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Virtual Reality as an Immersive Teaching Aid to Enhance the Connection between Education and Practice

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Abstract: Maximizing knowledge transfer is one of the main factors of modern education. It is important to raise the probability that students can successfully apply acquired knowledge into practice. This article deals with virtual reality (VR) as an alternative method to provide students with a more immersive approach to semester assignments and their completion. In addition to information on paper, they are provided with an immersive virtual environment that interactively visualizes problems. To test this approach, a case study took place at the Department of Industrial Engineering, Faculty of Mechanical Engineering at the University of Žilina. Students were given a standard assignment for workplace analysis and optimization. However, in addition to papers containing all the necessary information about the workplace and its processes (a drilling workplace), the students could also put on a VR headset and walk through a virtual copy of the assigned workplace. Instead of relying on a 2D layout and a few photos, the students observed every detail of the workplace from any angle. Moreover, the immersive virtual workplace was interactive, and the students could interact with machine tools and replicate the real manufacturing process. With this new addition, the students completed the assignment and then filled out a short questionnaire questioning their satisfaction with the chosen approach. With positive feedback, the implementation of VR into the teaching process could further motivate students and make the transfer of knowledge into their future jobs easier.

Keywords: emerging technologies; virtual reality; education; visualization; knowledge transfer

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1. Introduction

Teaching is a dynamic process that should be up to date with new approaches and technologies [1,2]. The teaching profession faces rapidly changing demands, while teachers are increasingly under more pressure to keep up with current competency standards than ever before [3]. Moreover, in recent times, during the world pandemic [4], the possibility and need for online education have come to the fore [5–10]. It was the pandemic that forced education to look for different platforms and new technologies to keep the learning process uninterrupted [11]. This has created space for the application of virtual and augmented reality technologies, which have their justification not only in higher education, [12] but in all forms of education [13]. In her study, Gómez-Trigueros [14] pointed out the low use of technology in didactic use and the need to respond to pedagogical changes, across Europe and the world, related to teacher training in the didactic technological area. Given the ever-increasing application of digital technologies and their importance, it is necessary to apply them to the curriculum [15]. Educators need to constantly find new ways of teaching to improve their students' performance [16]. One of the attractive approaches to transferring these new technologies to the teaching process is the use of a virtual continuum in the form of digital games [17,18] and virtual training [19]. Virtual reality as a medium is currently entering educational technologies, as well. It can help students to practice practical interactions, observations, and innovative skills [20].

It is vital that students can utilize lessons in the practice of their future careers. Therefore, securing sufficient knowledge transfer should be one of the main goals of teaching method designs. One of the possible approaches to a virtual continuum is the visualization of a problem using augmented reality (AR). In their studies, Hwang [21,22] and An [23] presented a playful approach to educational activities. The results of the survey showed that an augmented reality gaming approach can improve students' learning attitudes, as well as their learning performance. In her study, Badilla-Quintana [16] pointed out that augmented reality is a sustainable technology that can also help with the education of students with special needs. Nevertheless, many educators refuse to accept augmented reality into the teaching process due to doubts about pedagogical effectiveness [24]. In his study, Lai [25] evaluated the use of digital technologies at the University of New Zealand across three age groups to see if there were differences in learning characteristics. No practical generational differences were found in the study. Today's students are overwhelmed by digital technologies, and therefore, there is a need to approach this generation differently [26].

In addition to augmented reality, there is another way to use immersive technology, namely, virtual reality (VR). The presented article focuses on VR; however, AR also represents a very high potential for a sustainable and effective educational aid. The authors also intensively experiment with AR applications in education, but focused on VR for this study. One of the reasons is more affordable headsets in the case of a limited budget, but another reason is a bigger potential in environment customization, as VR can not only simulate real objects, but also the entire environment, including laws of physics. VR can arguably also provide a more immersive interaction with a created environment, which is vital for virtual workplace training. Moreover, in the case of VR, locomotion is not confined to exactly matching real movement, which is suitable for extensive virtual environments (such as large virtual workplaces). According to Edwards [27], the use of virtual reality in education can promote immersive learning through simulation and gamification [28] in subjects that require spatial skills. The results of a study carried out by Suleman [29] showed that three-dimensional visualization media using virtual reality can help the teacher in the pedagogical process and, at the same time, serve as an effective tool to increase student engagement. Mystakidis [30] wrote in his study that educational games in VR are appropriate for training, providing challenge, enjoyment, and mastery. Chiu [31] pointed to promising applications of artificial intelligence and the analysis of student learning, with the most extensively researched applications being in AR and VR. In a systematic review, Nesenbergs [32] evaluated the applicability of AR and VR in higher education and their impact on distance learning. The results showed that the main advantage of the application of these technologies is in the area of laboratory exercises, especially in cases where the physical presence of students is not limited. However, it is important to note that neither AR nor VR can fully replace face-to-face teaching. The limitations of VR are often set only by the creativity of the user. The possibility to simulate any kind of environment or process can enhance any educational process with a new way to improve knowledge transfer and retention. The connection between education and practice is a vital part of modern education. However, it is still neglected in many parts of the Slovak education system. Therefore, the utilization of VR may be the right tool for an alternative approach. Possible real-life scenarios can be simulated in a safe, virtual environment that can precisely copy the properties of real environments or processes. This can enable students to solve problems based on real data without leaving the school.

