Virtual Reality as an e-learning tool in the student-centered vehicle development project "proTRon"

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Abstract: Immersive Virtual Reality (VR) is increasingly being used in many engineering disciplines. This paper presents the practical use of an e-learning tool for project-based learning in higher education in the context of a student-centered, industrial-sized project. The benefits and challenges of VR technology in education are examined. The paper briefly outlines the advantages of VR in its practical application in education as well as in the professional industry. In conclusion the paper argues that VR applications can be useful in improving effectiveness and efficiency in existent processes. However, such applications must be designed with great care in order to achieve the desired effects in the long term.

Keywords: immersive virtual reality, e-learning, project-based learning, vehicle development

1 Introduction

Virtual Reality technology has seen use in simulation, training and visualization for decades. A great number of different applications have been developed for engineering, medicine and computer science [VRL17]. In recent years a lot of progress has been made in VR hardware and software, especially in the field of head-mounted displays. As a result, the over-all relevance of immersive Virtual Reality technology in education continues to rise strongly [VRL17].

This paper outlines the experiences gained with VR technology as an e-learning tool, following a project-based learning approach. It describes the development and use of a VR prototype in the student-centered vehicle development project "proTRon" (cf. [Pr19]). It outlines the potential benefits of similar applications in education as well as in the professional industry. In "proTRon" students are developing the hyper-efficient, future-car concept "proTRon EVOLUTION" (cf. [Pr19]). The goal of our research is to determine to what extent problem-based learning can be complemented by VR within the context of projects like "proTRon". More specifically, we try to find out how to best support the development of problem-solving skills through e-learning in an immersive VR environment.

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1.1 Related Work

Through the recent technological advancement head-mounted, immersive VR has become a widespread and distinctive way of interacting with a virtual environment, setting itself apart from traditional desktop applications [VRL17].

Competency-based learning has been called an appropriate response to the changing demands of the professional industry [RWB14]. Virtual learning environments can be a suitable framework to teach students competencies, like problem-solving or independence [RWB14]. Interactive, immersive VR can outperform more passive learning methods such as video study or book learning due to its innate active learning approach [AV18]. The advantage of immersive VR lies in its positive impact on emotion and engagement, which is linked to student performance and knowledge confidence [AV18].

To avoid relying on the technology's novelty [AV18], educational VR applications need to be designed with great care, suitable to the target audience and based on the overarching instructional design [Ze18]. While VR in education seems to perform poorly in large groups, it performs especially well in learning environments featuring abstract problems [Ze18], which could be tailored to students' learning preferences for the most optimal outcome [AV18]. As a result, VR tools seem to be a suitable addition for project scenarios and e-learning in higher education [Ma17], a notion which we support in this paper.

2 Method

Our institution, as a University of Applied Sciences, puts a focus on teaching students the necessary practical skills and competencies sought for by the professional industry. This means to tackle real-life problems, often in collaboration with companies, and let students work on solutions. Those student projects retain the option to fail as opposed to the need of turning a profit in the professional industry, which allows students to take high risks and pursue creative approaches. This project-based learning approach is deeply ingrained in our Computer Science and Engineering departments and their curriculums. Endeavours like the CAD/CAM-laboratory LDPF (cf. [LD19]) and the interdisciplinary project "proTRon" (cf. [Pr19]) are prominent examples of that.

"proTRon" is a student-driven vehicle development project and most of its sub-projects are graded by professors for course credit. The student team was originally founded to develop vehicles for eco-challenge competitions (cf. [Sh19]) and is now working on the street vehicle concept "proTRon EVOLUTION". Every semester this results in dozens of group projects and theses in a hardware-agile and problem-oriented environment.

In 2016 the LDPF developed a VR presentation for the virtual rollout of the project's next vehicle design. This early tool laid the technical foundation for the "proTRon EVOLUTION VR Experience" (VRXP). The goal of the updated VR application is to educate and inform users by letting them explore the vehicle’s structure, its key sustainability aspects and the history of the ongoing student project. [Kü18]

The prototypical VRXP was developed as the practical part of a bachelor thesis. An agile development process, featuring frequent development prototypes, short-feedback cycles and a focus on the design phase ensured a high software quality [IS19]. Achieving a high level of usability and maintainability were the main goals coming out of this design phase. This resulted in 54 non-functional requirements and other design artifacts, providing measurable criteria for the prototype to fulfill.

