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Utilizing Virtual Reality to Support the ASCE UESI Student Surveying Competition

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Abstract

Surveying engineering is a major with strong professional and historical ties to civil engineering. However, compared to civil engineering, surveying has a lower public profile. Many engineering students do not know what surveying entails and how surveying contributes to engineering projects. The American Society of Civil Engineers (ASCE) Utility Engineering and Surveying Institute (UESI) organizes an annual surveying competition for Civil Engineering programs with ASCE student chapters. The educational and professional goals include a recognition of the importance of basic surveying principles to all civil engineering projects. The competition is an innovative and interesting way to engage civil engineering students and increase the awareness of surveying in civil engineering institutions. Due to the travel challenges brought by the COVID-19 pandemic, the 2021 UESI Surveying Competition was held virtually. The UESI Surveying and Geomatics Division in collaboration with Penn State Wilkes-Barre decided to utilize immersive and interactive virtual reality technology to simulate the field component in the student competition. Thanks to technological advancements of Head Mounted Displays (HMDs) in the past 10 years, immersive virtual reality technology has found widespread application in education. The SurReal (Surveying Reality) software that was used for the competition has a realistic virtual environment based on the Penn State Wilkes-Barre campus and a realistic differential leveling instrument. The software simulates all major components of the differential leveling process. This is the first national surveying competition with an integrated virtual reality component. This paper discusses the virtual reality component, the approach followed to adapt the existing SurReal software from the Oculus Rift to the Oculus Quest 2 platform, the challenges in providing the necessary hardware to the participating universities from different parts of the US, and the feedback received by the students participating in the competition.

Background

Brief history of surveying education

Civil engineering and surveying education have strong ties that go back to the early history (1800-1900) of surveying education in the U.S. [1]. In these early years surveying was taught in mathematics departments and later in civil engineering departments. The American Society of Civil Engineering (ASCE) was founded in 1852, and one of its early technical divisions was the Surveying Engineering Division. This was founded in 1926 [2] in order to provide leadership in surveying. For many years surveying grew under the wing of civil engineering. The average number of surveying credits in civil engineering departments was 14.3 in 1937, with many times between 20 and 30 credits [3]. However, this number gradually declined to 5.5 in the 1960s [4] to 2.1 credits in 2010s, with one third of civil engineering programs not requiring any surveying course [5]. At the same time, surveying grew in independent 2-year and 4-year surveying programs with more than 20 ABET accredited bachelor programs existing nowadays [6]. Despite this growth some surveying programs still face challenges with low enrollment due to the low profile of the surveying profession and low awareness in the community (e.g., [6], [7], [8]).

ASCE UESI

The Utility Engineering and Surveying Institute (UESI) of ASCE is relatively new. It was not initially established until October 1, 2015 and not officially recognized as ASCE's ninth technical institute until 2017. The purpose of this newest ASCE institute is to offer professionals, in both utility and pipelines engineering and the surveying and geomatics communities, a means to collectively improve the profession by providing products and services (e.g., technical activities, conferences, and the development of internationally recognized standards) that enable excellence in engineering, planning, design, construction, operation, and asset management [9],[10]. Additionally, the surveying and geomatics professionals are trying to bring attention to the amount of surveying engineering that a civil engineer can do as a professional engineer without any formal education on the topic, and encourage civil engineers to formally add surveying to their body of knowledge.

UESI student surveying competition

In 2017, UESI's Education committee began discussing the possibility of a national student surveying competition to be held in conjunction with ASCE's other national competitions, namely, the concrete canoe and steel bridge. Regional ASCE surveying competitions had been held for more than 30 years in a number of the regional ASCE Student Conferences, so this was not a new idea for many schools involved in ASCE. The goal of a national surveying competition was to help promote surveying and surveying engineering to civil engineering students that may not otherwise have an opportunity to be exposed to it. As mentioned above, as the number of surveying courses and number of civil engineering programs that offer any surveying courses declines, there still has to be an opportunity for civil engineering students to have exposure to a discipline that they will be allowed to practice under their professional engineering license and, in many states, have an abbreviated educational pathway to dual licensure if they want to.

