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The Use of Virtual Reality Technology in Intelligent Transportation Systems Education

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Abstract: Simulation-based education is a critical component of Intelligent Transportation Systems (ITS) education. This study discusses the experimental success of using Virtual Reality (VR) technology in simulation-based ITS education, which was found to improve the quality of education while increasing immersion and motivation. The study documents the application of VR technology to a microscopic simulation model within the ITS curriculum. Furthermore, the study also proposes using a standardized methodology to capture and evaluate students' subjective experiences. The findings of the study are discussed, along with potential ways to improve the planned VR technology implementation in the ITS laboratory.

Keywords: virtual reality in education; virtual reality assisted simulation; intelligent transportation systems

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1. Introduction

The United Nations Sustainable Development Goal 4 on Quality Education is as follows [1]: "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all." Virtual reality (VR) has the potential to play an important role in achieving the United Nations Sustainable Development Goal 4. Virtual reality technology can be used to create immersive learning experiences that can make education more engaging and effective [2–14]. For example, virtual reality can be used to create simulations of real-world environments, allowing students to explore and learn about different concepts in a more hands-on and interactive way [5–14]. By promoting and implementing virtual reality in education, it is possible to achieve the goal of providing quality education for all. One way to achieve this is by adopting modern technologies, such as simulation-based learning and virtual reality [2–14].

VR technology is not new; many commercialization and broad adoption attempts have been made to popularize VR technology in the last three decades [2,3]. Most of those attempts were short-lived or significantly failed [2]. However, there are lessons learned from these failures, and the problems and benefits of using VR technology were identified in time [2]. Moreover, as computer and peripheral technologies progressed, VR technology became better [2] and more affordable [3].

Significant progress in VR technology was achieved in 2016 in terms of increasing popularity, worldwide adoption, and hardware and software available (especially VR games) [15]. The pace of quick progress halted around 2020 due to the cost-effectiveness, compatibility, and limitation issues. Global technology firms and equipment manufacturers launched several major VR ecosystems in a relatively short period, each utilizing a proprietary VR technology with different hardware and software kits, taking different approaches and platforms for content delivery, and offering (and limiting) their ecosystems to specific platforms [16]. However, the benefits of progress are not lost today. Today, there are more affordable VR headsets with better hardware and more supported software compared to the past.

VR technologies can be used for simulation training purposes, hazardous training activities such as flight simulations and surgical activities, and access to limited resources such as labs and equipment [2,4]. VR technology can also be used as a tool to augment the quality of education [2–4].

VR technology enhances the ability to visualize and interact in a 3D environment by increasing the levels of immersion [3]. The higher levels of immersion achieved by using VR technology in education can improve students' knowledge retention, understanding, concentration, and academic performances [2,17–19].

Intelligent Transportation Systems (ITS) is a multidisciplinary field that focuses on developing, implementing, and managing sustainable and more intelligent transportation networks in all modes of transportation. Therefore, the ITS education can utilize different combination methods and tools for developing a multidisciplinary training curriculum. Model design and simulation-based learning are essential parts of the ITS higher education. ITS laboratories equipped with simulators can be dedicated to simulation-based learning [20], and ITS education curriculums might include entire courses aiming to develop the students' model design and simulation skills [21].

Today, simulators are used in higher education to improve the quality of education and students' complex skills [5–14,18,19]. Simulator-based education is also a very effective learning environment suitable for training students at all levels of expertise [14]. Simulators can utilize large tactile screens, projectors, and specialized equipment and require several networked computers for connecting interfaces and control surfaces [22]. Moreover, simulators might be specially reserved or always available for students, but in some cases, simulators might also be allocated for other purposes. Furthermore, simulators might be limited to simultaneously serve a limited number of students due to space and equipment limitations.

To summarize, simulators are great tools for learning in higher education but can take up large spaces and might be limited in availability.

