

# An Empirical Study Investigating the Effectiveness of Integrating Virtual Reality-based Case Studies into an Online Asynchronous Learning Environment

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**Abstract**—Widespread use of the Web and other Internet technologies in higher education has exploded in the last decade. Technology such as Virtual Reality (VR) has the potential to improve learning outcomes and student engagement in an active learning environment. This study investigates the extent to which VR-based education enhances learning outcomes and perceived engagement with technical curriculum. Using a between-subjects experimental design, 165 technical college students were randomly assigned to three conditional groups. The conditions included a VR simulation that tasked the user with identifying potential safety hazards in a manufacturing environment, a photo-based case study where users identified and categorized hazards from images of a manufacturing plant, and a control group. The control group for the experiment was tasked only with taking the online course, assessment, and surveys with no inclusion of either a VR or photo-based case study. Each experimental condition began with an online course designed to teach students about potential safety hazards that one may encounter in a manufacturing environment. Learning outcomes and perceived engagement, usability, and satisfaction were measured via tests and surveys. While no significant learning differences were found between the conditions, students' perception of learning including ease of comprehension, ease of memorization, usability, and active learning revealed significant improvements of the VR and control groups over the photo-based case study group. Interestingly, there were no statistically significant differences between the VR group and control group. Results indicate that VR has the potential to improve the learning experience by actively engaging users. Educational opportunities are enhanced with the use of VR for technician education.

## INTRODUCTION

ONLINE learning is an innovative educational approach where instruction and content are focused on interactivity, design, learner-centered approaches, and facilitated learning experiences which are primarily delivered through open, flexible, and distributed learning environments [1], [2]. Furthermore it goes beyond simply using the Internet for delivery and replication of traditional learning environments to expanding the experience of the learner and offering new

opportunities through a more robust learning environment with the availability of additional tools and resources. The most effective online learning models blend many different tools and resources and typically offer more flexibility for students in terms of choice (which has been suggested as an important element for motivation), learning styles, and schedules [3]. Further, in online learning the learning and content shifts from a lecture format to more interaction between the students, facilitators, and tools [4] and acknowledges the learner and the diverse skills, backgrounds, and preferences that he may bring to a course [5].

### A. Virtual Reality in Education

Virtual reality (VR) is the use of three dimensional (3D) computer graphics in combination with interface devices to create an interactive, immersive environment [6]. Due to improvements in technology and reductions in cost, the use of VR in education has increased greatly over the past ten years [7], [8]. VR, and technology in general, is believed to facilitate learning through engagement, immersion and interactivity [9]. Technology is also lauded for its ability to provide a more customized learning experience that can be accessed at the learner's convenience [10]. Of the educational technologies currently being utilized, VR is viewed as promising because of its unique ability to immerse learners in environments they are studying, such as in ancient cities, manufacturing environments, or a look into the human body. Research into the effectiveness of technology based educational tools, including VR, has demonstrated tangible benefits, such as reduced learning time and better learning outcomes [8], [11]. Technologies such as VR have also greatly expanded both access to educational opportunities as well as a range of programs that could be offered in an online setting.

Virtual environments (VEs) are often classified as desktop or immersive. Desktop virtual reality provides three dimensional (3D) multimedia simulations that users enter and explore using typical computer hardware (e.g., mouse, trackpad). Immersive virtual environments expand these capabilities, utilizing

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advanced technology-based tools, such as head-mounted displays (HMD) and data gloves in addition to the computer workstations [12]. With the exception of military training activities, where head mounted displays, data gloves and related hardware are more commonly used, desktop VR is the primary category of VR used in the educational realm. Desktop VR has the advantage of being more accessible and economical for widespread use. While immersion may be important for some types of learning activities, it is the level of interactivity, and not immersion, which is the main feature of educational VR application. Although some have questioned the ability to get a real sense of presence in a desktop VR setting, studies [12] have suggested that presence is created by the fidelity, level of interaction and user control as opposed to the specific characteristics of the virtual environment.