After much planning, the first national UESI Student Surveying Competition was scheduled to occur in May 2020 as the opening day of the 2020 UESI Surveying & Geomatics Conference in Lawrenceburg, Indiana. Because of the COVID-19 pandemic and the national shutdown of many events, this inaugural competition did not occur as planned. Both the regional and national competition were written to include in-person field exercises, and therefore the regional and national competition, and conference were eventually cancelled. As the UESI Education committee regrouped and planned for the 2021 regional competitions and a national UESI Student Surveying Competition, changes had to be made to create and hold virtual competitions. This required a new way of thinking about the traditional field exercise surveying competitions.

Virtual reality

In recent years, we have experienced rapid development of virtual reality technology. In virtual reality the user is immersed in a virtual world using Head Mounted Displays (HMDs) and interacts with the virtual environment and virtual objects using controllers. Thanks to technological advancements in the past 10 years, immersive virtual reality technology has found widespread application in education [11]-[20]. Virtual reality has also found application in surveying education. Application in surveying often focuses on field training with instruments (differential leveling and topographic mapping with total stations), and training in various terrain scenarios or other practical challenges to students. Therefore, virtual reality can be used to address challenges in outdoor labs related to weather, inaccessibility to sites, transportation costs, and enhance comprehension of surveying procedures. Few notable examples in the literature can be found in [14], [16], [19], [20]. For instance, in [16] students used a virtual total station to gather ground shots and create contour maps that were compared with reference contour maps that were developed by an expert. In [19] and [20] students conducted differential leveling using a virtual instrument and collected surveying datasets in different terrains including a city environment. However, one of the major drawbacks of virtual reality is the associated cost, as students often need to have access to a higher end gaming computer and virtual reality hardware.

Objectives

To address the challenges brought by the COVID-19 pandemic, the UESI board collaborated with Penn State Wilkes-Barre and turned into virtual reality technology to maintain a field component in the competition. This is the first national surveying competition with an integrated virtual reality component. This paper presents the competition details, the virtual reality component of the competition, the approach followed to adapt the existing software in the Quest 2 platform, and the feedback received by the students participating in the competition.

Methods

Competition details

Twelve ASCE regional conferences held a regional surveying competition and selected a winner to advance to the national competition. The regional competitions that were developed included two separate tasks. The first task involved creating a topographic map from field data that was supplied as part of the competition. The second task involved reducing and adjusting a set of differential leveling field notes and calculating elevations on a sewer line from data obtained from a set of profile leveling field notes. Teams also prepared a short presentation to talk about their topographic map leveling projects. Students could work remotely with appropriate surveying/civil software to complete the first task and they could complete the leveling calculations remotely, as well. Collaboration between team members was encouraged via various platforms. No in-person collaboration was required to complete these tasks.

In an attempt to change the national competition slightly from the regional competition and to make it a more advanced competition than the regional competition that would allow the students to experience surveying in a way that they may not have done before, a search was made for virtual methods that would allow someone to experience surveying. Penn State Wilkes-Barre collaborated with UESI, as Penn State Wilkes-Barre already had developed a software to simulate differential leveling in virtual reality [19] and [20]. Virtual reality technology was used in the differential leveling part of the competition. Two leveling tasks had to be completed by students (Figure 1): (1) collect a set of differential leveling measurements between two benchmarks, reduce and adjust their misclosures, and (2) calculate elevations on a sewer line from profile leveling data.