To test this approach, a case study took place at the Department of Industrial Engineering, Faculty of Mechanical Engineering at the University of Žilina. This department has long been developing activities in the field of application of AR and VR to the teaching process within the laboratory for augmented and virtual reality. The output of this research is several studies, as well as research in the field of reconfigurable production systems design, simulation, management, ergonomics, and other areas [33–37].

A group of students was tasked with the analysis of a workplace and finding possible changes for its optimization. The subject of the assignment (the workplace) was recreated

in a virtual environment with a certain level of interactivity. The students could then put on a VR headset to observe, walk through, and interact with the workplace and its objects. Instead of relying on paper data and 2D layouts, the experience became much closer to the real workplace optimization in companies.

On top of conventional assignments, students can also see problems in an accurate virtual replica of the real environment. Depending on the complexity, students could also interact with the environment and reliably replicate the processes of the real world. With the right execution, this is a powerful tool for any educational institution.

2. Materials and Methods

The case study took place between September and December 2021. The study took place within the teaching of the subject of the design of production and assembly systems, where students design production systems according to the requirements of the assignment in a provided software solution. The group of students (n = 30) at the Department of Industrial Engineering was given a modified version of their process analysis and optimization assignment, with the possibility of using VR for solving their assignment.

The main objective of the case study was to confirm or refute two hypotheses. These hypotheses questioned the effect of the immersive approach in virtual reality on students and their engagement in the assignment. These hypotheses were:

- The virtual reality-enhanced assignment further motivates the students while giving them a better understanding of the assigned process.
- The provided first-person experience encourages students to also focus on the human factor of the workplace and not just the technological process itself.

The first hypothesis questioned whether the technology of virtual reality could help students to better understand the problem, while making the assignment more interesting and engaging. The goal is for students to have fun while learning, which the novelty of VR can likely provide.

The second hypothesis focused on the new view VR provides. The students can see the workplace "through the eyes of the employee". This new perspective may help to look at the problem not only from the most optimal variant approach, but also from how these changes would affect the comfort of the employees in the workplace. The proposed changes may improve the performance of the workplace but, at the same time, negatively affect the workers. Therefore, students need to consider both sides when approaching a problem.

However, before the case study itself, a suitable interactive virtual environment needed to be prepared.

2.1. Virtual Workplace Creation

Before the case study itself, the conventional assignment was expanded with a virtual reality teaching aid. In addition to photos and 2D layouts, the assignment also offered the opportunity to see the full virtual copy of the assigned environment—the drilling workplace. This workplace was situated in the University of Žilina itself, as the teaching aid for the Faculty of Mechanical Engineering students. The copy was created in the Unity 3D game engine after the creation of all 3D models to represent the real objects of the workplace. The 3D models were created using either 3D modelling software, a small 3D scanner, or a combination of both. Using the C# programming language, the workplace was then made interactable. The machine tools and other objects reacted to the inputs the same way as in the real world. The level of interactivity was on a relatively high level, because the presented virtual environment was also designed as the virtual training tool created by the department's methodology [19]. For this assignment, visualization was the main point, but additional interaction may help during workplace analysis. The creation of the virtual environment is shown in Figure 1.