It is possible to implement VR technologies in simulation-based education. Entire simulation environments, including the interfaces and control surfaces, can be virtually interacted with and experienced within 3D VR environments [23]. Such an approach might decrease the space and equipment needed for the simulation and increase the quality of the simulation experience by offering a higher degree of realism and immersion. Simulators often utilize computers, and the power supply units in computers tend to offer low energy efficiency under lighter computational loads [24]. The total number of computers utilized can be reduced by setting up virtual machines running simultaneously on servers. As a result, it is possible to run multiple—however, a finite amount of—simulation instances on separate virtual machines, increasing the energy efficiency of simulators. Moreover, this approach can also be applied to VR applications. As a result, VR simulations running on virtualized machines on servers can increase the energy efficiency levels for the same workload and save energy.

In conclusion, the adoption of modern technologies in the field of Intelligent Transportation Systems education can greatly improve the quality of education and provide a more engaging and effective learning experience for students. As educators, it is our responsibility to prioritize and implement these advancements in order to better serve our students.

2. Literature Review

2.1. VR in ITS Education

Education augmented with VR technology has immense benefits compared to traditional approaches [2,5,17]. The most important benefits of implementing VR technology in education were increased immersion, higher motivation, and deeper learning [2]. VR education can motivate and stimulate learning, even in the form of distance education [2,17,18].

Kavanagh et al. [2] conducted a comprehensive and systematic review of the literature on the usage of VR technology in education, with a total of 99 papers [2]. It was observed that half of the papers reviewed were from higher education institutions [2], indicating a strong academic interest in VR technologies. A total of 44 articles evaluated were on using VR for general education and scientific purposes, with a significant portion related to implementing VR technology in medical education [2].

It could be stated that VR technology has been primarily used in the medical and aviation education fields in the early adoption era of VR technology, such as in the 1990s [2]. A significantly limited number of ITS education publications belong to that era: Only three publications mentioning VR technology usage in the ITS field were written in the early adoption era [25].

However, it shows that the idea of implementing VR technology in ITS education is not new and has already been successfully implemented in the early adoption era.

Hadipriono created one of the earliest adoptions of VR technology used in ITS by building a 3D VR system called INTREPID-VR, which consisted of a 3D model, an HMD, and a cyber VR glove at the Ohio State University in 1996, for trainees to virtually experience and interacted with a traffic accident hotspot at the time [26].

Today, there is a broad spectrum of different fields and approaches using different mediums and tools that implement innovative VR technologies which could be used for ITS education. Mahmood et al. proposed an ad hoc Vehicle-to-Vehicle network (V2V) that provides decentralized data to be visualized by VR systems that emergency responders carry [27]. Al-Hilo et al. proposed that the next generation of wireless cellular and V2V networks to be used in connected vehicles will increase the utilization of VR technologies [28]. Njoku et al. proposed a metaverse VR implementation that can enable remote ride-hailing and fault prediction, taking the data from real-time traffic analysis and simulating the driving habits in a metaverse environment into account [29]. Wu et al. proposed a brain–computer interface that can be used for VR training of ITS safety applications [30]. As the historical progress of VR technology shows, it is clear that simulation-based education, along with ITS education, will evolve and become more infused with VR technology in time.

2.2. Relationship between Immersion and Student Performance

It could be argued that the increased levels of performance of the students are related to the VR technology used and therefore the levels of immersion. In an earlier study conducted by Shin [18], it was concluded that the participants suggested that the level immersion was so low that the experience was not enjoyable.

However, in a recent study published by Khan et al., it is stated that the level of immersion in the simulation was high and the students felt that the cars were real and were self-motivated to get the highest score [5]. The higher level of immersion was achieved due to the utilization of the Microsoft Kinect sensor that captured the movement of students and three high-resolution monitors in an ultrawide arc configuration presented the simulation at a Field of View (FOV) of 180° [5].

