HandLeVR: Action-Oriented Learning in a VR Painting Simulator

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Abstract. The development of vocational competence has so far been inefficiently implemented in some trades, as for example in the training of vehicle painters. The HandLeVR project therefore underscores the use of Virtual Reality to promote action-oriented learning of techniques for carrying out vehicle painting work. This article describes both the instructional and technological aspects of a VR Painting Simulator developed in the project and presents intermediate results.

Keywords: Virtual Reality · Simulation · Vocational training

1 Motivation

A competence–oriented approach in vocational education and training requires comprehensive, action-oriented learning units with learning progress checks. By observing actions in authentic learning and exercise situations, it must be possible to become insight into the underlying competencies, both through reflection (by the trainee) and evaluation (by the trainer). Problems with the consistent implementation of this requirement are common, for example, in the training of vehicle painters. Here, various techniques for applying individual layers of paint to workpieces must be trained. Adequate, frequent and action-oriented training, however, is hampered by economic, physical, and social factors.

With Virtual Reality (VR), psychomotor coordination and skills can be trained as discussed in explorative learning approaches. VR technology enables a high degree of immersion and authenticity of the learning situation, allowing learners to immerse themselves in a learning world where they can control their learning process to a high degree and learn by exploring the digital artifacts. In addition, painting is predestined for VR use. For example, no haptic feedback from the 3D workpieces is required (apart from the paint spray gun), as these are not touched during paint application.

The aim of the HandLeVR project is to develop and evaluate an effective training system with a central VR learning application - the VR Painting Simulator. The system will be used for training and following evaluation of paint applications on 3D workpieces. It consists of an authoring tool for trainers as well as the VR learning application and

E. Popescu et al. (Eds.): SETE 2019, LNCS 11984, pp. 46–51, 2020.
https://doi.org/10.1007/978-3-030-38778-5_6

a reflection application for trainees. The instructional and technical conceptions as well as intermediate results are presented in the following sections.

2 VR Painting Simulator

This section describes the design of a VR training application, which is developed within the HandLeVR[1] project. The research questions ask weather VR technology can contribute to effective training of action-oriented learning in vocational education and how instructional design principles can be applied in this technology to ensure appropriate learning success.

2.1 Instructional Concept

While emerging technologies have fostered the development of technologically advanced VR learning applications, these solutions often lack a thorough instructional approach [1–3]. Consequently, some of these VR learning applications contribute little to the acquisition of competences and clearly stay behind their potential.

VR learning applications have proven to support both the training of simple psychomotor tasks and the development of complex competences including knowledge, skills and attitudes. These more complex competencies, however, need elaborated instructional concepts, which are based on findings in the field of learning psychology. Those concepts can be used to design appropriate VR applications to efficiently help learning and the acquisition of theses competences.

It becomes clear that digital technology by itself will not improve learning sufficiently and enduringly [4]. It is open to what extent available concepts for the instructional design of educational media will be applicable to the instructional use of VR technology [5, 6]. Although many VR applications try to address an educational problem, the lack of empirical studies on the instructional design of VR in the field of training, has been criticized [7, 8]. Therefore, the usefulness of already existing and new instructional design models for VR learning applications has to be studied and validated in the field.

The present aim is to apply a highly validated instructional design model, namely the 4C/ID model [9], in the earlier described VR training application to facilitate the development of skills and action-oriented learning in the vocational training of vehicle painters. The model was developed to train complex cognitive skills and provide instructional principles to design effective training programs. It focusses on the development of skills rather than knowledge by providing authentic whole-task practice and frequent part-task practice.

An additional aim of the current project is to study two instructional approaches in the current context, namely an exploratory approach versus a more systematic approach. Previous studies have shown that an exploratory approach often results in learning strategies on a trial and error basis. It remains questionable whether this is effective for the development of action-oriented competences [10, 11] as needed by vehicle painters. In addition, the often heterogeneous group of trainees found in the training for vehicle

[1] https://handlevr.de.

painters ask for more individual learning paths that can be customized according to trainees' proficiency level. Therefore, both approaches will be compared:

A. Explorative approach: Learners have access to all VR learning tasks. They can freely navigate through the learning application and independently decide which learning task they perform.
B. Systematic approach: The trainer or educational institution gives a pre-defined learning path that the trainees have to work through. However, the learning path may be customized according to the proficiency level of an individual trainee.