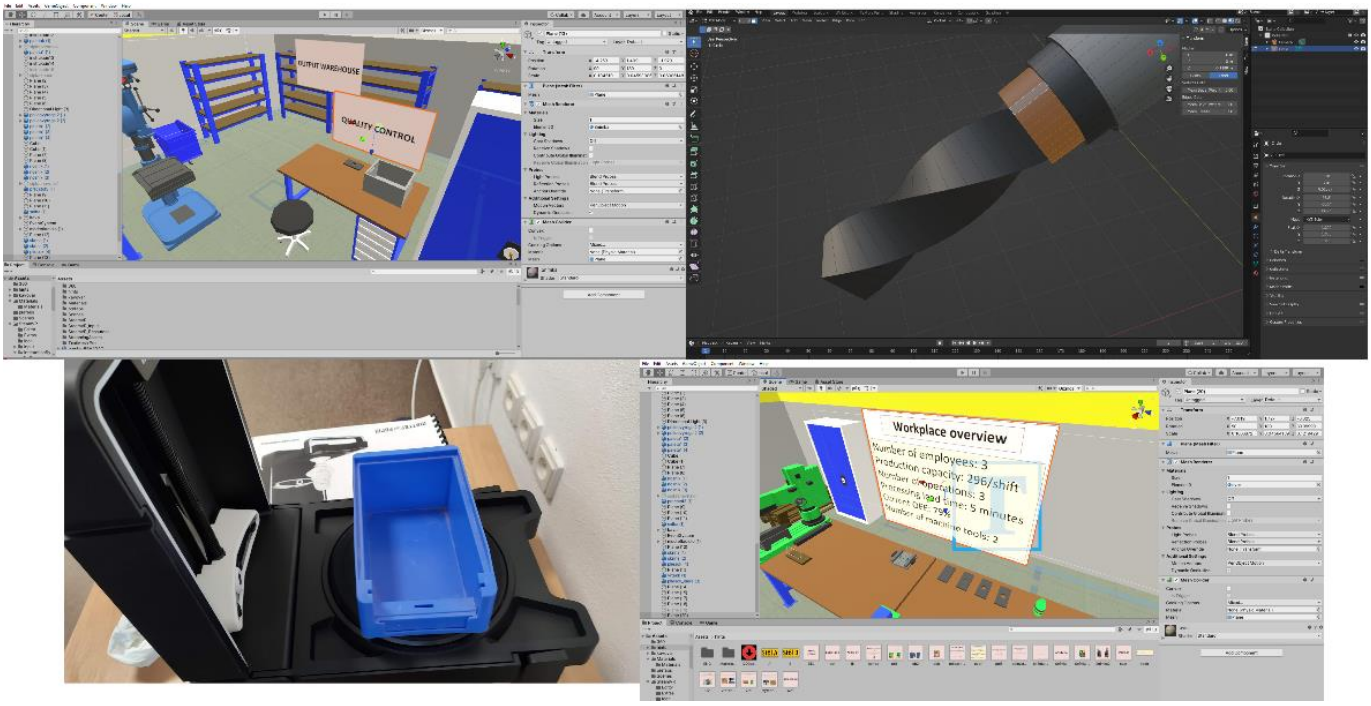

Figure 1. Creation of virtual workplace.

After creating a virtual environment and testing for any shortcomings, the workplace was ready for the students. In addition, the virtual workplace could be easily modified anytime, and tasks for students could also be modified.

2.2. Case Study Methodology

The main goal of the proposed approach is to connect teaching and practice more efficiently without any critical changes to the curriculum. Therefore, this solution modifies the currently used method of paper assignments with provided references, such as photos and 2D layouts. This approach was tested during classes in manufacturing and assembly systems design. The students used the provided data to create the assigned layout in a workplace design and optimization software. The assignment completion process remained very similar, but, in addition, students could now see the workplace "in-person" without leaving the school. The 3D copy of a workplace created in Unity 3D worked separately from the design and analysis software, but utilizing both at once had the potential for better results. During the assignment periods, the students could visit the laboratory of virtual and augmented reality anytime and analyze the immersive virtual copy of the workplace. In addition, they could also change the layout of the workplace and then preview the results in virtual reality. The fact that the students could freely walk in the virtual workplace and interact with it could potentially increase their creativity and motivation. They could see the flaws not visible in pictures or 2D layouts. With the current level of interactivity, the students could also simulate the entire operation and material manipulation, potentially discovering ways for improvement. Figure 2 shows the preview of the virtual workplace. Figure 3 shows the created workplace in its entirety.

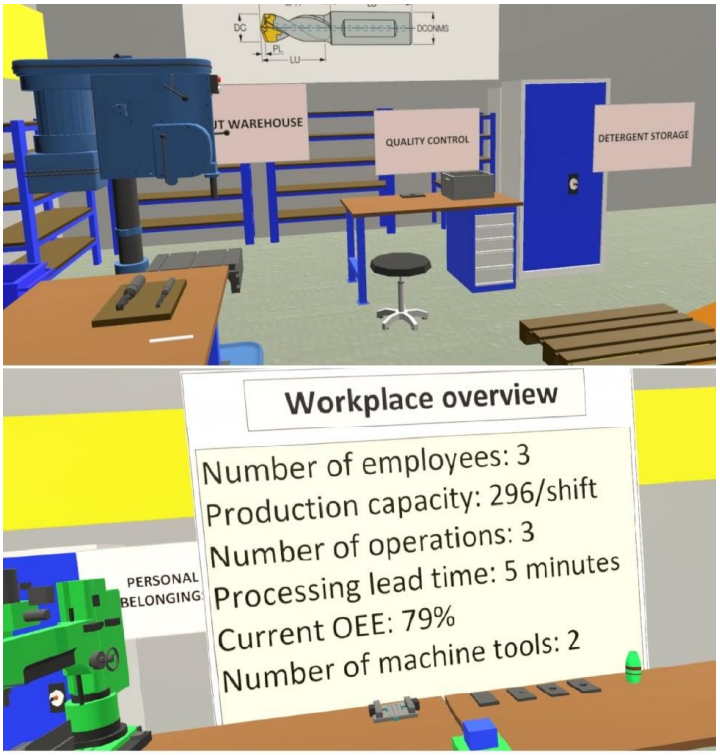

Figure 2. Workplace overview.

