Enhancing Advanced Manufacturing and Engineering Instruction with Augmented and Virtual Reality (AR/VR)

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zSpace

Abstract

As school districts, colleges, and universities evolve teaching models to incorporate in-person, remote, and/or hybrid models to deliver instruction, many courses require hands-on, experiential learning. Through augmented and virtual reality (AR/VR), content typically taught with physical materials is modeled and animated to understanding of content. This paper explores the experiential learning model and the delivery of content in AR/VR. Additionally, use cases illustrating the implementation of zSpace, an AR/VR hardware and software solution, are explored.

Introduction

As schools at the kindergarten through 12th grade (K-12) and post-secondary levels consider course offerings and programs of study, the instructional model for delivering courses, and the resources required to support faculty and students, developing a comprehensive approach to teaching and learning helps ensure the success of students. Currently, instructors are delivering instruction via one of four models: in-person, virtual, remote, and hybrid learning. Regardless of the environment in which students are learning, providing access to content in a meaningful way is critical to defining the approach. A key challenge to developing and delivering content is to identify content taught in a hands-on, experiential manner and develop learning experiences that are not restricted based on the model for delivering instruction.

The Case for Experiential Learning in Education

In lab-based courses, such as any of the core sciences, advanced manufacturing, and engineering, and other science, technology, engineering, and mathematics (STEM) related courses, providing students with access to materials and instruction that is problem-based and hands-on in nature is essential to developing student understanding and retention of concepts and content.

In a study completed by the Purdue University Discovery Learning Center and funded by the National Science Foundation (NSF), 126 eighth grade students from 10 classes were provided with instruction regarding the Earth's water. In five of the classes, students were provided with traditional instruction including textbook, lecture, projects, and tests while students in the remaining five classes used the same textbook and were tasked to design a water purification device. Based on an analysis of pre-test and post-test performance, students participating in the engineer-design project not only demonstrated higher performance on post-test scores but also demonstrated a greater percentage of improvement [1].

At the post-secondary level, a meta-analysis of 225 studies of undergraduate STEM courses, comparing student performance in traditional lecture and active learning courses, students in traditional lecture courses were 1.5 times more likely to fail the courses than their peers in active learning courses [2].

When designing instruction, the active learning model [3] of experiential learning includes four key components: 1) engaging students in a concrete experience based on the content being taught, 2) providing students with the opportunity to make observations and reflect on these observations, 3) allowing students to analyze and draw conclusions based on observations and reflections, and 4) allowing students to apply their new learning in other situations [3].

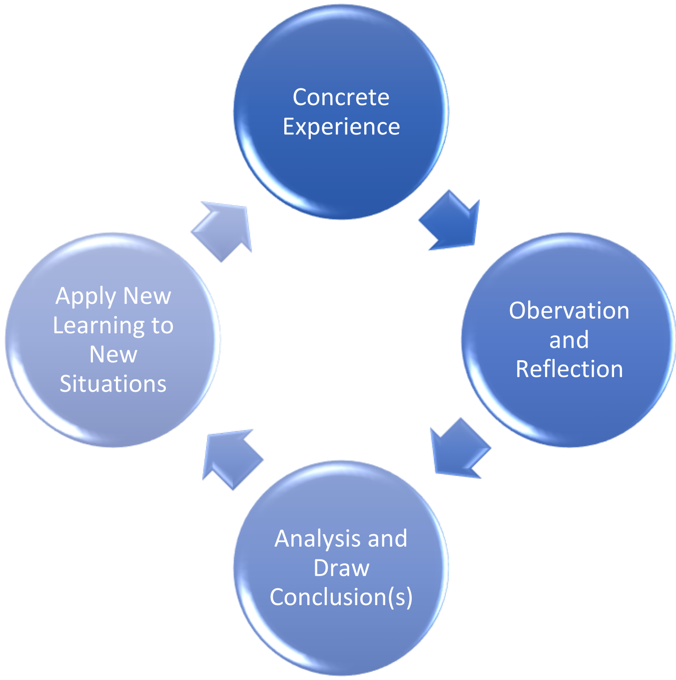

Fig. 1. Kolb's Experiential Learning Cycle.

Whether participating in the development of a water purification device or undergraduate STEM courses that integrate active learning, the need for instructors to assess the level to which students are engaged with course content supports ensuring student success regardless of the age of the learner.

Augmented and Virtual Reality (AR/VR) as a Tool for Delivering Experiential Learning

Augmented reality refers to the use of a technology device to capture elements in the surrounding environment while augmenting these elements with digital content. Common examples of AR include the game Pokemon Go! and the application SnapChat. Virtual reality (VR) refers to the use of a technology device to immerse the user with digital content. VR often includes use of a head-mounted display (HMD) that isolates the user from his/her surroundings. In *Experience on Demand*, Jeremy Bailenson [4] provides an analysis of studies, including work as early as 1980, regarding the use of VR as an instructional tool in the learning process. By examining the multiple uses of VR and categorizing them based on their affordance(s), Bailenson, founder of Stanford University's Virtual Human Interaction Lab, coined the acronym

DICE. In all cases where VR was used to provide access to or engagement with content, each case allowed learners to do something virtually that would have been too dangerous (D), impossible (I), counterproductive (C), and/or too expensive (E) to do in real-life.

