the fundamental truth of what we are learning. This framework provides a practical way to look at one key dimension of good educational design.

Kraemer's chapter, The Immersive Power of Social Interaction, reviews new technologies and their impact on learning and students' motivation. The main argument is that, in order to achieve immersion, social interactions should be fostered. Three technologies are discussed that either inherently draw on social interactions (pedagogical agents, transformed social interaction) or can be enriched by including collaborative learning elements (augmented reality). For each of the three technologies, a short overview is given on the state of current developments, as well as on results from empirical. Also, discussed is to what extent these developments have built on social interaction, how this usage might be extended and whether beneficial outcomes can be expected from increased usage.

The chapter by Shute, Rahimi, and Emihovich focuses on how to design and develop valid assessments for immersive environments (IEs), particularly those providing “stealth assessment,” an ongoing, unobtrusive collection and analysis of data as students interact within IEs. The accumulated evidence on learning thus provides increasingly reliable and valid inferences about what students know and can do across multiple contexts, for both cognitive and non-cognitive variables. The steps toward building a stealth assessment in an IE are presented through a worked example. The chapter concludes with a discussion about future stealth assessment research, how to move this work into classrooms to enhance adaptivity and personalization.

Shifting from the design focus in prior chapters to implementation issues, Richard’s chapter summarizes the distribution and availability of the infrastructure needed for using VR and MR in the schools. Using immersive media requires a technology infrastructure consisting of dependable high-speed Internet connectivity to the classroom, a ratio of at least one-to-one computer to student, an interactive white board, and curriculum materials that can be monitored and controlled by the teacher. This infrastructure, the Digital Teaching Platform, is quickly becoming a reality. However, a larger and more complex barrier remains: integrating the new technologies with existing classroom systems and with existing and emerging pedagogical practice. The evolving nature of digital curricula, formative assessment, and classroom practice impact how teachers will be able to integrate these new technologies. Richards also addresses how immersive media can work as supplemental digital materials for instruction and assessment. In particular, he focuses on issues of the sensory comfort and fidelity of interaction, as these impact the viability of these technologies in the classroom.

Liu and Huang provide the last chapter in this section, The Potentials and Trends of Virtual Reality in Education. This presents an overview of virtual reality research in education, including a bibliometric analysis to evaluate the publications on virtual reality from 1995 to 2016, based on the Thomson Reuters’s Web of Science (WoS). A total of 975 related documents were analyzed based on their publication patterns (documents types and languages, major journals and their publications, most prolific authors, most productive journals and their publications, and international collaborations). Bibliometric results show that the number of article has been increasing since 1995 exponentially. USA, UK, and Chinese Taipei are the top 3 most productive countries/regions that are involved in virtual reality research in education. The findings can help researchers to understand current developments and barriers in applications of virtual reality to education.

1.4.2 Case Studies of Immersive Learning

The Framework chapters are followed by chapters presenting case studies of immersive media for learning. Virtual Reality as an Immersive Medium for Authentic Simulations, by Dede, Grotzer, Kamarainen, and Metcalf, describes a design strategy for blending virtual reality (VR) with an immersive multi-user virtual environment (MUVE) curriculum developed by the EcoLearn design team at Harvard University for middle school students to learn ecosystems science. The EcoMUVE Pond middle grades curriculum focuses on the potential of immersive authentic simulations for teaching ecosystems science concepts, scientific inquiry (collaborative and individual), and complex causality. The curriculum is inquiry-based; students investigate research questions by exploring the virtual ecosystem and collecting data from a variety of sources over time, assuming roles as ecosystems scientists. The implications of blending in VR for EcoMUVE's technical characteristics, user-interface, learning objectives, and classroom implementation are discussed. Then, research questions for comparisons between the VR version and the "Classic" version are described. The chapter concludes with generalizable design heuristics for blending MUVE-based curricula with head-mounted display immersion.

Gardner and Sheaffer's chapter, Systems to Support Co-Creative Collaboration in Mixed-Reality Environments, examines the use of mixed-reality technologies for teaching and learning, particularly for more active and collaborative learning activities. The basis for this work was the creation of the MiRTLE platform—the Mixed Reality Teaching and Learning Environment. They report on some of the lessons learnt from using this platform on a range of different courses and describe how different active/collaborative approaches were used. They also provide evidence of the effect of these different approaches on the overall student attainment and discuss the implications on the use of this technology, describing some of the technological research being done to develop these mixed reality learning spaces and the affordances offered by this approach. Finally they reflect on the tensions between the pedagogy and technology and consider the implications for the wider systems that support teaching and learning and co-creative collaboration in mixed-reality environments.