Figure 3. Created workplace.

As mentioned before, there were no changes in the assignment goal, and the students were only provided with additional resources. However, virtual simulation could leave a much bigger impact on knowledge retention, because students can interact with the subject of optimization instead of analyzing the pictures and provided data. This creates a much closer environment to their potential future career and possibly makes the transfer of knowledge easier.

The assignment duration was, in total, six weeks long. There were two study groups (n = 30) of the same year participating in the experiment. A total of 30 students were divided into 10 groups of 3 students. The space for assignment completion was reserved mainly during classes for the design of manufacturing and assembly systems. However,

the students could also use the laboratory of virtual and augmented reality in their free time. After completing the assignment, the students filled out a short questionnaire that questioned their satisfaction with this approach. In addition, their assignments created with the help of VR technology were compared to the assignments from previous years.

2.3. Assignment Changes

The main goal of the assignment was for the students to come up with at least two workplace optimizations related to layout, material flow, ergonomics, or any important part of a manufacturing system. There were no drastic changes to the assignment. Rather, the assignment was enhanced with the representation of the optimization subject in VR. In previous years, students used provided data and a 3D model library to recreate the workplace in the selected software for workplace design and analysis, using a provided 2D layout, as is shown in Figure 4. However, the 3D model was only displayed on the monitor; it was not an immersion in the full sense provided by VR using a headset.