In an analysis of the use of VR in education, a recent analysis [13] found that 40 out of 53 studies focused on the use of VR in science, technology and math topics. This is not surprising as these subjects lend themselves to VR due to the persistence of abstract concepts and unobservable phenomena. Additionally, these are areas where hands-on experiences are deemed valuable for learners. VR not only simulates this environment through imitation of real world environments but can also encourage experimentation through the use of its technological features, such as those previously described. Studies thus far have found promising results when VR has been integrated in the classroom. In a study examining the effectiveness of desktop VR on learning outcomes in biology education, Lee and Wong [8] found that students who learned about frog anatomy in VR setting achieved better learning outcomes than students in a traditional classroom setting.

In addition to reinforcing concepts through lab types of activities, VR has also been applied to more creative endeavors. Researchers at the University of Warwick (UWG) in the UK conducted three case studies to demonstrate the potential benefits of VR in the design process. Each of the case studies involved the use of VR in creating digital prototypes to evaluate design decisions early in the development process. The researchers demonstrated that the technology could be used in training engineers and supporting creativity. They also believed that VR is a tool that could be used to bring together industry and educational institutions in preparing engineering students.

### *B. Educational Theories Addressing Integration of Online Learning and VR*

Constructivism is often cited as the learning paradigm that supports the implementation of learning in virtual environments because it aids learners in designing a model of the generation of viable knowledge. Constructivism suggests that students learn by constructing knowledge and incorporating it into their existing knowledge structure. Active learning, increased interactivity, and a personalized learning experience are advantages of VR [6], [13]. These benefits are also implied by a constructivist justification for the approach. Other commonly cited theories used to support the use of VR in education include experiential learning, inquiry learning, situated learning, and social constructivism [14]. Application of VR in learning

environments suggests a social constructivist approach where learning is a product of synthesizing information and experience [15]. Further, a true social constructivist approach incorporates learning environments that are collegial, draw from authentic activities and contexts, and recognize the importance of situativity in learning and knowledge development [16], [17]; all components that VR is well positioned to deliver in a learning environment.

The impact of media on student learning outcomes has been highly debated among educational technologists where much of the prior literature has shown no significant difference between technology-based and traditionally delivered instruction and media. Thus supporting the prior argument that media is a vehicle for delivery of instruction but does not influence student achievement [18]. The counter argument contends that use of the correct media medium could impact students' cognitive skills and that the media itself is a critical component of instructional design [19]. Further, it has been argued that the "technologies themselves do not directly cause learning to occur but can afford certain tasks that themselves may result in learning [20]." As time has passed, technology has significantly improved and there is a growing demand for technology-based instruction. Although studies have been published demonstrating the superiority of technology-based instruction over traditionally delivered instruction in the early 90s, including a meta-analyses on the effectiveness of computer based training, the common follow-up question has been what characteristics of the technology specifically lead to improved educational outcomes [21]. This trend has been similar for VR. Early skeptics of VR pointed out that the research on the effectiveness in VR in education failed to identify specific features or characteristics of the environment that positively impact learning [20]. Research in VR has more recently begun to identify specific characteristics of the technology that improve learning outcomes as well as justify the cost of adoption where specific characteristics, innate to VR, have been found to positively impact learning objectives [22].

### *C. Student Perception, Satisfaction, and Experience with Technology-based Learning*

Few studies have been conducted specifically focused on learner satisfaction and perception with online and technology-based instruction [23]. Examination of learner perception and satisfaction aids in determining what is important to the learner where previous higher education studies have shown that satisfied learners are more likely to be successful in academic achievement [24]. Further, previous research has revealed the efficacy of use of VR in acquiring new knowledge and skills [25] however, few studies have explored the importance of the students' perception and evaluation of their learning experience [26]. Design of technology-based instruction and selection of media which includes student-centered concepts has been shown to motivate and increase student participation online learning environments [1]. Student perception and attitude are significant factors in motivation and learning and it is important for instructional designers and educators to develop an understanding of how students perceive and react to elements

digital learning environments.

#### D. Purpose of Study and Research Questions

Although studies have found positive connections between the use of computers, information technology, student engagement and learning outcomes, most of them studied the general use of information technology instead of the specific use of instructional and learning management systems. This study investigates the nature of student engagement in the online learning environment to find out if student characteristics affect the use of the learning technologies and their impact on student engagement. Specifically, the following research questions were addressed:

1. What are the best ways of presenting context specific scenarios in an online asynchronous learning environment?
2. Does the amount of technology employed in a course have a relationship with student engagement, student perception, learning approaches, and student self-reported learning outcomes?

