# Virtual Reality STEM Education from a Teacher's Perspective

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**Abstract.** Maroon is a virtual laboratory designed for learning experiences with virtual reality setups. It provides access to various simulations and experiments to learn and understand better physics. In a first study, the experience is evaluated with 14 prospective physics teachers to identify and discuss the potential of the setup for the classroom. In this study, we found that the experience was described as highly engaging and promising as it makes the content more interesting for learners. However, also the need to provide specific VR learning in educational institutions, as well as proving pedagogical scenarios to support collaborative learning were identified.

**Keywords:** Virtual reality, STEM education, VR, Interactive Simulations

## 1 Introduction

Traditional STEM (Science, Technology, Engineering, and Mathematics) education often presents STEM fields as a collection of formulas. Therefore, students are memorizing facts instead of understanding the underlying phenomena. As a result, students often describe STEM fields as *boring and complicated* and failure rates are very high [9]. Instead of reciting formulas, students should be able to experiment with hands-on and interactive experiences [13]. Teaching models that encourage conceptual thinking in classrooms through interactive engagement and the use of visualizations, simulations, and hands-on experiments can support learners to understand the scientific phenomena [4].

However, for many schools and other educational institutions, the provision of hands-on exercises and examples poses a challenge. Experiment setups are often very complex and expensive. Therefore, learners can only conduct a limited number of hands-on experiments and also only for a short period. This leads to a higher demand for digital learning experiences. Additionally, the new generations of learners require flexible and engaging learning environments, which help them to focus, which are motivating, and also let them explore the learning content.

In previous studies [10–12], we have presented and evaluated Maroon, a virtual reality (VR) physics laboratory to learn physics through interactive simulations and visualizations. We have compared the different version of Maroon using different VR technologies and have shown that this form of learning highly engages learners. Especially the room scale VR version supporting the HTC Vive environment was described as highly engaging and immersive. However, working with a room scale environment in a classroom setting poses various challenges, such as the needed space, the setup, and missing pedagogical concepts on how to introduce this experience in a classroom. Therefore, in this paper, we want to shed light on the experience of the other side of the learning experience: the teacher's perspective. We present a first study with 14 physics teachers to find out more about challenges, requirements, and potential options and scenarios on how to integrate a room scale VR experience into a classroom environment.

## 2 Related Work

Digital learning experiences to support interactive learning and engage students are becoming increasingly important for the classroom and can be used to support active learning approaches [6]. In particular, in fields such as physics, animations, visualizations, simulations, and virtual experiments can help learners to understand the phenomena [5]. Computer-based interactive simulations are usually cost-effective, safer, and take less preparation time when compared to traditional experiments [15]. However, designing learning tools for generations becomes increasingly challenging. They require engaging and flexible learning tools. For this purpose, the use of game-based systems, as well as virtual reality based systems have been shown as promising tools to engage learning but also increasing learning outcomes.

Bonde et al. [1] presented a gamified digital learning laboratory for biotech education. In a study testing this gamified laboratory, they found that this environment can significantly increase the students' motivation and their learning outcomes when compared to traditional teaching methods. Also, the use of virtual reality environments has been shown to enhance, motivate, and stimulate the learners' understanding of various phenomena. These environments have been shown as particularly successful in helping learners to understand events and elements when traditional instructional learning has been shown as inappropriate or difficult. The application of virtual reality in physics education has shown already very early as a promising approach [8]. Loftin et al. described in 1993 an early version of a digital physics laboratory for a virtual reality learning experience. In recent years, a new peak of virtual reality technologies, which are more affordable and also more immersive [3], gives new options and chances to bring virtual reality education to schools and other educational institutions. Additionally, tools such as the game engine Unity make it easier to develop different simulations and experiments for these devices and make both the learning, but also the development open to a broader audience.

## 3 Maroon

Maroon is a three-dimensional virtual laboratory and learning management system supporting learning experience supporting the interaction with virtual reality devices. Maroon is designed as a virtual laboratory room with different experiment setups. When users approach an experiment, they get teleported into a new scene, where they can work with the experiment (see Fig. 1). We developed Maroon with the game engine Unity3D[4] and designed it similar to a first-person game.

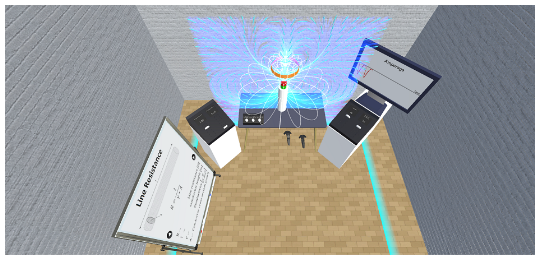


**Fig. 1.** Screenshot of an experiment room

The main version of Maroon supports different forms of interactions. On the one hand, Maroon can be used in a web browser with the own PC using the mouse and the keyboard to interact with the virtual world. On the other hand, it is also designed to be used with virtual reality devices such as the HTC Vive, the Oculus Rift, or mobile VR solutions (with the own smartphone). The different versions of Maroon were already introduced and evaluated in different studies [10–12]. These previous studies focused on evaluating the experience with these different virtual reality devices. In these studies, we compared room-scale VR experiences with the HTC Vive and mobile VR experience with mobile phones. We found that the room-scale VR experience was described as more engaging and more immersive. However, the HTC Vive environment also poses challenges, such as the needed space, the setup, and missing pedagogical concepts on how to introduce this experience in a classroom. Therefore, in this paper, we present a first study with a focus on evaluating learning and teaching perspective from a physics teacher's perspective to find out more about challenges, requirements, and concepts how to integrate Maroon in a classroom environment. For this purpose, we focused on evaluating the overall experience, as well as the experience with two different physics experiments: one experiment illustrating Faraday's Law and one experiment illustrating Huygens' Principle.