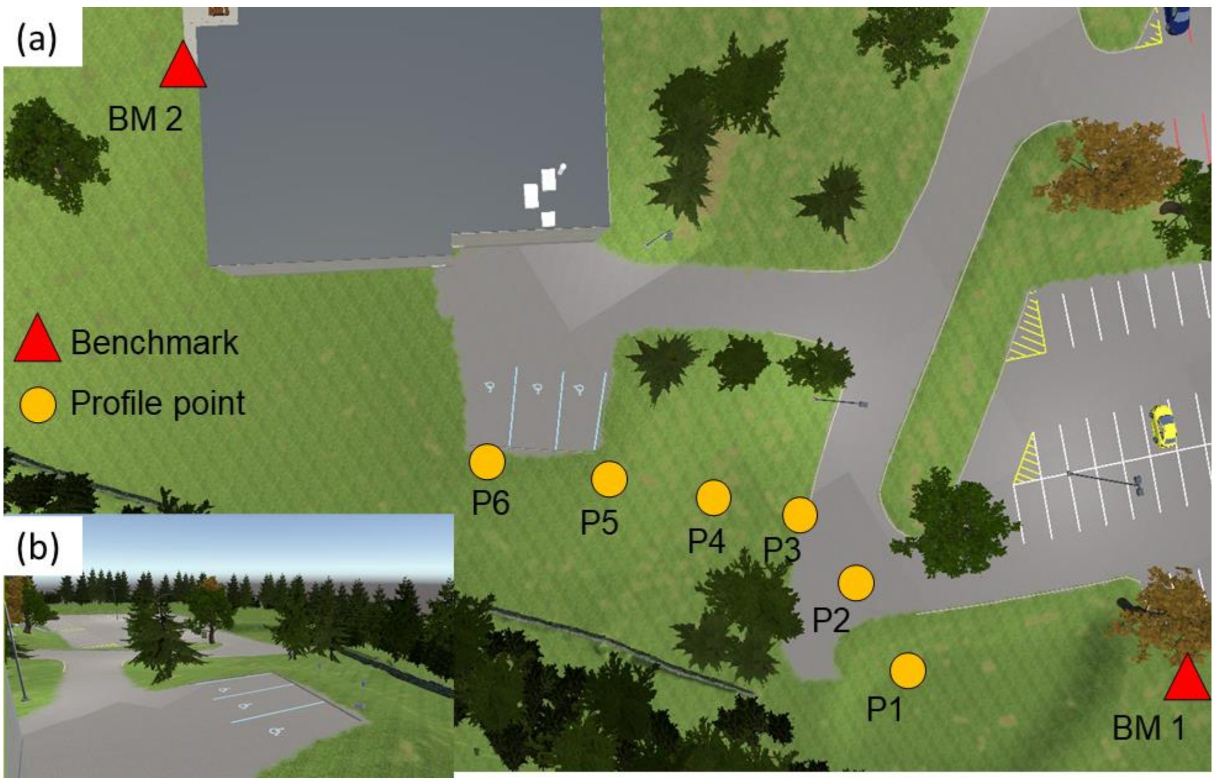

Figure 1. The virtual leveling tasks. (a) top view; (b) side view.

Of the twelve regional first place teams, ten teams accepted the invitation to compete in the national competition (Table 1). To create a fair competition environment, Oculus Quest 2 HMD were purchased by UESI to be used for each team in the national competition. HMDs were sent to a representative on each advancing team except for Rashtreeya Vidyalaya College of Engineering in India. At the time of the event, there was no way to ship the equipment to the team and ensure that they would have it in time for the competition deadlines. An alternate leveling experience was completed by India's team due to the inability to get the HMDs to the team because of the COVID-19 pandemic shutdowns in that country. A training manual was created, and training sessions were held with the competing teams to get them familiar with the software. Note that one student per university was assigned to complete the virtual reality portion.

Table 1. Participating universities in the virtual surveying competition.

University	**State / Territory / Country**
Bradley University	Illinois
California State Polytechnic University, Pomona	California
Christian Brothers University	Tennessee
Cincinnati State Technical and Community College	Ohio
Colorado School of Mines	Colorado
Fairmont State University	West Virginia
University of Georgia	Georgia
University of Puerto Rico at Mayaguez	Puerto Rico
University of Texas Rio Grande Valley	Texas
Rashtreeya Vidyalaya College of Engineering (did not participate in the virtual reality portion)	India

Virtual reality software

The software was based on the virtual reality software developed in [19]. The software has a realistic virtual environment based on the Penn State Wilkes-Barre campus [21], and a realistic differential leveling instrument [19], and the software simulates all major components of a differential level instrument. An important difference with real world differential leveling is that in the virtual world one person is handling both the differential level and leveling rod, as opposed of two. In the virtual reality software, the user can perform all major tasks that are performed in the physical world such as grab the differential level instrument, move it to any location, level it by moving the tripod legs and the tribrach screws, rotate the telescope, focus the instrument, make observations and record them in a virtual fieldbook. For instance, in Figure 2 we show the virtual rod and instrument, and an example of a student taking a measurement using our virtual leveling instrument. Using the software in the Oculus Rift version conducting surveying with an accuracy of few millimeters is possible [20]; however, due to the challenges brought by moving the platform from the Rift to the Quest 2 version (discussed below), accuracy deteriorated and an accuracy at the level of 1-2 cm was attainable.