The focus on maintainability meant setting up an effective and efficient pipeline of migrating the 3D data of the vehicle from proprietary CAD software to the employed game engine. It was paramount to be able to retain the original product structure and associated materials, while unifying coordinate systems, fusing little parts like screws and simplifying geometry for performance reasons. The proposed manual pipeline, together with the overall modular design of the software and the proprietary open-source libraries provide an application development framework for the purpose of creating VR applications for use in a product development process. This framework enables the original developer or other students to easily update vehicle parts, information and interactions, provided they act according to the existing documentation. The software’s design facilitates the addition of new modules like new scenarios or additional tutorials, a cornerstone of the prototype’s usability. The application prototype was designed in a way to ease users unfamiliar with VR into the virtual world and teach them how to use the provided tools to explore the VRXP on their own.

3 Results

The “proTRon EVOLUTION VR Experience” (VRXP) [Kü18] and its derivatives are highly interactive VR applications with a focus on user exploration. The primary goal of the VRXP is to provide a sandbox environment in which the user can learn more about the “proTRon” project. In its current stage it serves this purpose well, but there is still room for improvement when it comes to ease of access and additional features.

Key features of the “proTRon EVOLUTION VR Experience” include [Kü18]:

- 3D-visualization of detailed, industrial-grade CAD data in the original scale
  - dynamic cross-sections of parts (cf. Fig.1 [2])
  - simulating common real-life interaction patterns (e.g.: doors, steering wheel)
- package space review
  - study of data sheets and background information (cf. Fig.1 [1])
  - package group filtering (cf. Fig.1 [4])

  - manual dis-/assembly of parts (cf. Fig.1 [3,5])
- focus on usability in conjunction with exploratory user-interaction
  - basic "immersive VR" tutorial (e.g.: locomotion, virtual body presence)
  - context-sensitive tutorial prompts for interactions (cf. Fig.1 [5,6])

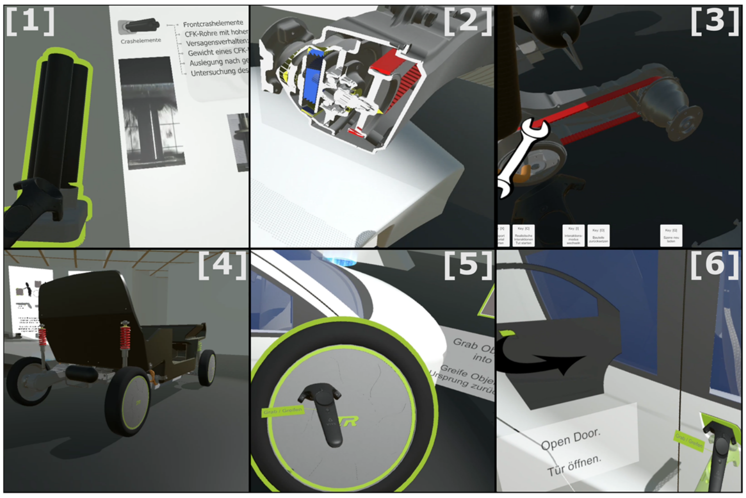

Fig. 1: Visual overview of some interactions and features in the VRXP

Originally the VRXP was showcased at trade expos and visitor events, where users were asked to fill in an evaluation questionnaire regarding the VR experience. The survey focused heavily on the users' engagement with the virtual world as well as on the perceived usefulness of usability features like the tutorial. Most subjects stated that the VR application caused higher interest in the project "proTRon" and the topic of energy-efficiency. They also reported a higher engagement, compared to traditional media. However, much of that could be attributed to the novelty surrounding the technology. The subjective evaluation by event visitors as well as members of "proTRon" noted the realistic visualization of 3D vehicle data in the original 1:1-scale and the interactive dis-/assembly of parts as the most satisfying and useful features of the application. [Kü18]

Within "proTRon" the VRXP was repeatedly used productively to review design concepts as well as package spaces and to adjust them collaboratively in a live environment. The examination in VR heavily supported the decision-making process through a higher degree of validation, a quicker consensus and a stronger confidence in the decision without the need to spend the time and the resources to build physical prototypes.