In the *Faraday's Law* experiment, a small magnet and a conducting non-magnetic ring (coil) are positioned on a horizontal axis. Users can grab the magnet and move it along the horizontal axis. When the magnet is moved through

[4] https://unity3d.com/

the coil, a current is induced. The current is displayed on a graph on a monitor on the right. The user can also feel the acting force through haptic feedback in the controller. In a panel on the right, the user can change the coil's mass, the resistance, and the magnet's dipole moment.

In the *Huygens' Principle* experiment, users can learn about diffraction. The experiment shows a basin filled with water. In the basin, a slit plate is placed, which allows users to observe the interference pattern generated by diffraction. Users can move the plate to the left or to the right and can also change the plate by grabbing it, throwing it away, and taking a different plate with more or fewer slits from the shelf to their left. On the control panel, users can change wavelength, wave frequency, and the propagation model. Users can also change the wave colors to enhance the visualization.

## 4 Evaluation

To understand better the value of the virtual reality learning platform *Maroon* for educators, as well as their needs and concerns, we conducted a qualitative user study with 14 prospective physics teachers. We designed the study with a focus on (1) experience and engagement, (2) usability, and (3) learning value from the teacher's perspective.

**Setup** The VR evaluation setup is a portable testing setup and consists of a Laptop, an HTC Vive[5] head-mounted display, the two base station, two controllers, and two tripods for the lighthouses. For the room-scale setup, an area of at least 2m x 2m is necessary. For this evaluation, we set up two HTC Vive room-scale experiences in one room. Both HMDs were captured with only two base stations. All participants were in one room and able to watch the others interacting with the environment to simulate an in-classroom learning experience. Test users did not wear any headphones so that we were able to interact and talk to them during the study.

**Material and Procedure** We recruited 14 student teachers of the teacher's study program. The participants filled out a 30-item pre-questionnaire to get information about their demographics, their experience with VR technologies, and their experience with educational tools. We familiarized all participants with the test environment and the VR setup. After giving a short introduction, we explained the different tasks and equipped them with the HMD. The first task was to interact with Faraday's Law experiment. The second task was to interact with the Huygens Principle experiment. After finishing all the tasks, we asked the participants to fill out the post-questionnaire. The first part of post-questionnaire consists of open-ended questions about their experience in the virtual laboratory and their opinion of the laboratory as a teaching tool. The second part consists of a 22-item scale with Likert scale questions between 1 (fully disagree) and 5

[5] https://www.vive.com/

(fully agree) about their motivation and experience in the virtual laboratory. We used the Computer Emotion Scale [7] to assess their emotion towards learning the new software. We used the System Usability Scale (SUS) [2] to evaluate the participants' satisfaction with the usability of the virtual laboratory.

**Participants** All 14 participants (11m, 3f) were in a student teachers program for physics education. The prospective physics teachers were aged from 21 to 28 (M=23.43; SD=1.72). We asked each participant to rate their experiences using a Likert scale between 1 (low experience) to 5 (high experience). All participants rated their experience with computers with 3 points or higher (M=3.4; SD=0.65). No participant rated the experience with virtual reality higher than 3 (M=1.39; SD=0.63). 7 participants stated to have used a VR device before. 6 participants have used the Oculus Rift before, only one the HTC Vive. 13 participants stated to use simulations for teaching. When asked about digital learning tools they use they named the e-learning platform Moodle, videos, simulations, the learning games from Kahoot, physics simulations from Phet, and physics simulations using the smartphone from phyphox[6]. All 14 participants stated that they think that VR is a promising way to teach physics through experiments. When being asked what they expect from a VR experience as a teacher the following items were listed: a new form of teaching, more engaged students, active and interested students, better understand through visualizations. They also mentioned that it is important that the tool is easy to use, that students cannot hurt someone or can destroy something, and a new form of teaching.

## 5 Results

**Experience and Engagement** All 14 participants rated the experience as engaging and motivating. To assess the participants' emotions while interacting with the VR lab, we used the **Computer Emotion Scale** [7]. The four emotions happiness, sadness, anxiety, and anger are assessed by asking the participants to rate 12 items on a Likert scale between 0 and 4. The results reveal that participants have significantly stronger positive emotions representing happiness (AVG=3.11; SD=0.54) and perceive very low emotions referring to sadness (AVG=1.0; SD=1.04), anxiety (AVG=0.82; SD=0.28), or anger (AVG=1.03; SD=0.29) while interacting with the VR experience.