2.3. Virtual Reality Sickness

Virtual reality sickness, also known as cybersickness, is a condition that can occur when using virtual reality technology as a result of a conflict between the body's natural reflexes and visual and vestibular (balance) cues that brain receives. Virtual reality sickness is characterized by symptoms such as dizziness, nausea, and disorientation [11,31]. In short, virtual reality sickness can be similar to motion sickness [11,31].

Several strategies had been suggested to minimize the effects of VR sickness, including limiting the VR session times, taking 5 to 10 min breaks during long VR sessions, reducing the level of immersion in the virtual environment, and providing clear visual cues to help the brain orient itself [32]. As a result, it was decided to limit the duration of the experiment using the VR equipment to a maximum of 20 min during the preliminary experiment conducted in this study.

2.4. Student Performance Evaluation

In recent studies that aimed to measure the effects of using VR-assisted education on students, a common method to measure the difference in student performance levels with and without the VR technology was observed. It was observed that conducting a pre-test and a post-test was an essential part of those studies [2,5–14]. It was also observed that a control and experimental group was formed in a randomized or controlled manner [5–14]. The control group was educated using traditional and classical teaching tools such as presentations and videos. The experimental group was educated using VR-assisted teaching tools such as simulators, virtual environments, gamified simulations, and 360° videos. As a result, the performance levels of both student groups were analyzed and compared.

The results of the student performance level analyses were mostly positive, clearly showing a quantifiable increase in the students' performance levels across multiple studies. While the majority of the studies resulted in a high level of increase in the students' performance [5–10,13], others found that the VR-assisted education had no significant effect on students' performance [11,12].

In the studies that resulted with no significant effect on the students' performance, it was made clear that there were several barriers that critically hindered the immersion levels in the study. Narciso et al. claimed that while using a 3D VR headset and headphones to get increased levels of immersion, the sitting position and joystick-based interaction hindered the realism for training firefighting students [11]. Ulrich et al. explained that the 360° VR video used for teaching physiotherapy students had no way for students to interact with the video [12].

2.5. Subjective Experience Evaluation

Capturing the subjective experience of the students is paramount to identifying the shortcomings of VR-assisted education [5–14]. Moreover, the data collected can be analysed and used to improve the quality of education. In the majority of the studies reviewed, the use of VR technology for educational purposes was highly praised and commented on as *good* or *very good* [5–10,13].

However, it was observed that the questionnaires used to capture students' subjective experiences were specific to the studies and cases evaluated in those studies. Therefore, the use of an existing, proven, and widely used [33] open-source tool [34] called the NASA Task Load Index (NASA-TLX) questionnaire, was proposed. NASA-TLX is a subjective measure that takes into account various factors that contribute to workload, such as mental demand, physical demand, temporal demand, and performance [34]. As a result, NASA-TLX allows researchers and designers to identify specific areas where interventions can be made to reduce workload and improve performance.

2.6. Limitations of VR Technology

VR technology is open for further development, and there are some common issues with implementing the technology for educational purposes. The most common issues with implementing VR technology for education are the problems with software usability and lack of engagement [2]. It was commonly reported in the literature that the user interfaces of the CAD software used in design education were often designed exclusively for workstation uses rather than with 3D VR technology in mind [2]. The same problem exists within ITS education, as well. The user interfaces of simulation software used in transportation engineering education are commonly incompatible with 3D VR environments. As a result, it is expected that the VR incompatible user interface issue should limit the benefits of the VR technology implementation approach in this study.

3. Motivation and Objectives of the Study

The main motivation for this study is the limited capacity of the ITS laboratory, which can currently accommodate only 15 students, despite the fact that the ITS department has 152 students enrolled in higher education programs. As a result, the goal of providing equal educational opportunities for all students was adopted.

After conducting a literature review, it was determined that implementing VR technology in ITS courses using the laboratory would be a cost-effective way to increase student capacity without sacrificing the quality of education. In fact, it is believed that the quality of education could be improved with the use of VR technology.