The software in [19] is based on Oculus Rift, which offers a stable platform for complex virtual reality implementations. Oculus Rift requires a graphics card NVIDIA GTX 1060 / AMD Radeon RX 480 or greater. We did not know if the participating schools will have computers with the necessary hardware, and due to COVID-19 restrictions we were concerned that student will not have unrestricted access to a computer lab. For this reason, we decided to move the virtual reality software from Oculus Rift to Oculus Quest 2. Quest 2 is an untethered version of Rift; therefore, the software can be directly loaded onto the HMD without needing a desktop computer. In addition, the tracking sensors are embedded into the controllers eliminating the need for external sensors. The primary issues we had to deal with and overcome dealt with compatibility and the lower power of Oculus Quest 2 as opposed to Oculus Rift.

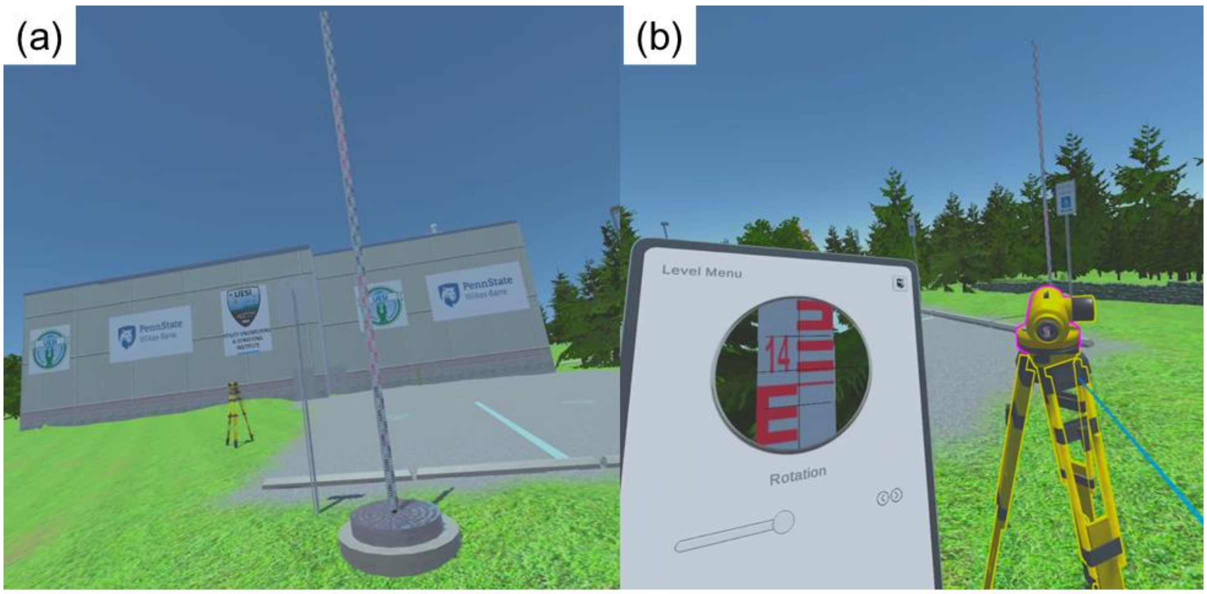

Figure 2. Virtual surveying. (a) example of rod placed on a manhole; (b) student takes a virtual road reading.

Because the Oculus Rift is always tethered to a desktop computer, more resources are available for the software. This is not the case for the Oculus Quest 2, which is used standalone, with computational resources similar to a mobile phone. We did extensive optimizations on the software to compensate for this difference, including spatial hashing for constant-time search when determining authority over equipment components, as well as occlusion culling, to reduce draw calls made on objects not in view of players. Considerable improvements were also made to the communication links between entities, which yielded objective performance improvements even on the Oculus Rift headset. Despite these optimizations, to achieve smooth framerates we were required to lessen or remove some graphical effects.

Questionaries

Students (one student from each university) were asked to complete an online questionnaire and provide us with feedback on their virtual competition experience. Questions were grouped in four main categories: (1) background, (2) virtual competition and pedagogical feedback, (3) technical feedback, (4) symptoms. Background questions help us understand whether students are experienced with the surveying tasks in question and with virtual reality. The second category questions are aimed in understanding whether students liked the addition of virtual reality in the competition, and whether they would like virtual reality in their schools. The third category questions focus on giving us technical feedback about the virtual reality software. The questions in the fourth category help us monitor nausea symptoms and how these affect students.