## METHOD

### A. Participants

A total of 171 two-year college students participated in the study. However, six participants did not complete the study. In total, 165 two-year college students participated in this study. Minimal demographic data was collected. Participants were not identifiable by name or demographic information. The data collected is stored in a password protected computer, accessible to only the investigators, during and after the study has been completed.

### B. Apparatus

The study used a Dell OptiPlex desktop computer connected to the Internet. Participants were also provided headphones, a keyboard, and a mouse. The research study was created in the online learning platform EducateWorkforce.com, a custom portal created specifically for two-year colleges to help integrate web and digital solutions into their existing courses. The system was built using the Open edX codebase, an open source, course management system (CMS) developed by edX that offers interactive online courses and Massive Open Online Courses (MOOC). The Open edX platform is used all over the world to host MOOCs as well as smaller classes and training modules.

### C. Design of the Learning Environments

#### 1) Instructional design and curricula development

National Science Foundation Advanced Technological Education (NSF ATE) funding is being used in Clemson's Regional Center for Aviation and Automotive Technical Education using Virtual E-Schools (CA2VES) to promote a highly skilled aviation, automotive, and advanced

manufacturing technological workforce through creation of original digital learning content and state-of-the-art virtual reality simulations.

The CA2VES instructional design model integrates regional industry input, two-year college instructor and K-12 teacher expertise, feedback from a broad spectrum of stakeholders (non-profit, governmental agencies, training experts, etc.), and methodology from leading instructional designers and learning scientists.

#### 2) Structure of learning module used for research

The learning environments utilized in this study, mimic the existing structure of curricula with VR integrated but were reduced from an entire Manufacturing Safety course with ten modules, to a single abbreviated learning module. All primary elements of the instructional design model were included in this module however, it was abbreviated to allow participants to complete in approximately one hour. Key elements of the model, included in this study, are identified and described in Table I.

#### 3) Method for virtual simulation design and development

The virtual simulation was designed to teach students how to identify various hazards or deficiencies in a manufacturing facility. Users navigate the virtual world in a first person perspective using the keyboard to move and the mouse to look around. The virtual environment was modeled after a car manufacturing assembly line and includes components such as robotic arms welding car parts together, high storage racks, and forklift lanes. Potential hazards include oil spills, blocked lanes/exit doors, and simulated fires.

The virtual environment was created using the Unity game engine and all models were made using Blender and SolidWorks. 3D models in virtual simulations require low polygon counts in order to render in real time at 60 frames per second. Models were initially created using a high amount of tessellation to capture small details of a 3D object. After the high polygon model was complete, a low polygon cage model was created on top of high-polygon model. The UV maps were created either by defining edge seams or automatically generated using Blender's UV island generator. Then, the high-polygon mesh would create an impression on the texture map applied to the low polygon map. This can be used to add in normal map information to increase the fidelity of the lighting and textures without the need for processor intensive high polygon models.

Scripts for controlling the game state, interaction and user interface were written in C#. An Event Manager singleton handled communication between all objects. The Unity game engine handled basic physical interactions. Primitive colliders surround all objects to block the user from passing through them. Many object textures were procedurally generated using Allegorithmic's Substance materials, leading to smaller build sizes and increased performance.