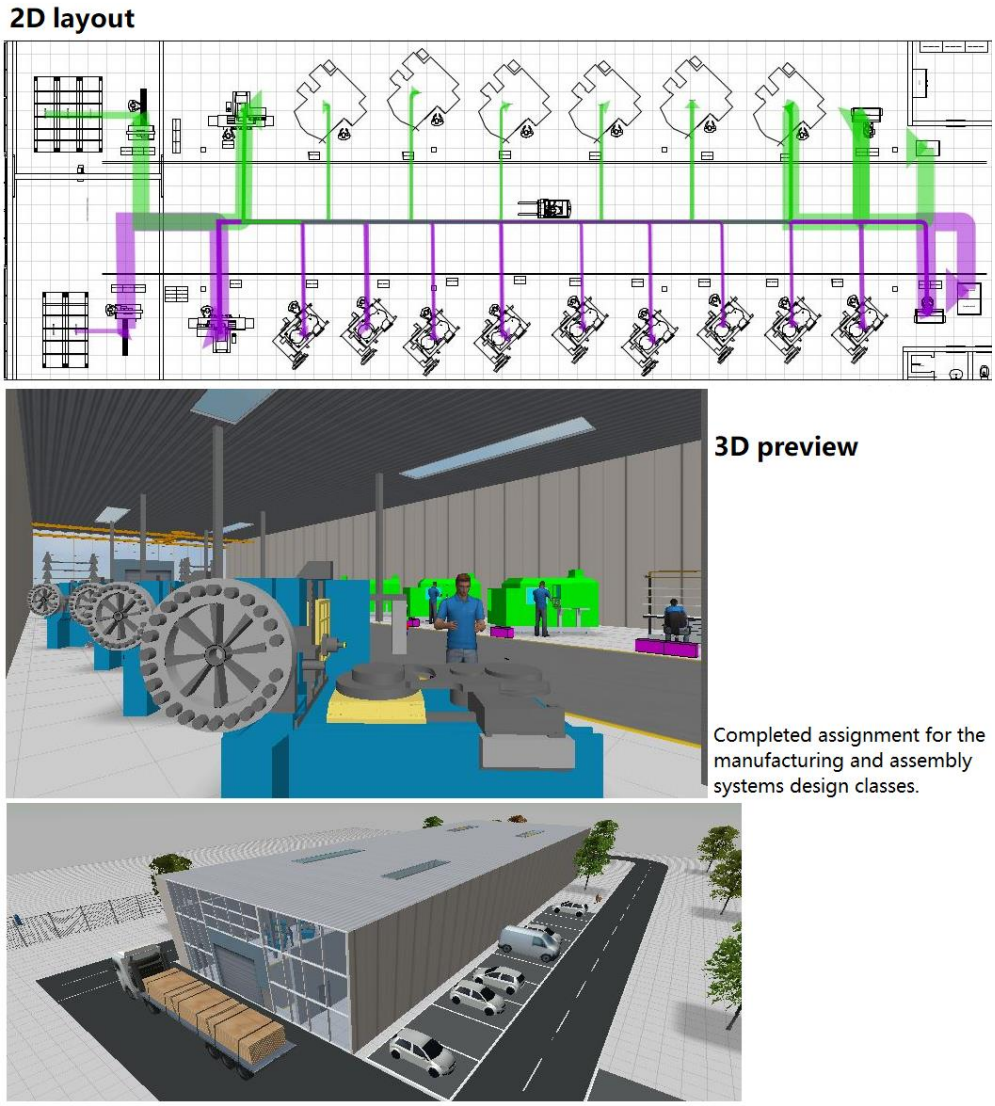

Figure 4. A student's work in the previous year.

This time, on top of workplace design and analysis software, the students were provided with a 3D virtual copy of a default workplace created in the Unity 3D game engine. This not only helped the students to better recreate the workplace in the optimization software, but also enhanced the analysis and optimization process. The students could walk

around the virtual workplace and interact with it to some extent. The virtual workplace also enabled the students to simulate the entire technological process; therefore, the students could experience the process through virtual training. The students also had access to the source project of the virtual workplace. Therefore, any changes made in a workplace design and analysis software could be repeated in Unity 3D for better visualization.

3. Results

The students took full advantage of this new addition. Using the workplace analysis and design software provided the students with a 3D model of the assigned manufacturing system. In addition, new virtual experiences allowed them to interact with the workplace objects and see the environment from the position of the employee. If they rearranged the layout, and they could see how a change would feel for the employees. Industrial engineering sees the view of an employee as an important factor in system design and optimization; therefore, these changes added an important depth to the assignment.

The initial reaction of the students to these changes seemed positive. The technology of virtual reality is an attractive topic, mainly for people with minimal experience with it. After getting familiar with the VR environment (Figure 5), the students proceeded to divide roles within their groups. While the previous years focused on the optimization software and provided data, this year, at least one student analyzed the layout and manufacturing process through the provided VR experience while referring to data on paper. The completely new point of view through the VR workplace encouraged discussion within the groups, resulting in the students being more active and motivated to find a solution. This motivation was reflected in the opportunity to use the VR laboratory outside of classes. The ability to experience their suggestions in a virtual reality simulation visibly influenced their creativity.

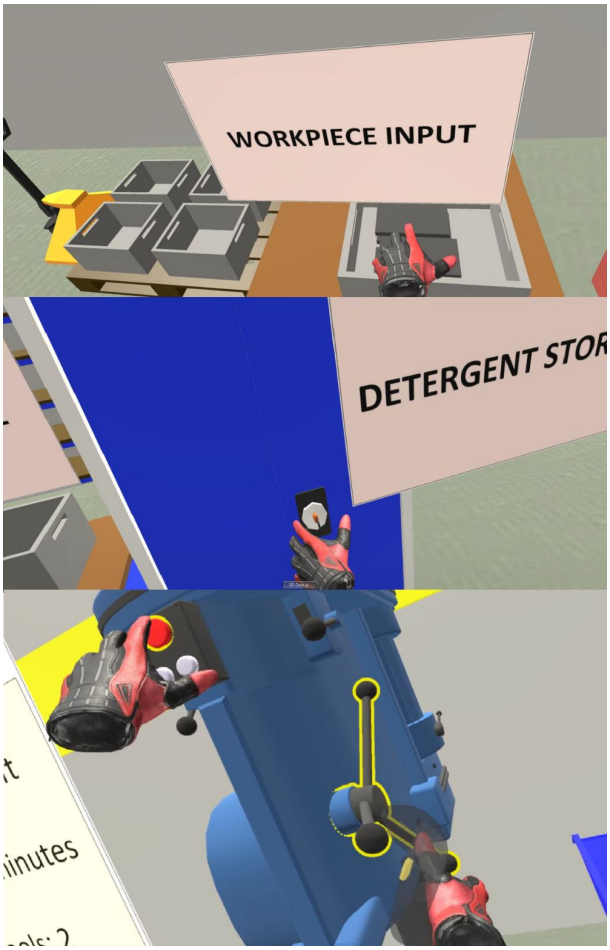

Figure 5. Student exploring the workplace.

The assignment stated that the students needed to come up with two proposals for optimization. In the previous year, students mostly provided two solutions for workspace optimization, which was enough for the passing grade, but not to showcase their creativity and skills. However, this time, only one group came up with two solutions, while the others provided at least three more solutions. The extra solutions were often related to the ergonomics, which may collate with students seeing the workplace from an employee perspective (Table 1). Therefore, they often rearranged the layout to be more suitable for the employee (but remain efficient) or add extra tools to decrease the strain during the shift. The students had the freedom to improve the workplace in any way, as long as the provided data backed up their suggestions (to prove it really was an optimization). The groups added new tools and objects to the workplace, some of which had no available 3D model; therefore, the students made their own. Figure 6 shows the students rearranging the assigned layout and adding new things to the scene to improve the workplace.