In general, VR applications possess a set of characteristics that have the potential to greatly enhance a digitalized product development process (PDP). Aside from the abstract view on product layers and the agility in prototyping that VR applications offer, they can also enhance or even evolve many traditional processes. Its nature makes VR highly adaptive in its application (cf. Fig.2). In industrial applications VR seems to be particularly strong in the PDP when communicating (interdisciplinary) interfaces, visualizing products, working collaboratively and validating results.

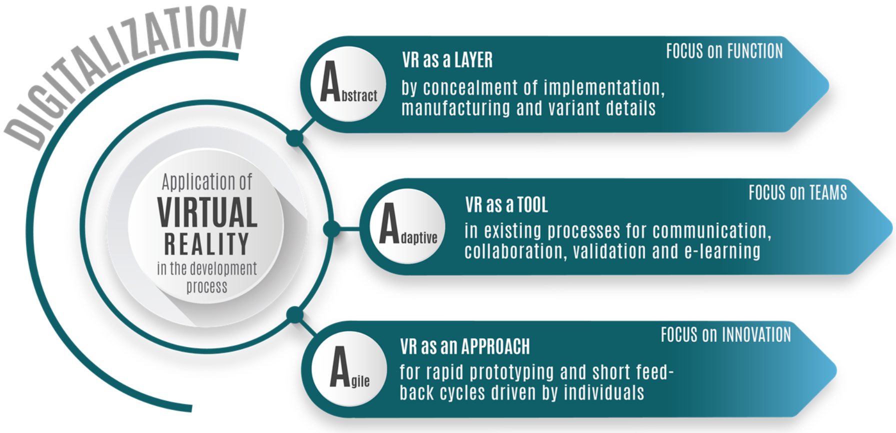

Fig. 2: Three key aspects of Virtual Reality in the development process

Many processes in "proTRon" can be complemented by VR tools, which offer low-cost, reusability and variance exploration. VR as a form of e-learning can succeed in engaging students that have a hard time with traditional learning approaches. VR makes physical products and related problems more accessible to the user, supporting a problem-based learning environment as an e-learning tool. Examples of helpful VR features include visualizing package spaces and designs as well as visually explaining interdisciplinary interfaces or overlaying additional product part information. The technology offers new ways of abstracting complex systems, solving communication difficulties and developing solutions by aid of its immediate, 1:1 scaled visualization. For the students it is rewarding to experience and present their project work in a virtual environment, especially when their designed products are too complicated for immediate manufacturing or prototyping. Within our teaching approach VR has become an additional medium of ever-increasing value, offering a new degree of freedom and creativity in shaping content and facilitating skill gain. In the context of product design, VR is a valuable alternative or supplement to prototyping with physical models or traditional blueprints.

4 Conclusion

VR in general seems to have the potential to completely rewrite whole processes in the digitalized industry, being a new way of visualizing and interacting with data. As such we believe that higher education must adjust accordingly and introduce VR technologies to the students. On the one hand it is important to teach the handling of VR applications and their development, as this is becoming increasingly more relevant in the professional industry. On the other hand, to enable VR as an additional medium in teaching methods is inevitable. In our case that means making VR part of student projects where physical products are being designed and manufactured. Students get to learn how to use VR as a powerful tool for rapid prototyping and validation, helping in the decision-making process and delivering an additional value to the developers by a real-scale visualization.

Going forward, every student team in “proTRon” will have the opportunity to quickly access their data in VR for review and collaboration. The pervasive integration into the design processes of the (sub-)projects is more important than adding new features and improving maintainability and usability of the VRXP.

Our next focus is to integrate the immersive VR technology as a review and prototyping tool into our existing processes and study its effectiveness, acceptance and impact on the student projects. We hope to learn more about how to tailor the medium to support our project-oriented teaching methods in our student-centered industrial-sized environment.

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