TABLE I  
ELEMENTS OF THE INSTRUCTIONAL DESIGN MODEL

| Element   | Description  |
|---|--|
| Pre-Test, Pre-Survey  | The <i>pre-test</i> included ten multiple choice questions covering key objectives throughout the primary module content. The <i>pre-survey</i> included 21 questions; ten basic demographic questions including GPA and number of Internet courses taken and eleven questions designed to better understand student self-efficacy toward computer use.  |
| <u>Introduction</u> : Goal, Objectives, Connecting to New Knowledge   | The <i>introduction</i> provided an overall goal for the entire module, six objectives spanning multiple levels of cognition, and a brief section connecting the content of the Safety module to previous knowledge safety knowledge regarding people, the environment, and special industry considerations.   |
| <u>Primary Module Content</u> :<br>1.1 Safety at Facilities<br>1.2 Emergency Exits, Fire Safety, and Types of Inspections           | The <i>primary module content</i> was broken into two subsections; Safety at Facilities and Emergency Exits, Fire Safety, and Types of Inspections. Each subsection contained the specific objectives of the submodule, course content (delivered through interactive web based instruction including an eBook, mini video lectures, and instant feedback assessments), a subsection summary of main topics, and key terms which were hyperlinked to an interactive glossary.  |
| <u>Conclusion</u> : Key Concepts, Further Study   | The overall module conclusion included key concepts all directly aligned with course objectives and two recommendations for further study for students wishing to explore the topic further.   |
| <u>Assessment</u> : Formative and summative assessments, virtual reality simulations, photo-based case study, Posttest, post-survey | Students in all conditions used instant feedback <i>assessments</i> , embedded in each submodule, to review mastery of knowledge. All students also took a <i>posttest</i> consisting of 25 multiple choice questions and a <i>post-survey</i> which included 56 questions designed to evaluate student perception of learning outcomes, engagement with the online learning platform, usability of the system, satisfaction with and perception of the online learning platform, and open ended questions designed to collect any additional thoughts and feedback.<br>Only students assigned to the VR condition received the <i>virtual reality simulations</i> (described below) and only students assigned to the photo-based case study were given the <i>photo-based case study assessment</i> . Both the VR simulations and case studies were given to the student prior to taking the posttest and post-survey. |

Wayfinding aids in the form of arrows on the ground were implemented to show where to find the next potential safety infringement (see Figure 1). When a user approached a hazard, a pop-up box appeared asking questions on what to do if they encountered the situation in the real world. Procedural questions were handled using a drag and drop interface to demonstrate the order of the procedure.

#### 4) Method for photo-based case study design and development

The photo-based case study design was designed to address all key areas being addressed by the VR simulation inspections to understand the impact of VR as a media option on student learning outcomes when compared with use of 2D images and photos. Three separate inspections with five imbedded images of infractions, all aligned with the content presented in the module, all included instructions on how to complete the safety checklist (see Table II), the same reinforcement questions present in the VR, and images with markers to identify to students the specific areas to inspect for the assignment (see Figure 3).

#### D. Experimental Design

The study used a between-subjects experimental design. The study was approved by Clemson University's IRB. The study involved three conditions: (1) Online Module Only: An online learning module which was delivered through interactive web based instruction including an eBook, mini video lectures, and instant feedback assessments without the Virtual Reality (VR) component or the photo-based case study, (2) Online Module + VR Simulations: an online learning module, identical to the module described above, with a VR-based component, and (3) Online Module + Photo-Based Case Studies: an online learning module, identical to the module described above, with photo-



Fig. 1. Online learning environment with embedded virtual reality



Fig. 2. Fire hazard where participants determine the next course

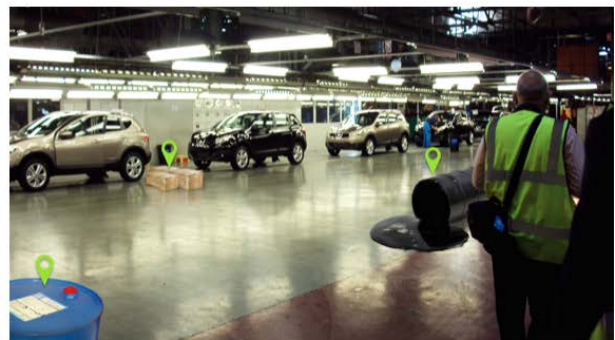


Fig. 3. Sample of photo-based case study image

based case studies. Participants were given a demographic survey and randomly assigned to one of the conditions. The participants completed the experimental task which included completing the pre-test and pre-survey, completion of the online module, and the completion of a posttest and post-survey.

**E. Procedure**

The process for conducting the research in this study was adapted from the process suggested by Chen and Teh [16] and involved:

- a) Selection of an instructional design model (see the above section titled Structure of learning module for additional details).
- b) Designing the model for the study. This process involved modification of the existing model currently being implemented by the National Science Foundation Advanced Technological Education Center CA2VES on the [www.educateworkforce.com](http://www.educateworkforce.com) site to present all elements of the model in a modular format which could be completed in approximately one hour.
- c) Conducting the study statewide across five sites partnering with three two-year colleges.
- d) Collecting and analyzing data.
- e) Developing results and conclusions based on data analysis.