Table 1. Types and number of optimizations.

Groups	Number of Optimizations	Type of Optimizations
Group 1	3	Layout change, material flow alternation, ergonomics-related change
Group 2	2	Layout change, material flow alternation
Group 3	3	Layout change, material flow alternation, ergonomics-related change
Group 4	4	Layout change, ergonomics-related change, material manipulation change, warehouse re-organization
Group 5	3	Layout change, material manipulation change, warehouse re-organization
Group 6	3	Layout change, ergonomics-related change, warehouse re-organization
Group 7	3	Ergonomics-related change, material flow alternation, transportation vehicle modernization
Group 8	3	Layout change, ergonomics-related change, HR change
Group 9	4	Layout change, ergonomics-related change, material manipulation change, warehouse re-organization
Group 10	3	Layout change, material flow alternation, ergonomics-related change

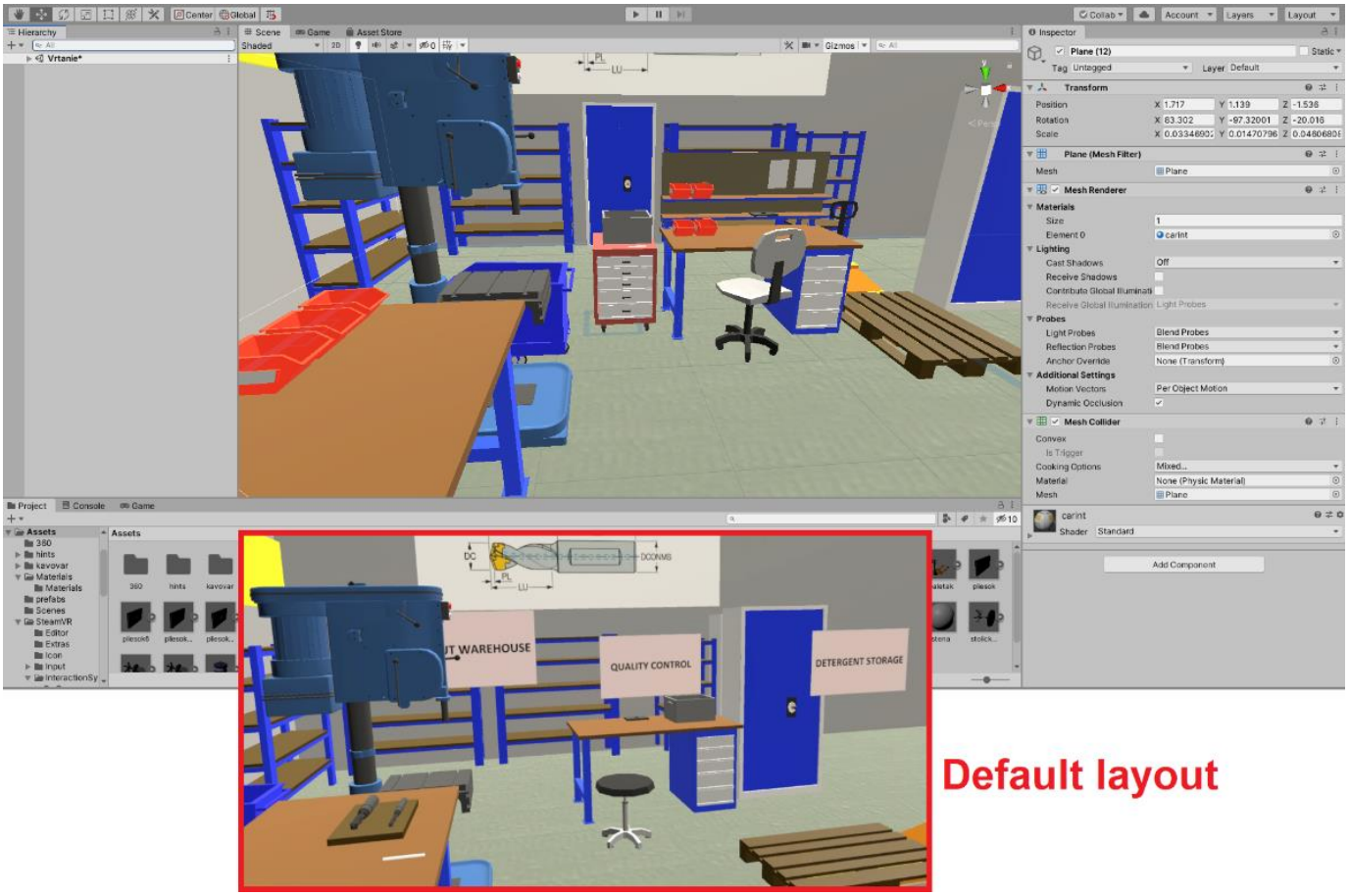

Figure 6. An improved workplace layout.