The primary objective of this study is to explore how VR technology can be effectively utilized in ITS education. The first step in this process is to determine which courses in the curriculum would be suitable for VR technology assistance. The next step is to conduct a preliminary experiment to assess the benefits and drawbacks of VR technology in these courses.

The secondary goal of this study is to propose the use of an existing scientific method for data collection after the implementation of VR technology in the laboratory, in order to evaluate the benefits and drawbacks of VR technology in ITS education. It is important to evaluate the methods, technology, and educational materials used in the curriculum in order to improve ITS courses. However, primary data must be collected in a precise and scientific manner in order to be used for evaluation purposes.

4. Materials and Methods

4.1. The Courses Suitable to Be Assisted by VR Technology

Bandırma Onyedi Eylül University was founded in 2015 and selected by the Turkish Council of Higher Education as the specialized university to work ITS in 2016. In 2017, the Bandırma Onyedi Eylül University ITS Application and Research Center (BAUSMER) was founded along with the ITS department under the Faculty of Engineering and Natural Sciences. An ITS laboratory was founded in 2020 and is reserved exclusively for the BAUSMER staff and students of the ITS department. Moreover, the ITS laboratory houses the necessary equipment for ITS courses focused on the design and simulation aspects [20].

The ITS department's graduate program curriculum explicitly offers four courses on the ITS field's model design and simulation aspects [10], as shown in Table 1.

Table 1. A total of four ITS courses include model design and simulations as a part of their curriculum.

Program	Course Title	Criteria for Selection
Masters	Traffic Simulation and Modelling Geometric Design of The Roadway Network	CAD, 3D modeling and simulation-based education
Ph.D.	Traffic Micro Simulation Traffic Macro Modelling	

The ITS Ph.D. program course titled Traffic Micro Simulation was deemed suitable for the purposes intended in this study and therefore selected as the pilot course for the experiment.

4.2. The Experiment

The authors conducted a preliminary experiment using the equipment in the ITS laboratory to identify the benefits and disadvantages of using VR technology. The experiment consisted of the following steps:

- Determining the simulation and VR server software and model to be used;
- Having a suitable VR headset;
- Making necessary physical and software-based adjustments to obtain the best image quality and error-free interaction;
- Conducting a SWOT analysis of the VR implementation method and VR experience.

The preliminary experiment included extensive interaction with a 3D model running on simulation software. At the ITS Laboratory, PTV Vissim is currently the licensed simulation software used for creating the digital twin models of existing networks in Bandırma. PTV Vissim is an advanced microscopic multi-modal traffic flow simulation software [35].

PTV Vissim models can be visualized in several ways for different purposes. In this study, a 3D microscopic model of an intersection was utilized.

The microscopic model used was prepared by BAUSMER within the scope of the Transportation Master Plan of the Bandırma district. The model is based on the at-grade signalized cross-road intersection with two slip lanes on opposing directions on the D200 state road and an offset exit, marked with number 9 in Figure 1 and shown in 3D in Figure 2.

Figure 1. Overview of the transportation network for the Bandırma Transportation Plan analyzed by BAUSMER. The model for intersection number 9 was used within this study.

Figure 2. The 3D model of the intersection number 9 was shown in PTV Vissim.

4.3. The User Interface and Interaction

There was no additional layer of user interface used other than PTV Vissim running full screen on a Windows 11 operating system. The 3D visualization mode integrated into PTV Vissim was used throughout the experiment. The *rotate* and *flight* modes were thoroughly experimented with to control the camera angles. In both modes, it was seamless and easy to adjust the camera angles with the VR headset and navigate the scene using a wireless keyboard. There were no issues experienced with the camera angles or controls during the experiment.

The simulation software used in the experiment, the PTV Vissim, could visualize models in a 3D environment, and it was easy to interact with in the 3D environment. However, it became clear that the user interface was designed to be used on a 2D display rather than a 3D VR headset. While the VR server software correctly visualized the 3D virtual environment on the VR HMD, the text scaling had to be increased for a more legible text.