**Usability** Only one participant described issues with the interaction with the experiments and with the user interface. The other 13 participants described the experience as very intuitive and self-explaining. We used the **System Usability Scale** [2] to assess the usability of the VR experience. The SUS is a 10-item standardized questionnaire on a Likert scale between 1 (not agree) and 5 (fully agree). The environment received an acceptable SUS, which is above average

[6] https://kahoot.com/, https://phet.colorado.edu/, https://phyphox.org/

(SUS = 68+) but also indicates room for improvement. The participants rated the overall usability of the system with 70,628 points out of 100.

**Learning Value from the Teacher's Perspective** Many participants mentioned that it would be helpful to add audio tracks to each experiment, which explain the concept of the phenomena and the effect when changing any parameters of the experiment. Participants mentioned that the VR Lab makes the content more interesting, fun, and engaging. However, when being asked if they think the VR Lab makes the content easier to understand, the answers were very mixed. Especially elements such as the visualizations the engaging and interactive interaction with the experiment, and the many options to interact with the experiment very rated as very positive. They suggest adding an audio track or other forms of explanations directly to the experiment. Additionally, one participant suggested adding the assignment protocol directly into the scene.

**Use Cases** The teachers were also asked to describe ideas and scenarios on how to use the VR lab in schools. Several participants mentioned the introduction of experiments which they are not able to perform in schools because they are not visible, too dangerous, or too expensive. Examples included acoustics or optical experiments. They would use in lab courses or as a project instead of using it as part of the traditional classroom experience. Also, one participant was concerned that students would see the experiments as a game instead of a learning experience.

**Qualitative Observation** During the evaluation, we collected qualitative feedback to be able to identify challenges, options, and use cases of the setup.
*"What did you like?":* When asked about what they liked about the virtual laboratory they stated that it is showing *"physical phenomena which are usually invisible"*. They liked that it is very interactive, user-friendly, and playful elements. One participant mentioned that one feels "as a part of the experiment". Several participants also mentioned that the virtual reality setup engages to experiment, explore, and research.
*"What did you not like?":* Participants mostly mentioned technical difficulties and dangers. This sometimes includes technical disruptions when other participants were standing in front of the base stations (sensors) and dangers through the cables. Additionally, participants mentioned that they did not like the feeling that others were watching them. One participant mentioned a feeling of dizziness. No participant felt nausea.
*"Would you use it for teaching?"*: Most of the teachers mentioned that they would use it for teaching but also noted several requirements and limitations. This especially includes the needed space, the needed setup time, and the costs. Additionally, teachers mentioned that especially the first interaction with the VR setup might be challenging because students will be very excited and distracted by their first experience with VR and will not concentrate on the experiments.

## 6 Discussion and Limitations

The results of this evaluation reveal that teachers would use VR technologies in the classroom. However, in the current state, they would prefer to use it on dedicated "project days" instead of making regular use of the technology. Their main concern hereby is the setup time. In the current experiment setup, the VR setup is designed to be mobile and requires a setup and calibration time. This issue can be solved by integrating VR setups in dedicated "VR Laboratories" or "VR Rooms" in each educational institution.

The qualitative observation and feedback we got from the participants also indicate concerns that the use of room scale VR with large student groups (e.g. 20 - 30 students) might be overwhelming and students would start to misuse the technology instead of focusing on the learning content. The need to develop specific pedagogical strategies was identified. For a future study, we are developing different pedagogical strategies to involve student groups in the whole learning process. Students can work, for instance, in groups of three. While one is working with the experiment in VR, the other two can give him or her instructions from the assignment sheet. This sort of collaboration was identified as a valuable tool to engage also in other VR experiences such as the VR game Keep Talking and Nobody Explodes[7]. Experiment assignments can be designed in a way that they would be only able to solve them while working together. This scenario would also be supporting the concept of collaborative learning, which has been shown to help learners understand the learning concepts [14].

All participants in this study were very young prospective teachers. All of them were 28 or younger. Their openness towards the use of new technologies might be higher compared to teachers who are already used to work with traditional teaching methods for many years. However, we also believe that introducing new learning technologies to prospective teachers is an important strategy to bring such innovative technologies to schools and other educational institutions.

## 7 Conclusion

In this paper, we presented a qualitative study with 14 prospective physics teachers to understand better their needs when working with a virtual reality setup to teach in classroom settings. The VR setup was described as a tool, which can enhance the students' engagement and help to get them interested in the topic. However, we also found that especially the room scale setup, which requires setup time and a dedicated space poses challenges. We were able to identify the teachers' need for a fixed setup (e.g., in a dedicated VR learning lab in the school), where they do not need to set up and calibrate the VR devices themselves. Additionally, we identified the need to define and evaluate various pedagogical models supporting collaborative learning in VR. Collaborative setups, which require students to work together on the assignment (one in the VR

[7] https://keeptalkinggame.com/

experience, two from the outside) by talking to each other can help to overcome various issues and help them to learn together.

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