The study was conducted at three Greenville Technical College locations, one Florence-Darlington Technical College location, and one Spartanburg Community College location. Locations on Greenville Technical College campuses were the Brashier Campus, the McKinney Automotive Center, and the SC Technology and Aviation Center. Participants at the Greenville Technical College locations were students in automotive and aircraft maintenance education programs. Participants in the Florence-Darlington Technical College location were students in automotive maintenance education programs. Participants in the Spartanburg Community College location were students in Computer Program Technology (CPT) 101 courses. The age range of participants varied but all were full or part-time students in two-year college educational programs.

Students were provided a desktop computer and a set of headphones. Each study was conducted in a computer lab. A pre- and post-test assessment was given to each student. Participants were provided a disclaimer at the beginning of the study and participation was voluntary. Participants listened engaged with the safety module in the online learning platform and responded to questions about the material.

Select students observed a virtual reality simulation. The time to complete the study averaged between 60-90 minutes. Participants received a \$10.00 Amazon gift card upon completion of the study. The procedure used for this study is shown in Figure 4.

TABLE II  
SAFETY CHECKLIST ACCOMPANYING PHOTO-BASED CASE STUDIES

|   | Acceptable | Needs Improvement | False | Comments  |
|---|------------|-------------------|-------|---|
| <b>GENERAL SAFETY</b>   |            |                   |       |   |
| Stairways/floors/aisles unobstructed                          |            | X                 |       | Boxes have been placed in aisles and need to be removed |
| Aisles are covered to protect workers from production hazards |            |                   | X     | No such requirement exists.                             |
| Hazardous wastes are marked and have a cover                  | X          |                   |       |   |

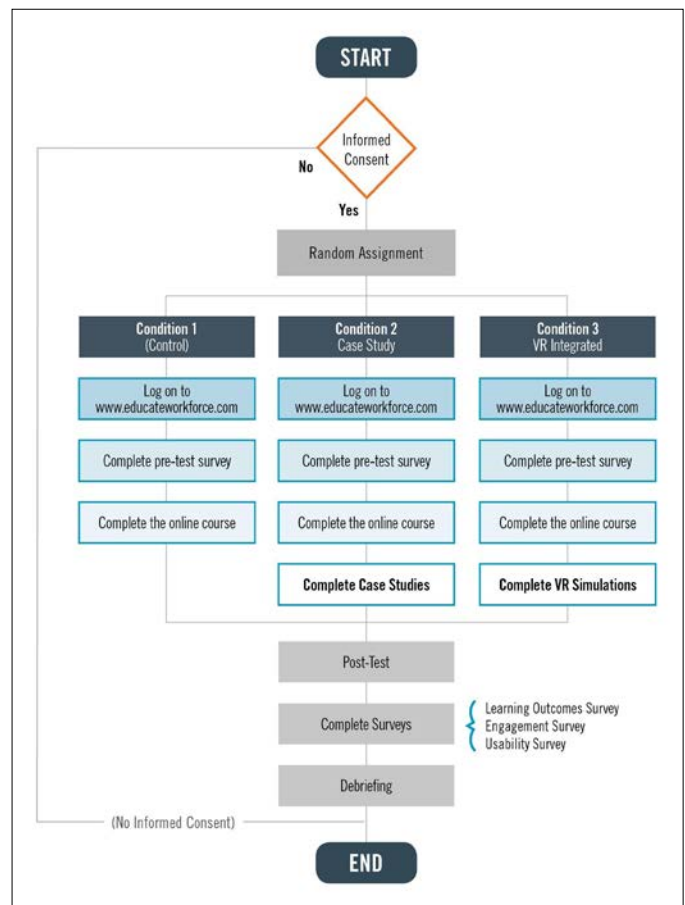


Fig. 4. Experimental procedure

### F. Measures

Students in each course completed a ten-question multiple choice pre-test in class at the beginning of the study and a course-specific 25 question multiple choice posttest at the end of the study. To help quantify student learning gains, the outcome of interest was the percent of items the student answered correctly on the course specific post-test. In addition, students completed both a pre- and post-survey. Both the pre- and post-survey developed for use in this study utilized previously constructs: perceived learning outcomes [27], engagement [8], usability [28], [29], and satisfaction and perception [30]. Table III below provides a brief overview of primary questions in terms of the number and types of questions asked.

### G. Analysis

SPSS 22.0 was used to analyze the data. To determine the presence of significant differences across the different conditions, between-subjects one-way ANOVA was used with a 95% confidence interval. Tukey post-hoc comparisons were used to determine the locus of significant differences.