The presented instructional design results in two concrete technical requirements of the VR learning application. First, to allow a systematic instructional approach, a well-constructed authoring tool is needed that allows the trainer to define customized learning paths according to the proficiency and needs of the trainee. Second, to foster the development of action-oriented competences (plan, execute, check, if necessary correct and lastly evaluate actions) a reflection application is needed that will present performance feedback to the trainee (e.g. thickness of the coat) and reports individual stages of learning and support self-reflection.

2.2 Technical Concept

The central instrument for investigating the usefulness of the instructional design models for VR learning applications is a multi-component learning system, the VR Painting Simulator. The core of this system is the training and quality control of paint applications on 3D workpieces. On the technical side, there are particular challenges in simulating the physics of paint applications (e.g. paint particle density) and the reproduction of the paint spray gun both in VR and as a comprehensible, sensor-equipped input device.

As visualized in Fig. 1, the use of the system is subdivided into 3 phases, which are based on the instructional requirements. In the preparation phase (1), a web-based authoring tool is used by the trainer or the training institution to concretize the general scenario (application of color layers). The tool supports the integration of finished templates for specific learning units and 3D models as well as the creation of new learning units and their interconnection in terms of learning paths.

In the next phase, the trainees perform their learning actions (2) in the VR learning application within the context of the previously defined specific learning scenarios. They use a typical HMD which immerses them into the virtual world. With a physical controller in the form of the familiar paint spray gun and its virtual counterpart visible in the VR, virtually displayed 3D workpieces can be painted by the trainee in authentic actions. The detailed results of these actions are transferred into a trainee profile.

In the last phase, this profile can be imported into the web-based reflection application to assess the learning performance with fellow trainees or the trainer (3).

2.3 Intermediate Results

Regarding the instructional concept a training analysis was conducted which included interviews and field observations at two different sites. First, interviews at the painting

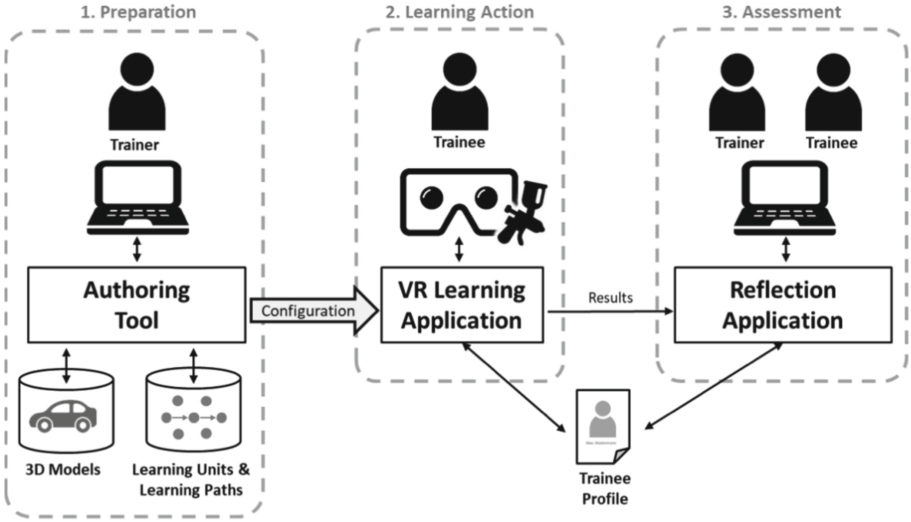

Fig. 1. Architectural sketch of the overall learning system.

shop of a German automobile manufacturer were carried out with (1) the trainer for car painting, (2) three trainees and (3) two former trainees now working on the production site. In addition, a typical training session in the painting shop was observed. The 4C/ID model served as a basis to design the interview scheme and the observation guidelines. The collected data provided the input to design a first concept for the training of vehicle painters in VR. In the second phase of the training analysis the developed concept was validated with a group of trainers for vehicle painters working at a center for cross-regional education for vehicle painters. The results of this second phase are currently analyzed.