Most answers followed a five level Likert scale. For ease of presentation and calculating median scores, student responses were converted to a 1-5 scale, with 1 meaning strongly disagreement and 5 meaning strongly agreement with a question. A median score is preferred than an average score to reduce the influence of extreme values, as the sample is small.

Results

Student background

Of the nine universities that participated in the virtual part of the competition, eight completed the online questionnaire. One student from each university was tasked to conduct the virtual reality part of the competition; therefore, the sample in this study has a size of eight.

Table 2. Background of participating students. Sample size is 8 students.

Question	**Answer**	**Notes**
Have you ever worked in surveying?	Yes answered 4 out of 8 students	3 less than 6 months, 1 2-5 years
Have you ever used augmented / virtual reality?	Yes answered 4 out of 8 students	3 through gaming, 1 through a course
Have you ever conducted a similar leveling task?	Yes answered 3 out of 8 students	2 in class, 1 in work
How experienced do you think you are with this leveling task?	3 (Median score with 5 being highest)	2 very experienced, 1 not experienced at all

Table 2 shows the background of the participating students with respect to surveying experience and virtual reality. Half of the students have some experience with surveying, and half of the students have some experience with virtual reality. Three out of the eight students had conducted a similar leveling task, mostly as part of their coursework. For half of the participating students this competition would offer their first exposure with leveling and / or virtual reality. This introduces a significant pedagogical challenge, as leveling is a very challenging task, requiring skill to operate the instruments and theoretical knowledge of the leveling procedures, and students would be learning about leveling for the first time through our virtual implementation. Teaching leveling in surveying programs includes few lectures and demonstrations before moving to the physical labs, which are then used to develop and enhance their surveying skills. As part of the learning process, students need to touch and experiment with the various knobs and handles of the differential level instruments. Therefore, having to learn leveling virtually, creates a unique and challenging pedagogical scenario. The SurReal software was developed having this in mind, and faithfully replicating the main functions of the differential level instrument, and the main activities in differential leveling, allowing students to experience and understand the main steps involved in leveling before conducting a physical lab [20].

Virtual competition and pedagogical feedback

In general, student opinion was positive showing that the virtual reality component improved the overall experience of students (Table 3). Some students commented that “With the short amount of time given, I think it went better than expected”, “It was a good experience because it was something new and creative. It took practice to learn to use the virtual reality lab and that's what motivated us to keep learning.”, and “Valiant effort, but could use some work”. These responses indicate that the students liked the overall experience, and they acknowledge that the Penn State Wilkes-Barre team had only a couple of months to adapt the virtual reality software from Oculus Rift to Oculus Quest 2, and deal with the performance challenges that Oculus Quest 2 introduced to the project. Some of these challenges are discussed in the following paragraphs and subsections.

Table 3. Student feedback about the virtual competition. Median scores with five being the highest score. Sample size is 8 students.

Question	**Median scores**
I liked the virtual competition	3.5 / 5
Virtual reality improved my overall competition experience	4 / 5
I liked the virtual reality lab overall	4 / 5

The student pedagogical feedback in Table 4 further highlights the usefulness of virtual reality for learning, as a training tool, and understanding surveying methods. These results are in accordance with the results received from different implementations using the same software and labs [20]. Some examples of student comments about the pedagogical uses of virtual reality are: “I believe the virtual reality lab had helped me learn how to use Surveying equipment in the virtual world as I have never used this type of technology before. The tutorial really helped me understand the software.”, “The virtual reality lab is good for showing and understanding concepts.”. However, there was some stronger criticism by one student who indicated: “Virtual reality labs should not be incorporated into surveying and civil engineering. This is a hands-on field, and it should remain that way as much as possible”. Addressing this comment, we would like to emphasize that the virtual reality labs were not developed to replace physical labs but to enhance surveying instruction, and address some of the important challenges in surveying education with outdoor labs [20]. The overall positive attitude towards the virtual reality labs further enhances that this technology can have an important role in surveying education, especially in preparing students for physical labs and for training students in different conditions (e.g., different terrain complexity), and in tasks that cannot be physically accessed (e.g., construction surveying).

Table 4. Pedagogical feedback. Median scores with five being the highest score. Sample size is 8 students.