There was a notable increase in the number of proposed solutions per group, rising from two to three in most cases. Most of the new solutions were ergonomics-related, which was possibly an effect of the new perspective provided by the VR simulation. Trying the workplace tasks themselves, the students could experience the small inconveniences employees would have to deal with during their shifts. There was also a drastic increase in the interest of the students to work on the assignments outside of classes, as is shown in Table 2. This option was also available in previous years, because the required software was only available in the laboratories (classrooms). However, this year, they could also work with the VR simulation in their free time. For many students, this was their first experience with VR, which could the main reason for this significant interest spike.

Table 2. Comparison with results from recent years.

	2021	2020	2019
Avg. number of optimizations	3.1	* 2.4	* 2.2
The ratio of ergonomics-related changes per total group count	80%	* 40%	* 20%
Number of students interested in working on the assignment outside of classes	90%	* 10%	* 20%

* These data were obtained after the analysis of archived assignments from previous years. The total number of groups was 10 in both cases, but the number of students per group varied from two to four.

3.1. Questionnaire Results

After finishing the assignments, the students filled out a short questionnaire. Every student filled it as an individual, not for a group. For the first three questions, the students could answer "yes", "no", or "not sure". The answers were mostly positive for every question regarding VR and its effect on the teaching process.

The survey questioned these main points:

- Did virtual reality help you get a better grasp of the assignment goal?
- Did VR reality visualization help you to better understand the assigned workplace and its processes?
- Would you welcome the usage of virtual reality in more assignments in the future?
- How exactly did virtual reality help you in the process of assignment completion?
- Did you have any problem with using virtual reality during the assignment? What was the main drawback?

Most of the questions could be answered with a yes or no, while few of them allowed the students to express their opinion with an open answer. Moreover, the teachers supervising the class during the study had years of experience teaching this subject. Therefore, they could safely assess the differences between the process and result of this year's special assignment and the previous ones.

The first three questions represented the first part of the questionnaire. The first question asked the students if virtual reality helped them to get a better grasp of the assignment goals. All the students answered positively. The second question questioned the effectiveness of visualization using VR. A total of 93% of the students answered that VR visualization helped them to better understand the assigned workplace and its processes, and 7% answered negatively. The last question surveyed if the students would welcome more assignments based on VR. A total of 87% answered positively, 6% negatively, and 7% were undecided. Finally, the students were also asked if they had previous experiences with VR. A total of 67% of them answered that they had never had any experience with immersive VR.

The second part of the questionnaire consisted of two questions with open answers. The students could write their opinion or leave the answer field blank. The main goal was to analyze the main advantages and drawbacks of VR in the educational process for the subject of the design of production and assembly systems. The students that answered often matched in their answers. The results are visualized in Figures 7 and 8.

Figure 7. Open answer 1 results.

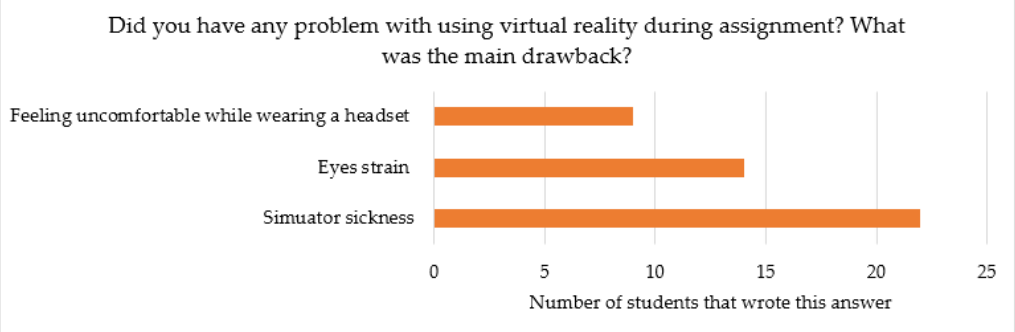

Figure 8. Open answer 2 results.

Overall, the students felt more engaged and motivated during the assignment completion. Many students highlighted the opportunity to see the workplace through the eyes of an employee as the main contribution of the addition of VR, as well as an overall better understanding of the process itself. However, the prolonged use of the VR headset had a negative impact on the students. These negative effects were mostly resolved by the students starting to use VR in shorter sessions and longer breaks.