Klopfer's chapter, Massively Multiplayer Online Roleplaying Games and Virtual Reality Combine for Learning, argues that the way Virtual Reality (VR) can really make a difference in learning are involve bringing a truly unique experience to students. The simulated online world of games is an ideal genre for this, because these games provide a set of structures that not only scaffold learners in solving complex problems, but also provide a great deal of freedom to explore personally interesting pathways. In particular, Massively Multiplayer Online Roleplaying Games (MMOs) offer an environment that supports social learning and exploration around increasingly challenging problems. VR can greatly enhance MMOs through opportunities for more natural and expressive communication and collaboration, as well as ways to visualize the complex information resulting from interactions in this space. When this approach is applied in an educational context, learners can be presented with challenging problems, requiring participation from multiple players around realistic scientific concepts. As this genre moves forward, it can explore interesting hybrid approaches that combine VR with Augmented Reality (AR) and traditional displays to meet the needs of schools, teachers, and learners.

Johnson-Glenberg's chapter, Embodied Education in Mixed and Mediated Realities, provides a summary of some of this lab's immersive media and embodied STEM learning research. This synthesis focuses on the integration of gesture in learning, and a new gesture-based assessment. A taxonomy for embodiment in education is included. The chapter concludes with several design principles that the Embodied Games Lab has culled over the years while creating educational content that maximizes the affordances of virtual and mixed reality technologies and meshes those with best pedagogical practices.

Schneider's chapter, Preparing Students for Future Learning with Mixed Reality Interfaces, explores how new learning environments, such as mixed reality interfaces (i.e., interfaces that combine physical and virtual information), can prepare students for future learning. He describes four controlled experiments in which students learned complex concepts in STEM via a Tangible User Interface that created a "Time for Telling". This is followed by a summary the findings from this research, a discussion of the possible mechanisms for the effects found in those studies, and a suggestion of design guidelines for creating this type of constructivist activities. He conclude by discussing the potential of mixed reality interfaces for preparing students for future learning.

Following these sections on Frameworks and Case Studies, a concluding chapter summarizes cross-cutting themes and advances a proposed research agenda. The book ends with a glossary of terms related to immersive learning.

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Christopher J. Dede is the Timothy E. Wirth Professor in Learning Technologies at Harvard's Graduate School of Education (HGSE). His fields of scholarship include emerging technologies, policy, and leadership. From 2001–2004, he was Chair of the HGSE department of Teaching and Learning. In 2007, he was honored by Harvard University as an outstanding teacher, and in 2011 he was named a Fellow of the American Educational Research Association. From 2014–2015, he was a Visiting Expert at NSF, Directorate of Education and Human Resources. Chris has served as a member of the National Academy of Sciences Committee on Foundations of Educational and Psychological Assessment, a member of the U.S. Department of Education's Expert Panel on Technology, and a member of the 2010 National Educational Technology Plan Technical Working Group. In 2013, he co-convened a NSF workshop on new technology-based models of postsecondary learning; and in 2015 he led two NSF workshops on data-intensive research in the sciences, engineering, and education. His edited books include: *Scaling Up Success: Lessons Learned from Technology-based Educational Improvement, Digital Teaching Platforms: Customizing Classroom Learning for Each Student,* and *Teacher Learning in the Digital Age: Online Professional Development in STEM Education.*

Dr. Jeffrey Jacobson, Ph.D., has investigated fully immersive virtual reality (VR) as a learning medium for two decades, developing the technology and conducting experimental research. His early technical work in affordable free software is widely cited in the literature. His experimental trials on VR verses desktop displays were one of the few successful media comparison studies ever conducted. His later work (NSF and NEH funded) is highly regarded among scholars of cultural history and heritage. He has given hundreds of talks and demonstrations at top universities, academic conferences, and industrial conventions. Today, Dr. Jacobson is a co-founder and leader BostonVR, the fifth largest VR meet-up group in the world. He is currently consulting with educators and professionals in several industries, including university graduate studies, architectural design, large-vehicle piloting, and virtual reality display.

John Richards, Ph.D., is Adjunct Faculty at the Harvard Graduate School of Education teaching Entrepreneurship in the Education Marketplace. He is founder and President of Consulting Services for Education, Inc. (CS4Ed). CS4Ed works with publishers, developers, and educational organizations, as they negotiate the rapidly changing education marketplace to improve business—planning processes, and to develop, evaluate, and refine products and services.

John was President of the JASON Foundation, and GM of Turner Learning–the educational arm of CNN and the Turner Broadcasting System. Over the years, John has served on boards for a variety of education groups including NECC; Cable in the Classroom; Software Information Industry Association (SIIA), Education Market section; and the Association of Educational Publishers (AEP). John's projects have won him numerous awards including two Golden Lamps and several CODIEs, as well as several EMMY nominations. He is a respected keynote speaker, has been responsible for the publication of over 1000 educational products, and is the author/editor of over 100 chapters and articles, and four books, including Digital Teaching Platforms, Teacher's College Press (with Chris Dede). He is the primary author of the Software and Information Industry Association's annual U.S. Educational Technology Market: Pre K-12 report.