4.4. The VR Equipment

The authors did not use a pre-built or standalone VR headset in this study, as it was not strictly necessary to utilize such VR headsets for the experiment. Instead, it was possible to build an adequately performing VR headset with off-the-shelf equipment in tandem with existing VR software. The custom-built VR headset was trialed extensively in the ITS laboratory, as shown in Figure 3.

Figure 3. The custom-built VR headset was trialed in the ITS laboratory.

The physical assembly and adjustment of the VR headset took a few minutes and required little effort. While it was relatively effortless to put the headset on, adjusting the straps and diopters to the optimal position to best suit the user might require a first-time user to follow instructions. The technical details and comments on the equipment and software used within the study are given below:

- Head-mounted display (HMD) unit is a mobile phone with a 6.67″ IPS LCD touchscreen that operates at a refresh rate of 120 frames per second with a resolution of 2400 × 1080 pixels. The screen in the HMD has a 20:9 aspect ratio. Two side-to-side screens are projected on the HMD to form a stereoscopic 3D image with a per-screen resolution of 1200 × 1080 pixels and a 10:9 aspect ratio.
- It is stated that modern VR headsets are capable of delivering 10–15 pixels per degree per eye, taking a widely used FOV of 100° [36,37]. Our setup is capable of delivering 11 pixels per degree per eye at a FOV of 100°. While the degree of immersion or the quality of the VR experience is not only limited to the technical parameters mentioned here, the parameters such as resolution and pixel density are crucial for conducting a fair comparison between VR headsets or HMD units.
- The HMD has an integrated Micro-Electro-Mechanical System (MEMS) sensor that incorporates an integrated accelerometer and gyroscope. The MEMS sensor output was utilized for directional control as an input to the VR server software.
- A wireless keyboard with an integrated touchpad surface was used for interacting with the user interfaces of the software running on the workstation. However, using the keyboard was not strictly necessary as a mouse, touchpad, or even joystick (with remapping) or similar input device was competent for the task at hand.
- A VR HMD housing with adjustable diopters. The diopters are adjustable on the horizontal and depth axis. This enables adjustment for different physiological properties as well as pre-existing vision problems. Students were asked and helped to adjust their HMD to get the sharpest possible image they perceived before beginning the quiz.
- A workstation that is capable of running simulation and VR server software. The authors took steps to reduce the available system resources in order to evaluate the effects of running several virtualized instances on a single workstation. By virtualizing the Operating System (OS) in a Virtual Machine (VM), it was possible to allocate 2 CPU cores and 4 GB of ram to the virtualized OS instance. As the PTV Vissim micromodel and the VR server software used in the experiment did not have a high resource demand, the performance was identical to the non-VM OS.
- Wireless local area network that the HMD and workstation are connected to.
- A high-performance GPU that supports high-speed and low-latency hardware video encoders. It was observed that higher refresh rates were reached with hardware-accelerated encoding technologies than with pure software-based solutions. It was also chosen because it simultaneously achieved ultra-low latency at the selected resolution. It is stated that minimized input latency is helpful in minimizing any possible side effects of using VR headsets, such as nausea, dizziness, and confusion [32].

4.5. The VR Server Software

A VR server software and its mobile phone client application were used for converting and transferring the 3D interactive window on the user interface of PTV Vissim software into the HMD unit. The server and client were also adjusted to convert the MEMS sensor readings for controlling the camera movement within the PTV Vissim software.

The authors trialed several VR server and client software to achieve the best possible combination of picture quality and frame rate. The authors also conducted a preliminary test to check whether the sensor output of the VR headset is correctly converted to 2D camera controls before using it in the study. After the trial phase, several settings on the software side had to be tweaked so that the image quality and camera controls were good.

Using such a custom-built VR headset enabled the authors to try different settings by using the settings available in VR server software while still having on-par functionality and performance with entry-level standalone VR headsets.