3.2. Study Limitation

The results of the study were undoubtedly positive. However, the main limitation of the study is the small sample of students; however, the study was conducted in the harsh conditions of the COVID-19 pandemic, so the number of participants was severely limited. The amount of 30 students cannot entirely confirm the benefits of the new addition to the assignments. Therefore, this study is likely to be complemented in future classes and may be applied to various subjects where the use of VR could be beneficial to knowledge transfer. In the end, this pilot study provides pointers for the future.

4. Discussion and Conclusions

A lack of connection between education and practice is one of the problems many schools experience and can be crucial in the transition of students into their future careers. Virtual reality can be utilized as an answer to this problem. Created virtual environments can simulate real workplaces and real problems that companies may face. Even though students are not in the real process, they can still experience simulations within their classrooms. Instead of relying on the data, they can also visually analyze the problem in a virtual reality simulation that puts this data into a virtual experience of a real problem.

Virtual reality can possibly enhance the students' experience with the real problems they will encounter in their future careers [38]. Simulating selected environments or processes in a virtual space is a powerful tool that can be utilized in an educational process. Students of industrial engineering at the University of Žilina will deal with various problems in their future employment that require the application of obtained knowledge to real problems. For that reason, finding new ways to connect education and practice is an important task. One of the possible approaches was tested in this study. The main goal was to enhance the provided assignments with virtual reality tools. During the design of manufacturing and assembly system classes, on top of a conventional assignment, students were provided with a virtual copy of the assigned workplace—the subject of the optimization. The main objective of this addition was to simulate the possibility of seeing the workplace in person, which would be natural for workplace optimization in a company. Seeing the details of the workplace gave the students a completely new perspective and opportunities for assignment completion.

Throughout the entire assignment, the students appeared more active and motivated. The novelty of VR technology helped the students to be more interested in presented tasks, which provided a new way of interaction and possible approaches to problem solutions. Moreover, the students used the laboratory of virtual and augmented reality outside of their classes, affirming their increased interest and motivation. Additionally, compared to previous years, the students presented more suggestions for optimization at the final assignment presentation. Furthermore, these changes were often related to ergonomics, which means the students were more likely to consider the human side of the process.

The main goal of the study was to confirm or refute two proposed hypotheses.

The first hypothesis questioned whether VR gives students a better understanding of a problem while further motivating the students to successfully complete an assignment. Throughout the study, the students appeared more active, while achieving better overall (a significant increase in the number of proposed changes). Therefore, it is possible to consider this hypothesis confirmed.

The second hypothesis focused on how VR can affect the perspective on a problem. Compared to previous years, the students were more focused on the comfort of the employ-

ees. Almost every group proposed a change related to the ergonomics of the workplace. It seems that seeing the problem from the perspective of the employee helped the students to be more considerate of how the changes would affect the workflow for the employees. The students appeared to hold the well-being of the workers in high regard, while still proposing the changes that could significantly increase the overall performance of the manufacturing system.

In conclusion, virtual reality and its application in education and other sectors bring a new effective and sustainable solution to the presented problems. Further technological and scientific advancements will continue to lower the price and knowledge entry level for smooth implementation. The presented study showed that people, in general, are interested in the novelty of new technologies and appear more motivated when facing problems with VR as a potential aid. This could serve as a basis to help increase the motivation of employees or students in various situations.

One of the benefits of VR is the possibility to reuse previous assets. During the creation of a virtual environment for this study, a lot of content was able to be reused from previous studies and transformed into a new application. Therefore, with the increasing application of VR within various institutions, the creation of solutions for presented problems can be simplified, potentially creating a sustainable network of VR solutions.

The study also highlighted the fact that a virtual reality environment can be used to simulate every process. The created virtual environment focused on the simulation of the workplace and its processes: the operation of machine tools. This included many specific actions to operate workplace drills and other tools. Nevertheless, the presented process was able to be replicated with sufficient precision. This suggests that VR can safely simulate the real world even when facing complex and unusual actions. This observation further increases the potential of VR and its application.

On the other hand, one of the drawbacks during the study involving the use of virtual reality (with head-mounted devices) was the limitation of prolonged use. Some of the students needed to take breaks during the session to avoid simulator sickness, especially those who experienced immersive VR for the first time. However, after several experiences using VR hardware, their tolerance for simulator sickness increased, and they were more comfortable with longer sessions. The long-term effect of the regular use of VR hardware is still unknown, since this technology became widely used only in recent years. Nevertheless, these potential issues can be hopefully addressed with the rapid technological progress we now experience. For now, regular breaks for students sensitive to simulator sickness were the best option during this study. As mentioned before, it may not be as prominent after several immersive VR sessions.

This new addition to a standard assignment for the subject of the design of manufacturing and assembly systems proved to be a step in the right direction. Further studies are planned in the future, with a more significant sample size, with a possible expansion into a different subject. The possibilities of VR application are vast and may be the right alternative for connecting the educational process and practice.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in the case study are available from the corresponding author.

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

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