Implications of AR and VR in the Instructional Process: Breaking Barriers with zSpace Experiential Learning

Providing learning experiences in lab-based courses is critical to student success, and instructors have always been faced with how to provide these experiences in a safe, productive, and economical manner. VR has provided an opportunity for instructors to address some of the previous barriers to access. zSpace is a computer leveraging components of both AR and VR to provide an immersive learning experience without use of an HMD. As a result, students learning with zSpace can interact with content while working collaboratively with their peers to accomplish defined learning tasks.

Fig. 2. Students using the zSpace desktop computer and zSpace laptop.

When students use zSpace, content is viewed virtually in the space between the student and computer. Fig. 3 illustrates students using zSpace to study anatomy.

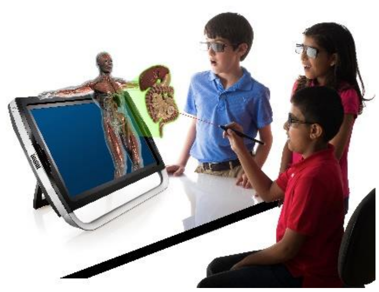

Fig. 3. Students collaboratively using zSpace to study anatomy.

In addition to breaking the barrier between learners and content, zSpace has allowed schools to deliver learning experiences to students learning at school, at home, and in virtual learning environments.

Case Studies and Research Reflecting the Use of zSpace to Provide Experiential Learning

In "Reimagining the Role of Technology in Education: The National Technology Plan," the US Department of Education [5] highlighted technology-enabled learning experiences in action and identified the need for schools to provide students with interactive three-dimensional content to create "potentially transformational learning experiences." Specifically, the plan discusses zSpace and notes that, "With three-dimensional glasses and a stylus, students are able to work with a wide range of images from the layers of the earth to the human heart. The zSpace program's noble failure feature allows students constructing a motor or building a battery to make mistakes and retry, learning throughout the process. Although the content and curriculum are supplied, teachers can customize and tailor lesson plans to fit the needs of their classes. This type of versatile technology allows students to work with objects schools typically would not be able to afford, providing a richer, more engaging learning experience."

Further, in a study of students using zSpace to learn content related to the heat, students demonstrated an average 15% improvement in pre-test to poste-test scores [6].South Orangetown Middle School in New York uses zSpace to support their STEAM lab instruction. Students use the engineer-design process to build prototypes of the boats they will build for the Massachusetts Institute of Technology's Cardboard Boat Regatta competition. Research findings showed that zSpace had a significant impact on creativity and critical thinking, skills that are both indispensable in engineering design. Students reported becoming more aware of just how important critical thinking can be, observing how it can help avoid problems and lead to better work. In addition, students and researchers observed additional soft skills attributed to their experiences with zSpace, such as grit. Akin to persistence and resilience, grit relates to one's interest in pursuit of a long-term goal [7]. The ability to stick to difficult tasks is perhaps a better predictor of achievement than traditional measures, according to recent research [8], and providing multiple tools to complete a task, like zSpace, may have helped the students get through the toughest parts of the assignment [9], [10], [11].

Other use cases include

- The University of Texas at San Antonio uses zSpace to provide lab-based experiences in the core sciences including Biology and Chemistry.

- The University of Florida uses zSpace in the College of Education to provide pre-service teachers with preparation for teaching computer science, science, and mathematics.

- Renton Technical College in Washington State uses zSpace in its automotive program to deliver a lab-based automotive lab to students remotely during the 2019-present school years while the COVID19 pandemic restricted student access to the lab.

- Motlow State Community College in Tennessee uses zSpace to provide students seeking certification in advanced manufacturing, welding, and nursing with lab-based learning experiences.

- High school students at the Metropolitan Regional Career and Technical Center in Rhode Island use zSpace to explore career pathways in advanced manufacturing, health science, automotive technology, engineering, welding, and other pathways before selecting a program of study.

Conclusion

Multiple use cases illustrate the implementation of zSpace to teach specific content through AR/VR to impact the delivery of hands-on, experiential learning delivered in in-person, remote, and hybrid learning environments. Instructors and students support the use of AR/VR as an effective means to deliver instruction [9].

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Biography

JOE PARLIER. After a career in public education serving as a science and math teacher, elementary principal, high school principal, assistant superintendent, and associate state superintendent, always eager to learn, Joe extended his career into the private sector supporting schools in the implementation of reform initiatives and emerging technology. Joe currently serves as the senior director of education at zSpace, an award-winning company focused on providing experiential learning in STEM and career and technical education. In this role, Joe supports subject matter experts, engineers, and end-users in the identification and development of learning content that can be enhanced through experiential learning in augmented and virtual reality. Examples of projects range from learning simulations for K-12 and college students to applications supporting medical doctors in visualizing large data sets. Joe has a BS from Mercer University, a MEd. from the University of Georgia, and an EdD from the University of Florida.