4.6. The Proposed Method for Evaluating Students' VR Experience

There is a fundamental reasoning for using a standardized questionnaire for subjective evaluation. Replicability is a primary principle of scientific research, as it allows other researchers to verify the findings of a study and build upon them. Therefore, it is hoped that the use of the standardized NASA-TLX questionnaire to capture the data will enable the replicability of the experiment and equal comparison of the results.

The ITS laboratory is expected to be equipped with standalone VR units to be used for ITS education in the near future. As the funding is secured and the Traffic Micro Simulation course curriculum is updated to take advantage of the VR units, an evaluation of the implementation of the VR technology is planned to be conducted.

A structured scientific approach will be utilized to collect the primary data from the students. The ITS laboratory was selected as a suitable environment for the experiment to be conducted as it provides a properly equipped and controlled environment for the experiment.

4.6.1. Pre-Test Quiz

In order to evaluate the changes in the students' performance levels, a pre-test quiz will be conducted to set a baseline grade, before conducting the test.

The control and experimental groups will be formed with an equal number of students, and then will be tasked with the same objective during a paper and pen quiz. The questions, instructions, and time limit will be equal in the quiz for both groups to experiment under the same conditions.

4.6.2. Traffic Micro Simulation Model-Based Test

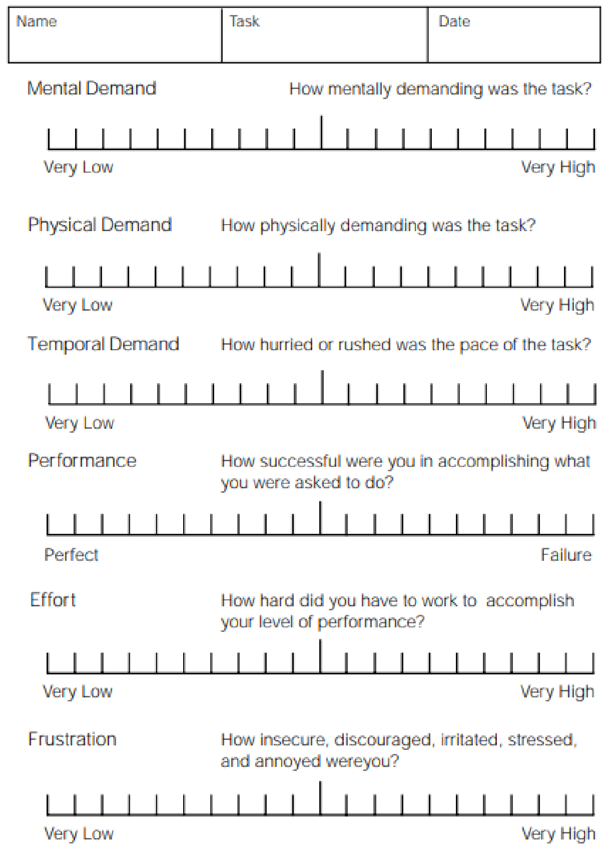
The control group and the experimental group will be given a traffic micro simulation model to identify issues and develop solutions as a test, using the knowledge and skills gained as a part of the Traffic Micro Simulation course. The control group will be asked to use a traditional Human–Computer Interface (HCI), while the experimental group will use the VR headset and wireless controls. The time limit will be a maximum of 20 min to avoid any form of virtual reality sickness.

4.6.3. Post-Test Questionnaire

After completing the experiment, students will be asked to fill out a questionnaire, which will be used to evaluate the participants' ratings on their experiences.

The students will be asked to assess their perceived workload using the open-source NASA-TLX questionnaire [34]. Mental demand, physical demand, temporal demand and performance, effort, and frustration levels of students will be calculated in compliance with the paper and pencil package manual [34], as shown in Figure 4. In order to obtain the mean unweighted scores from the NASA TLX questionnaire, all points marked by each participant in each scale will be subtracted by one and then multiplied by 5 to get a numerical result over the base of 100. Then, the weighted scores will be calculated using the perceived workload weights stated by the students [34].

