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Formal and Non-Formal Learning in Virtual Environments

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Summary

In recent years, the necessity of improving the delivery of educational content has led to an increased interest in technological solutions able to revolutionize traditional teaching approaches. Specifically, many efforts have focused on the integration of Virtual Reality (VR) into training scenarios, exploiting the intrinsic advantages of this technology, e.g., the capability of enhancing procedural learning, the simulation of dangerous situations, and the automation of guiding and evaluation systems. However, the creation of effective VR Training Systems (VRTSs) and the acceptance of VR as an effective tool for education remain critical. In fact, the design of new VRTSs is often context-dependent, thus leading to a lack of general guidelines for the implementation of new systems. This leads to a clear imbalance between the number of VRTSs adopted in non-formal contexts, where VR is considered as a rather common training solution, and non-formal contexts, where the use of VR is still more limited. This imbalance if further exacerbated by the intrinsic differences between the two contexts.

Chapter 1 describes the context in which this thesis is placed, focusing on the state of Vr-based education, whereas the following chapters progressively investigate the use of VR in education, moving from a non-structured, non-formal context to a formal one. The progression of the chapters represents the chronological development of the author's research during the three years of the Ph.D.: Chapter 2 presents two studies from the first year, Chapter 3 focuses on a study that was carried out in the first part of the second year, and Chapter 4 is based on one study that was carried out predominantly in the third year and one that is still unpublished. Each of the considered studies focuses on a different training scenario. On the one hand, this is a confirmation (and a consequence) of the context-dependent nature of VRTSs; on the other hand, this was a necessary choice to reach more general results that could be generalized to new contexts. Moreover, each study represents a step that builds upon the considerations made and the hints gathered in the previous ones. Namely, each of the systems devised to tackle the above scenarios was developed using the previous ones as reference, leveraging the structure underlying the previous simulations (e.g., part of the application logic) as a foundation, and adopting the evaluation procedures used or developed in previous studies

as the base to further investigate the considered topic. Moreover, each study focused on procedural learning and hands-on, practical activities, providing outcomes that were then reused, with some adjustments, in the following body of work, thus enforcing an overall structure framing the research described in this document.

In detail, Chapter 2 focuses on the adoption of VRTSs in non-formal education, by exploring two studies on training First Responders (FRs). Leveraging two VRTSs designed in collaboration with CBRN (Chemical, Biological, Radiological, Nuclear) and High-Capacity Pumping (HCP) trainers, the impact of these two systems and their effectiveness as training tools were evaluated. No comparison with existing courses was carried out, mainly due to the lack of standard teaching methods in the real-world scenarios. These two studies helped the author to identify some indications about the design and the validation of VRTSs, later used in the remaining part of the research. Subsequently, Chapter 3 presents a pivotal study on the integration of a VRTS in a structured course; the considered system was designed with the help of trainers from a firefighting body, and was conceptualized as training tool to be deployed in non-formal education. Its introduction in a structured course enabled the possibility to outline the strengths of a VR-based solution with respect to more traditional approaches, proving that this technology can ameliorate existing training experiences that focuses on safety education. Finally, Chapter 4 focuses on the use of VR in formal education, and is based on two studies. The first study extends the work reported in the previous previous chapter, by contrasting a VRTS designed for formal learning against an existing course, achieving positive results. The second study further confirms these outcomes, then builds upon them and investigates the use of an unconventional pedagogical model in a VR setting, showing that combining VR with approaches that are typical of formal education can further improve the positive results that are normally achieved by the use of this technology.

In conclusion, the research presented in this thesis shows that VRTSs can be effectively deployed either in non-formal and formal education, and provides a possible path to successfully move the development of these systems from the non-formal context to the formal ones. The path is not unique, and encompasses deriving a series of hints and considerations to drive the design of these systems despite the inherent scattered nature of the training panorama. Specifically:

- During the design phase of a VRTS, the contribution of domain experts is necessary, and the help of expert trainers is specifically required in order to focus on the aspects of the procedure that are usually critical for the trainees; in particular, experts trainers can also contribute during the evaluation of the VR-based training experience, designing, e.g., the quizzes and the practical exams to collect information on the learning gain.

- A detailed guiding system, using both voice-based instructions as well as visual cues that are integrated in the virtual environment (e.g., highlights), and

an in-depth evaluation module are both required for supporting an effective VR-based training experience. A suitable scaffolding system grants the possibility to use the VRTS without the need of real trainers, and enables the use of VR in combination with uncommon pedagogical approaches.

- Testing the usability of the devised VRTS is necessary, but not sufficient. Standard questionnaires are required to evaluate the quality of the training experience, investigating aspects such as the motivation at learning, the attractiveness of the experience, the cognitive load, and so on.

- The devised VRTS need to be integrated in existing courses an/or contrasted to existing training approaches. Moreover, it can be used in different ways, depending on the context, and can be either serve as a complementary tool to existing activities, or as a replacement for traditional, less effective approaches. When a comparison is conducted, it is necessary to create an experimental procedure that is fair and can effectively isolate the contribution of VR.

Following these considerations, it is possible to enforce a common structure on the design and the testing of these systems and the corresponding training experiences, thus balancing the differences that are associated with the context-dependent nature of the simulated procedures. Furthermore, moving the adoption of VRTSs towards formal education opens up a range of possibilities, e.g. the use of unusual pedagogical approaches, that can further enhance the quality of the resulting experiences.

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