TABLE III  
OVERVIEW OF SURVEY ITEMS

| Construct                   | Author                 | Number of Questions | General Topics  |
|-----------------------------|------------------------|---------------------|---|
| Perceived learning outcomes | Antonietti et al, 2000 | 5                   | Comprehension, memorization, application of learning, analysis of problems, overview of content   |
| Engagement                  | Lee et al, 2010        | 5                   | Sense of presence, responsive and active in learning process, control over learning, promotes self-paced learning, engaged with activity  |
| Usability                   | Lewis, 1995            | 19                  | With the system: satisfaction, efficiency, learning, productivity, information finding, simplicity, interface, functions and capabilities |
| Satisfaction and perception | Davis, 1989            | 5                   | Satisfaction, learning/academic performance, effectiveness of learning, pace of learning, support of learning                             |

## RESULTS

### A. Task Completion Time

All tasks which included logging-in, completing the pre-test and pre-survey, completing the online module, completing the photo-based case study (only if in condition 2), completing the virtual reality simulation (only if in condition 3), and the post-

test and post-survey; were designed to take the average user approximately one hour to complete. Students participating in this study took various amounts of time to complete the tasks which ranged from approximately thirty minutes to an hour and a half. Typically, students who were in the control condition completed the assignment more quickly because they did not have a case study or VR simulation to complete.

### B. Learning Gains

Learning gains were evaluated through comparison of pre-test and post-test scores where students were given a ten question pre-test (each question was aligned with one of the six objectives being taught in the module) and a twenty-five question post-test (which included the ten pre-test questions plus fifteen new questions; all questions were also aligned with one of the six objectives being taught in the module). Comparing the pre- and post-test scores revealed that while students did indeed experience learning gains from completing the online modules, there were no statistically significant differences between the conditions.

### C. Perceived Learning Outcomes

*Ease of comprehension.* The perceived ease of comprehension was evaluated using the question, “this type of computer program makes comprehension easier.” A statistically significant difference between groups was identified for ease of comprehension of the material ( $F(2,161) = 5.618, p = .004$ ). A Tukey post-hoc test revealed that the ease of comprehension for the control ( $M = 5.690, SD = 1.451$ ) and virtual reality ( $M = 6.087, SD = 5.301; p = .003$ ) integrated conditions were significantly higher ( $M = 5.307, SD = 1.261$ ) when compared to the photo-based case-study based condition. There were no statistically significant differences between the control and virtual reality integrated conditions ( $p = .198$ ).

*Ease of memorization.* The perceived ease of memorization was evaluated using the question, “this type of computer program makes memorization easier.” There was a statistically significant difference between groups was identified for ease of memorization of the material ( $F(2,161) = 8.104, p < .001$ ). A Tukey post-hoc test revealed that the ease of memorization for the control ( $M = 5.454, SD = 1.32$ ) and the virtual reality integrated ( $M = 5.87; SD = 1.196$ ) conditions were significantly higher ( $M = 6.087, SD = 5.301; p = .003$ ) when compared to the case-study based condition. There were no statistically significant differences between the control and virtual reality integrated conditions ( $p = .207$ ).

*Ability to apply what was learned.* The perceived ability to apply what was learned was evaluated using the question, “This type of computer program helps me to better apply what was learned.” There was a statistically significant difference between groups was identified for the ability to apply what was learned ( $F(2,160) = 7.615, p = .001$ ). A Tukey post-hoc test revealed that the perceived ability to apply the concepts that were learned for the control ( $M = 5.509, SD = 1.399$ ) and the

virtual reality integrated ( $M = 6.178$ ;  $SD = .955$ ) conditions based ( $M = 5.288$ ,  $SD = 1.333$ ;  $p = .001$ ) condition. There were no statistically significant differences between the control and virtual reality integrated conditions ( $p = .629$ ).

*Ability to better analyze problems.* The perceived ability to better analyze problems was evaluated using the question, "This type of computer program helps me to better analyze the problems." There was a statistically significant difference between groups was identified for the ability to apply what was learned ( $F(2,161) = 5.150$ ,  $p = .007$ ). A Tukey post-hoc test revealed that the perceived ability to better analyze problems for the control ( $M = 5.490$ ,  $SD = 1.339$ ) and the virtual reality integrated ( $M = 6.017$ ;  $SD = 1.077$ ) conditions were significantly higher when compared to the case-study based ( $M = 5.313$ ,  $SD = 1.157$ ;  $p = .007$ ) condition. There were no statistically significant differences between the control and virtual reality integrated conditions ( $p = .731$ ).