The quiz, test and the questionnaire results will be subject to quantitative analyses to measure the effects of using VR technology in ITS education. The analysis results shall be used to evaluate the implementation of VR technology in the Traffic Micro Simulation course. Steps shall be taken to reduce the workload while increasing students' performance levels, and the curriculum shall be updated to improve the implementation of VR technology, depending on the findings from the study.


Name	Task	Date

Mental Demand — How mentally demanding was the task?
Very Low — Very High

Physical Demand — How physically demanding was the task?
Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?
Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?
Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?
Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?
Very Low — Very High

Figure 4. The paper and pencil NASA-TLX questionnaire form [34].

5. Results

It is necessary to mention that the preliminary experiment was completed without facing virtual reality sickness. Apart from the temporary minor discomfort during the strap and dioptric adjustment period, there were no issues during or immediately after using the VR headset.

The assembly of the VR headset was straightforward. Even with the entry-level equipment, it was possible to get good image quality from the HMD unit.

The software side of the VR implementation required a trial of several VR server software to find the best possible image quality, frame rate, and head movement tracking. After configuring the server and client software to utilize hardware-accelerated streaming capabilities and adjusting the input to filter out the MEMS sensor noise, the interaction felt more natural, and immersion in the VR experience significantly increased.

The only issue encountered during the experiment was the user interface which is not optimized for use with a 3D VR headset. The 2D content used in menus and windows was difficult to read and required more effort to view. To improve the user experience, the interface should be redesigned to better accommodate the use of a 3D VR headset. This could include using more intuitive navigation and larger, more legible text, as well as incorporating more immersive 3D elements into the design.

As a part of the experiment, two VM running an instance of the PTV Vissim software ran simultaneously on a single workstation. The VR software in each VM was properly configurated to stream to the correct IP of the client HMD. The simulation performance was adequate on a 12-core CPU and dedicated GPU workstation setup, and running two simultaneous instances of VM did not affect the immersion in the VR experience in any adverse manner.

The SWOT analysis of the VR experiment, which takes the immersive 3D VR experience and the traditional 2D monitor experience into account, is given in Figure 5.