Independent from the instructional concept, a basic realistic representation of paint jobs, the working environment and the tools used is required. Therefore, the early technical developments focused on both, an authentic VR setting in terms of a multifunctional painting booth and paint gun as well as an accurate simulation of the basic painting process. Figure 2 shows the current version of the painting booth including an exemplary engine hood and the user interface (left image). The 3D models of the painting booth and our highly authentic paint gun (right image) where created on basis of their real counterparts. The user interface in the form of a monitor on the wall gives access to the current functionalities of the application. Besides an engine hood, several parts of a car were modelled in detail and integrated into the application.

The aim of the current prototype was realistic representation and behavior of the spray cone and the paint job on the workpiece. To help the user find the correct distance to the work-piece, a ray can be activated that turns green when the correct distance is reached. Additional first in-process evaluation possibilities were integrated, allowing to determine the quantity and costs of the paint used and how much of the paint has been wasted. If too much paint is applied the paint runs down the workpiece. This is one of the

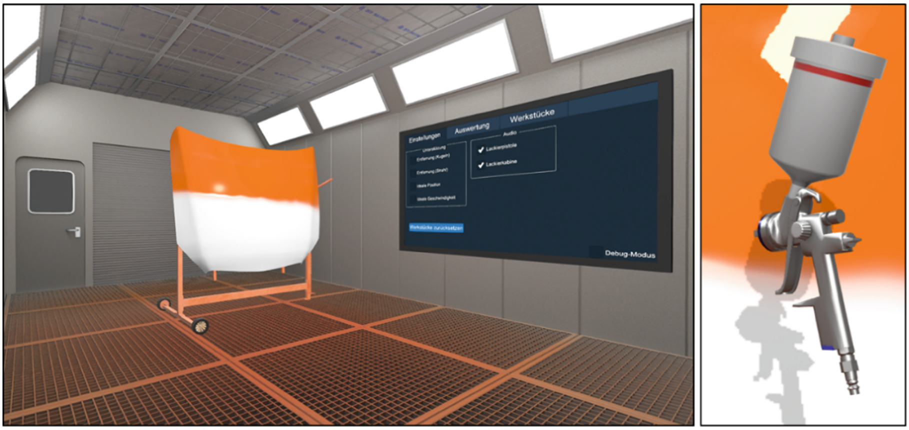

Fig. 2. Paint booth with a blank car part and the user interface on the wall (left image) and the current version of our highly authentic paint gun (right)

error types which have to be implemented. Furthermore, a measurement mode allows the highlighting of areas where too much or too less paint has been applied.

3 Conclusion and Future Work

The VR Painting Simulator described in this article focuses on the promotion of action-oriented learning of techniques for performing automotive painting work through virtual reality. First, it is investigated which contribution VR technologies offer to enable action-oriented learning in vocational education and training and how instructional design principles can be applied in these technologies to ensure appropriate learning success. The findings from this study will be transferred into a VR-supported training (the VR Painting Simulator). This learning framework consists of an authoring tool for trainers as well as a VR learning application and a reflection application for trainees.

Concerning the instructional design, the developed concept will be revised and validated repeatedly. Therefore, a close collaboration with trainers and trainees in the field of car painting as well as with computer scientists to transfer the instructional concept into VR is needed. The resulting VR Painting Simulator and its prototypes are evaluated continuously during the project as well as in dedicated field tests.

In addition to vehicle painters, the transferability of the results to other trades with related learning activities (e.g. classical painters, welders) will be examined during the project. The project team will transfer the project results to the vocational training centers of the chambers of skilled trades located throughout Germany and provide appropriate advice to accompany the practical application. In addition, the sustainability of the project will be promoted by the final publication of the project results under an open source license and as an open educational resource.

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