#### D. Perceived engagement levels

*Responsiveness and active learning.* This construct was measured using the question, "This type of computer program allows me to be more responsive and active in the learning process." There was a statistically significant difference between groups was identified for the ability to apply what was learned ( $F(2,165) = 9.307$ ,  $p < .001$ ). A Tukey post-hoc test revealed that the perceived responsiveness and ability to be active in the learning process for the control ( $M = 5.518$ ,  $SD = 1.5872$ ) and the virtual reality integrated ( $M = 6.245$ ;  $SD = 1.022$ ) conditions were significantly higher when compared to the case-study based ( $M = 5.096$ ,  $SD = 1.587$ ;  $p < .001$ ) condition. There were no statistically significant differences between the control and virtual reality integrated conditions ( $p = 0.270$ ).

#### E. Usability

The perceived usability was evaluated using the IBM CSUQ instrument. A statistically significant difference between groups was identified for the perceived usability ( $F(2,162) = 13.002$ ,  $p < 0.001$ ). A Tukey post-hoc test revealed that the usability for the control ( $M = 6.160$ ,  $SD = 1.187$ ) and virtual reality ( $M = 6.508$ ,  $SD = 0.734$ ;  $p = .003$ ) integrated conditions were significantly higher ( $M = 5.442$ ,  $SD = 1.334$ ) when compared to the case-study based condition. There were no statistically significant differences between the control and virtual reality integrated conditions ( $p = .220$ ).

### DISCUSSION

This study has focused on developing a deeper understanding of student learning and use of technology-based learning environments and tools revealing significant differences in students' perceptions of learning outcomes, engagement, and usability when including VR or a photo-based case study in a technological education module.

In evaluation of technology-based instruction and VR several

were significantly higher when compared to the case-study prior studies have found that VR was effective in producing learning gains [9] while many have also found no significant difference in learning gains between conditions. However, the descriptive results of this study indicated that overall students positively perceived the use of VR in the module as a tool to improve learning, engagement, and usability in an online environment. While the findings revealed that while there were no significant differences in actual learning gains between the control, VR, and photo-based case study conditions; they did show that the control and VR integrated conditions actually enhanced the student's experience and perception of learning more than the photo-based case study condition. This suggests that the best way of presenting context specific scenarios in technological education modules, similar to the one tested here, includes authentic and active learning activities such as VR [31]. This reinforces findings of other studies indicating that technology enhanced student-centered approaches are effective tools to enhance learning [32] and that authentic learning, transformative learning experiences such as VR can create greater motivation and excitement for learning.

Further, in the areas of perceived learning outcomes, engagement, and usability the similarities among the findings for both the control and VR conditions suggest that the amount of technology employed in a course does have a relationship with student engagement, student perception, learning approaches, and student self-reported learning outcomes. As previous studies have indicated, learner satisfaction and perception map to aspects of effective instructional design and as demonstrated by this study amount of technology employed, specifically in this study VR, by the instructional designer within the course can positively impact student learning perceptions, engagement, and usability.

#### F. Limitations

Although this study yields significant implications in establishing a connection between amount of technology used in presenting context specific scenarios and learning perceptions, engagement, and usability, it also has limitations in terms of generalizability of results. First, student performance and attitude is impacted by many variables including personal goals, cognitive styles, and computer attitudes. In this study, students spent a finite amount of time (five to ten minutes) interacting with the VR; observing students' VR use and learning gains over a more extended period of time may yield different observations of learning outcomes, attitudes, and perceptions. Further, replication of this study in different learning context, with other more advanced technical education skills, is recommended for future research to determine whether VR and the amount of technology utilized in teaching and learning does indeed have a relationship with learning outcomes, engagement, perception, and usability of technology-based instruction.

### G. Implications

The findings of this study have important pedagogical instructional designers, educators, administrators, and VR developers.