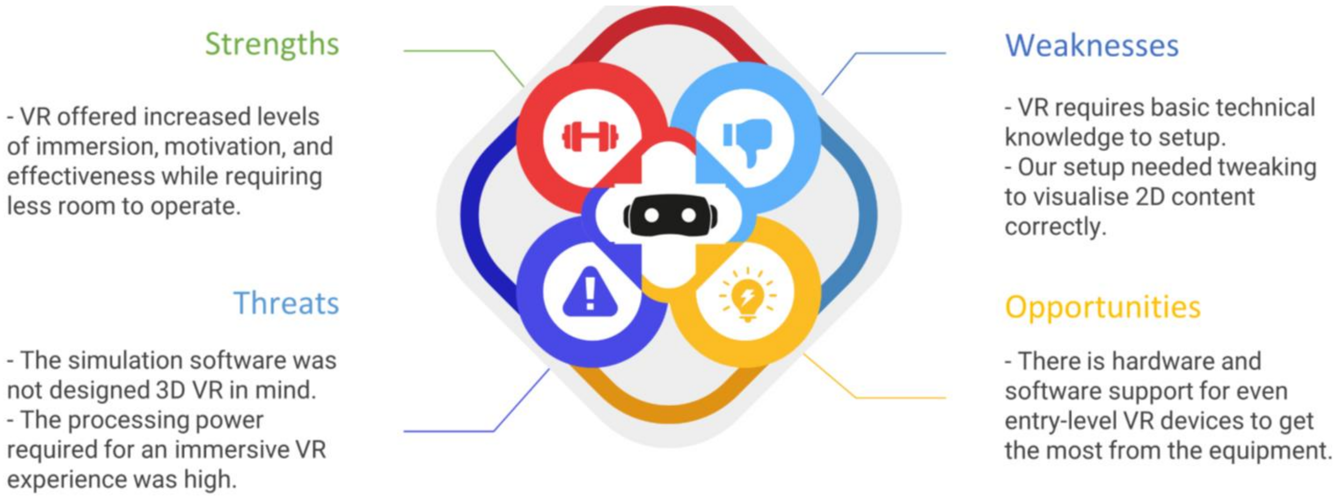


Figure 5. The SWOT analysis of the VR experience.

6. Discussion

VR technology has come a long way since the 2000s. High-resolution screens with fast refresh times, devices with precision sensors and cameras, and an increasing number of VR video games and software are consistently driving the technology further. The immersive and interactive nature of VR allows students to experience concepts and ideas in a whole new way, making learning more engaging and memorable. One of the biggest advantages of using VR in education is that it allows students to explore and experiment in a safe and controlled environment. For example, students can learn about traffic rules without facing the risks related to real-world traffic, train for high-risk scenarios, or experiment with complex chemical reactions without the risks associated with working with real materials. Another advantage of VR in education is that it can be personalized to each student's needs and learning style. For example, students can learn at their own pace and repeat lessons as necessary, or tailor the virtual environment to their specific interests.

One of the challenges of using VR in education is the cost of the technology. VR headsets and other equipment can be expensive, and not all schools have the budget to implement VR in their curriculum. However, as the technology becomes more widely available and affordable, it is highly likely that VR technology will see an increase in education.

The benefits of using immersive VR technologies are apparent and significant for educational purposes. Students' knowledge retention, understanding, concentration, and academic performance can be improved by implementing an educational approach incorporating VR technologies. The preliminary experiment also showed that even putting on a VR headset motivates the user to interact with the 3D environment.

While VR equipment has become more cost-effective in the last decade, it might be more cost-effective and worthwhile to utilize a temporary solution, especially if the use case is not repetitive or regular. The experiment proved that it was possible to utilize off-the-shelf equipment that was made for purposes other than VR applications to build an entry-level VR headset. However, the configuration required a relatively basic technical knowledge and software configuration. Therefore, building a custom entry-level VR headset was not as straightforward as having a dedicated standalone VR headset.

The availability of different VR server software for custom VR headsets and the support of low-latency streaming solutions significantly improves the capabilities of the said VR headsets. For example, during the experiment, minimizing the camera jittering introduced due to the noise generated by the MEMS sensor was possible with a noise-filtering option in the VR server software.

The experiment showed that the higher levels of immersion achieved with the 3D VR headset increased the effectiveness in detecting problems during a model creation trial within the Traffic Micro Simulation course, compared to the traditional 2D monitor screens. The primary factor was deemed to be the higher pixel density and ease of use of VR headsets compared to 2D monitors. The secondary factor was deemed to be a higher situational awareness due to interacting with the environment in a different and new way.

There is a significant benefit to using VR headsets for educational purposes, especially in classrooms or laboratories with computers, as it decreases the space required per person. Even an entry-level VR headset can give the visual clarity of a large monitor. Combined with a controller and VR-ready software, it might be possible to eliminate the need to use a keyboard and mouse for input. Furthermore, it is possible to reduce the physical number of computers required with local or cloud virtualization of the workstation or desktop environments. As a result, less space would be taken by computers, and more space would be available for other uses.

Although the costs associated with software licenses are expected to be the same as having the same number of computers, the benefit of increased energy efficiency due to virtualization can significantly reduce total costs. Therefore, classrooms or laboratories might serve more students while reducing total costs.

As a result of this study, it could be stated that implementing VR technology in the ITS education as a more immersive, new, and exciting tool to interact and learn can be significantly beneficial for bringing out the best in students.

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Conflicts of Interest: The authors declare no conflict of interest.

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