Question	Median scores
Virtual reality is useful for learning	4 / 5
I would like my school to adopt virtual reality to enhance labs	3 / 5
If I have access to virtual reality, I am motivated to use them for my education.	3.5 / 5
Virtual reality labs helped me understand surveying methods as well as techniques.	4 / 5
Virtual reality labs helped me understand how to operate surveying equipment.	3 / 5
Virtual reality labs can help me prepare for the real labs	4 / 5
Virtual reality labs are a useful training tool	4 / 5

Technical feedback

Technical feedback also shows that students interacted with the software clearly, movement in virtual reality was good, and so was the quality of the virtual environment, and handling of the virtual leveling instrument. Median scores in those questions are 4/5 in most cases (Table 5). Students complemented the quality of the virtual environment, with some examples of student comments being: "The virtual environment was excellent. There were changes in elevation that where easily understood.", and "The virtual environment that was used for this lab was well laid out".

Students found the virtual reality lab very comparable with physical ones, validating that the developed software faithfully replicates differential leveling for surveying (median score 4/5). Note that there was some lag, which was due to moving the software from the Oculus Rift platform, which requires a desktop computer, to the Oculus Quest 2 platform that is standalone and less powerful. Several students made a comment about the lagging issue such as "…the refresh rate and lagging was the real issue". In addition, there were few minor glitched that were created when transferring our software from the Rift to the Quest 2 platform. For instance, the students could not scroll down in the virtual fieldbook, and for a couple of students their measurements were missing after attempting to scroll down, and students had to repeat the task which generated frustration. For instance, one student commented: "The fieldbook gave me lots of trouble when I tried to scroll down, basically becoming unusable unless I restarted the program after five or six shots". Unfortunately, we could not address those issues promptly due to time constraints.

Table 5. Technical feedback. Median scores with five being the highest score. Sample size is 8 students.

Question	Median score
I interacted in the virtual reality lab with a clear and concise manner	4 / 5
Movement in virtual reality was good	4 / 5
The overall quality of the virtual reality environment (e.g., terrain, buildings, signs, etc.) was good	4 / 5
Handling and leveling of the surveying instrument (differential level) was good:	3 / 5
Handling and leveling of the surveying instrument (rod) were good	5 / 5
The functions in the virtual tablet were good; helpful	4 / 5
How comparable is the VR lab with respect to physical ones?	4 / 5

Symptoms

The lag issue amplified nausea symptoms for participants. Half of the students indicated that they experienced nausea and headache, with 3 students stating that these symptoms were a lot or moderate (Table 6). Students commented: "The symptoms were mostly cause by the lag. The symptoms appeared when we were using the virtual reality lab for a relatively long time.", "Just needed to take a break after 45 mins or so". The virtual leveling task were designed to not take more than 10-15 minutes for experienced users. The time spent in the labs depends on how quickly students understand the handles on the Quest 2 controllers and understanding of the required surveying tasks. Half of the students were not familiar with virtual reality or the leveling tasks, which explains why students needed significantly more time than expected to complete the tasks. The tutorial that was developed for this competition was a great resource to students; however, a virtual tutorial cannot replace the multiple sessions of instruction that are often needed to teach students about leveling. In addition, the lag and some of the aforementioned glitches contributed to extending the time needed to complete the labs. Despite the experienced nausea symptoms, the students indicated that they still liked the experience.

Table 6. Student feedback about symptoms. Sample size is 8 students.

Question	Answer	Notes
I felt nausea during the virtual reality lab	Yes answered 4 out of 8 students	1 a lot, 1 moderate, 2 little
Other symptoms (headache)	Yes answered 4 out of 8 students	2 a lot, 1 moderate, 1 little
Other symptoms (eyestrain)	Yes answered 3 out of 8 students	1 a lot, 2 moderate

Conclusions

The ASCE UESI national competition is a great initiative in increasing the awareness of Surveying in Civil Engineering programs. However, the COVID-19 pandemic created several challenges that did not allow for participating universities to have the field component experience, which is critical for surveying. To address this challenge UESI collaborated with Penn State Wilkes-Barre to integrate virtual reality in the competition by using the SurReal software. Given the time constraints, we managed to move our software from the Oculus Rift platform that required a higher end computer, to the standalone Oculus Quest 2 platform, and improved the overall experience of students. Student feedback highlights that the virtual component of the competition improved their experience, it can be used to understand surveying and it is a useful training tool. Further development of similar virtual tools and software can be used to address many of the existing instructional challenges that surveying instructors have to face, in particular with outdoor labs. In addition, such virtual reality software can be used to support online education, and even contribute to increasing the awareness of the surveying profession, as demonstrated in this paper.

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