As professionals who develop, create, and deliver instructional content these implications have great impact for instructional designers and educators. As demand is growing for technology-based instruction it is imperative that instructional designers have a deep understanding of the relationships among online and digital learning tools and student outcomes, attitudes, and beliefs. E-learning systems are made up of numerous subsystems which all interact to produce an instructional model [33] and studies such as this which examine components of the model (such as VR) are important to understanding the overall impact on student learning. It is critical for future instructional designers to not only recognize the importance of student learning outcomes but to also integrate tools which positively impact student attitude, perception, and usability of technology-based learning systems. Next, experienced professional educators know that feedback has immense potential to impact learning gains in positive and negative ways and online and technology-enhanced systems, such as the one tested in this study, provide an opportunity for students to receive instant feedback as they are navigating a learning module. This study also confirms that utilizing VR to reinforce learning concepts is an acceptable and even a recommended approach to teaching context specific scenarios in technical education. Also, student motivation and perception are strongly linked to student-related outcomes and course retention rates [34] and utilization of VR and online systems can improve student perceptions and attitudes of learning. Specifically, educators in two-year college environments may find these results encouraging because as instructors of students who are typically older, have increased family commitments, full-time or part-time workers, and commute longer distances to campus there is greater need to provide online and VR options which enable students to learn anywhere, anytime [35]; the results of this study confirm that in educational situations similar to those tested here that the learning outcomes are as good as those experienced without increased technology tools with the positive benefit of increased student perceptions and usability.

It is also imperative to recognize the importance of these findings for administrators who are making financial and instructional decisions at a high level. Administrators of higher education, through tremendous financial investment, continue to acknowledge the importance of and demand for online and technology-based learning [33]. Selecting tools and systems which positively support students and educators is of utmost importance. VR not only provides a cost-effective solution to real world scenarios where costs may be prohibitive or safety of the student or equipment is of concern but also, as this study has shown, has the ability to positively impact student attitudes, perception, and usability of technology-based instructional tools.

Finally, the results of the study imply that VR developers should focus on highly interactive simulations in order to fully

implications to a variety of educational professionals including

engage the user's attention and create an active learning environment. VR interactivity can range from simple simulations that require little input from the user similar to the the photo-based condition all the way up to requiring constant input from the user and the results from the study indicate that developers should focus on creating simulations that have the user constantly engaged in the task. However, implementing high interactivity increases the complexity of the simulations, resulting in increased development time and compounds the chances for software failures. VR developers need to find a balance between what the level of interactivity while maintaining a reliable and effective simulation.

### CONCLUSION

The use of VR and e-learning in education has expanded greatly in the past decade. Drastic improvements in the technology and subsequent decreases in prices have made VR much more accessible outside of the industries from which it is typically utilized. Better instructional design and consideration of educational principles have helped precipitate the rise of VR in education and specifically the STEM (science, technology, engineering, and math) fields. The ability of VR and e-learning to reduce costs, allow students to interact with unobservable phenomena, and to increase perceived learning outcomes, student engagement, and usability provides tremendous potential to the field of education. Further, use of these tools also has the ability to increase equality of access to education [36]-[40] which is especially important in two-year technical education where students require more diverse learning opportunities as a result of the need to balance educational pursuits with family and working responsibilities. As the technology continues to improve it is quite obvious that VR has become a vital part of education and will continue to grow in use. Along with instructional support, teachers also need to provide technical and pedagogical assistance in technology-enhanced learning environments. When preparing a course, faculty and instructional designers need to address how to support students in various ways. Creating learning environments where appropriate support for student learning is designed and provided becomes critical, particularly in online courses.

This study provides information that further validates the use of VR and technology-based instruction as a part of presenting context based scenarios in technical education settings. While this study did not reveal significant differences in actual learning outcomes, the student perceived improvement in learning outcomes is significant and demonstrates the importance of integrating technology-based instructional tools such as online e-learning systems and VR into instructional models. Further, perception that students were more engaged in their learning and found the systems overall to be more usable when VR was incorporated is also significant and suggests that VR positively enhances the entire student learning experience.



Thus, educational modules should be constructed with technologies (similar to the online system and VR assessed in this study) to improve overall learner experience and increase when incorporating VR and related tools and these approaches show great potential to improve learning experiences in technician education.

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## BIOGRAPHICAL INFORMATION

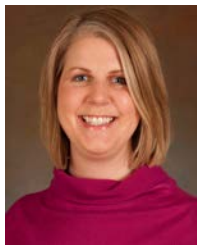


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