Immersive and Interactive Digital Twins to Train Engineering Students

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Abstract. Immersive Digital Twins (IDT) have many advantages for training engineering students in the use of industrial machines. Some of the advantages are practical, such as avoiding the need to buy machines that are very expensive to maintain, saving energy and journeys. There are also advantages in terms of learning, since immersion improves performance for certain types of content. In addition, immersive environments now make it possible to integrate intelligent virtual agents, thanks to the development of language models. These new possibilities will undoubtedly lead to new forms of teaching in engineering schools. Most of the researches are focused on optimizing course situations. However, there is currently a lack of research regarding their impact on the learners independent study, and on the role of the teachers in the use of these devices.

Keywords: Digital Twins, Virtual Reality, Learning.

1 Introduction

There are several very different definitions of digital twins [1]. In this work, we refer to digital twins defined as virtual models that interact simulate a physical system and interact with it. Digital twins are more and more used in industry, as well as immersive technologies, defined as technology that offers a high quality or quantity of sensory information to the user [2]. Immersive technologies have three main uses in industry: process simulation, design and training [3]. Immersive technologies are emerging as a valuable educational resource, although the pedagogical effectiveness of learning in Immersive Virtual Environments (IVE) depend on type of knowledge to acquire, pedagogical method and IVE features. Accessing an engineering qualification requires rigorous training, which imparts a wide spectrum of knowledge and skills. IDT merging digital replica of a machine with the immersive capabilities of virtual reality offers an educational experience that closely mirrors the authentic interaction an engineer would have when operating the actual machine in an industrial setting.

2 Practical Usefulness of IDT for Teaching

IDTs, compared with their physical twins, offer certain practical advantage for teaching. An IDT can be used remotely if a suitable terminal is available, which can reduce learner travel and potentially give students around the world access to training in

industrial equipment. The use of an IDT rather than a physical twin also often results in savings in materials (the material consumed or degraded by the simulated machine), or energy (in the case of foundry systems, for example). Last but not least, the use of IDTs makes it possible to confront machines without endangering either the students or the machine, in cases where certain actions could damage the equipment. This open the way to safety-oriented training in which teachers can let learners go as far as the accident.

Investing in technological platforms at industrial scale for educational institutions can swiftly escalate into a substantial financial commitment. One strategy to mitigate these expenditures involves collaborative pooling among multiple campuses or educational institutions, and potentially with research laboratories as well. Another problem with physical machine is the lack of availability when there are several users. Having a IVE replication allows to have a lower-cost installation, accessible at all time and from remote locations. While digital technology may not fully substitute the physical environment in the actual production of mechanical parts, conducting preliminary tests to explore various configurations for feasibility validation also serves as a means of saving on costs..

IVE facilitates access to specific work scenarios for individuals with disabilities. While some real workstations may be inaccessible, understanding an operational workstation allows them to better understand upstream tasks such as design or process management. Consequently, IDT present novel opportunities for individuals previously excluded from such employment prospects.

IVE attracts the curiosity of younger populations, particularly through video games. Engaging young learnings in a virtual educational setting depicting industrial work scenarios has the potential to ignite enthusiasm. These lifelike situations can help dispel misconceptions about certain professions, potentially inspiring aspirations for further education in specialized training programs.

3 Pedagogical Effectiveness of IDT

Depending on the type of learning and content, IDTs and more generally IVEs can have a positive, negative or neutral impact compared to non-immersive media. Immersive technologies appear to have potential whenever training requires users to feel a sense of social presence, i.e. the feeling of “being there” with a “real” person [4]. This sensation is supported by stereoscopic 3D, immersion and consistent representation of the people we are with. In this case, individuals' emotional responses are analog to those measured in real-life situations, which is relevant to train social skills (public speaking…). IVE also has the capacity to generate a feeling of physical presence. A visually realistic environment is an effective way to help learners to familiarize to a specific workplace or to contextualize a learning content.

Through headset and gamepad position tracking, IVE lead users to adopt postures that are more or less equivalent to those they would adopt when carrying out a similar activity in a real situation. It is therefore particularly suitable for learning technical gestures or procedures [5].

Finally, many studies show that course sequences based on immersive technologies often improve course attractiveness and learner satisfaction. For instance, an immersive anatomy course by [6] did not make any difference to the traditional course regarding anatomy knowledge, but it was perceived as more captivating, enjoyable and motivating for students. In certain instances, enhancing course attractiveness is crucial for trainer satisfaction, student engagement, and institution reputation.

4 Pedagogical Potential of IDT

Over and above the concrete advantages mentioned in the previous section, IVEs generally have potential that could also be of added value for learning. Three-dimensional representations enable the visualization of invisible phenomena within realistic context: cross-sectional views of machinery in operation or representations of invisible physical phenomena like airflow and heat distribution. IVE offers the added benefit of presenting the visualization of phenomena from a first-person perspective and at a 1:1 scale, thereby facilitating intuitive interaction with the data [7].

IVEs can be populated by virtual agents, which can be connected to language models and act as assistants to the learners. Key attributes of effective pedagogical agents include utilizing a human-like voice instead of a synthetic one [8], exhibiting a range of facial expressions rather than maintaining a neutral expression [9], employing specific gestures [10]. Ideally, these agents have to be designed to be consistent with the learning content [11]. For example, Albert Einstein can give a mathematics lesson, or a historical figure can present his/her own story. They have the capacity to transmit knowledge interactively (by answering questions, for example), but they are also a way of generating social engagement [12].

5 Avenues for Future Research

The role of teachers in the use of IVE topic seems crucial but little studied. In most research on IVEs for learning, the authors do not mention teachers, so we do not know what they do. Do they stand by while learnings use the IVE? Do they give instructions? Is this activity part of a longer pedagogical sequence? There are several ways to teach in IVE (See Fig. 1). The artificial situations of experiments generally do not answer these questions. And yet, when it comes to deploying digital training systems, teachers are there, they exist and they cannot be ignored. Thus, it is essential to analyze what they can do and to dedicate specific interfaces to them, enabling them to monitor and possibly interact with learners in IVE.

Fig. 1. Illustrations of two possible classroom situations with an immersive digital twin and a group of student supervised by a teacher.

A second major topic is independent study that is an essential factor in the success of one's studies, but it is rarely studied. The positive effects of IVE on the pleasurable and motivating nature of the activity offer a potential that can be interesting in cases where learners have the freedom to do exercises for practice or not to do so. Having access to an attractive practice tool can make a difference to the amount of practice done.

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