Reflections on the Adoption of Virtual Adaptive Learning Tool for Industrial Training

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Abstract. Ensuring proper education for employees represents a key factor in most of the industrial sectors. Several researches have been conducted in order to test the efficiency of new educational methods for improving their flexibility and effectiveness. At the same time, the introduction of emergent technologies, such as Virtual Reality (VR), is offering new solutions for industries for both reducing cost of training programmes and for better tailoring those on the needs of the users. Based on a first cross-industry reflection, the paper analyses how the combination of adaptive learning methods with VR could bring substantial benefits to companies (railway and process industry) in replacing the actual training programmes based on traditional learning approaches. Firstly, the paper offers a short overview on the features of adaptive learning and VR. Secondly, a consideration on the main requirements on railway sector and process industry is conducted in order to link them with constrains appeared during the current training programmes. Finally, possible solutions based on the previous findings are highlighted in order to sketch a possible working framework for creating a Virtual Reality Adaptive Learning Tool. Our research, thereby, shows how long-term strategic educational policies can impact the performance of the industries.

Keywords: Adaptive learning · Virtual Reality · Railway · Process industry

1 Introduction

Several companies in railway and process sectors consider the training of their employees a flagship for their development and success. In particular, major risk installations, well-known as "Seveso plants" according to the European Directive 2012/18/EU, have a mandatory learning plan to be respected, that requires to deepen the knowledge of all the plant operators about the use of dangerous substance, both during normal operations and during emergency situations.

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Using real assets for training can be quite expensive and dangerous itself and it requires to have them out of service. Therefore, nowadays companies are trying to find more effective and cost-efficient solutions.

Moreover, apart from financial and logistic aspects of the training, companies also have concerns regarding the performance and effectivity of their training from a learning perspective. General feelings and feedback point out that employees lose their interest if every year they have perform the same tasks.

All in one, it seems that the actual training programmes are not realistic enough for all employees to become engaged, demotivating them in doing all tasks perfectly, or overestimating their capabilities in irregular situations.

2 Virtual Learning Environment Model

A possible approach to overcome the mentioned problems in the previous section, namely effectiveness of the training, engagement of the trainees and cost reduction is represented by virtual learning environment (VLE). VR is a well-consolidated technology adopted in several fields from design to education.

Nevertheless, technologies in themselves do not create learning, but they do afford tasks that can stimulate learning [1]. For this reason, it is helpful, not only looking at cost reduction, but also determining exactly how a VLE can influence a learning experience. What are features that create a positive influence on learning outcomes that could be considered for a given learning objective?

Dalgarno and Lee in 2010 [2] developed a model for achieving the intended learning outcomes in a VLE. They stress the importance of immersion, which they claim to be a feature created by two factors that are unique for VLE: representational fidelity (RF) and learner interaction (LI). RF is the degree to which the virtual world is realistic. It is mainly influenced by the display of the environment, by the smoothness of the object motion and by the consistency of object behavior. LI describes the richness of the interactions, such as embodied interactions and object manipulation in order to adapt the learning environment to difference situations.

Together, these two characteristics of VLE create a sense of presence, co-presence and the construction of identity in the participant. Consequently, the participant is able to acknowledge his/her own presence in the virtual world as well as create an identity in his/her actions. These three consequences of RF and LI support the psychological sense of being immersed in a virtual world and in the performance of tasks. However, Dalgarno and Lee argue that there may be an optimum to this, which if exceeded could result in compromised learning benefits and increased costs.

Also, this model portrays a very technology-oriented view of immersion to achieve learning outcomes. Fowler in 2015 [3] argued that this model is therefore incomplete and should be elaborated by also adding pedagogical requirements to ensure that the learning outcomes are achieved.

2.1 Elaborated VLE Model with Psychologically and Pedagogically Attributes

The learning model described by Dalgarno and Lee defines immersion purely as a consequence of technology. As said, immersion is a concept that can be described not only technologically, but also psychologically and pedagogically. Fowler [3] in particular uses the concept of immersion to bridge VR technology with pedagogy differentiating three types of pedagogical immersion corresponding with the three psychological stages of learning: conceptual, task, and social immersion. These three concepts will be explained briefly in the context of skill learning:

- Conceptual immersion: this is all about demonstrating what needs to be learned. Introducing a new concept, phenomenon or process for example.
- Task immersion: the concept needs to be translated to knowledge or skill of the participants. This can be done by exploring and practicing what they have learned.
- Social immersion: if a skill is learned, it should then be put in a social context. This way, participants test their understanding of the concept or skill and its consequences.

A second focus point of VLE should be knowledge construction instead of reproduction [1]. Knowledge construction should be done with focus on both content and context. This implies that specific knowledge needs to be constructed for solving a specific problem [4].

For participants to become pedagogically engaged with the tasks, they should also be authentic. Important to state here that it is not the same as realism: a task or environment can be authentic without too much realism, and a very realistic environment can be completely unauthentic. However, to create task immersion, a high degree of realism is certainly beneficial [3]. Using authentic tasks can help build contextual and content knowledge. To create authentic tasks, four aspects are of importance. It starts with purpose, i.e. the learning goals of a virtual environment. Then, the provided contents truth is of paramount importance. This can be seen as the message that the VLE should give to achieve the learning goal, or the relationship between the real world and its virtual replacement. Thirdly, accuracy, which comes down to achieving the exact level of detail to achieve the purpose. It also implies a comfortable and non-distracting experience. Lastly, continuity should be applied throughout the experience: the level of detail should remain constant, animations should not speed up without good reason and image qualities are not changed abruptly [4].

What above appears to be confirmed also by the results of the EU FP6 funded European programme VIRTHUALIS (2005–2010), that was aimed at the reduction of hazards in production plants and storage sites. During the project one of the main end-users' practical safety issues that have been addressed was the control room operators training, proper alarm systems designing and teams' coping with emergencies [5]. The objective was met through the development of an innovative methodology, which has merged HOFs-based knowledge and VR technologies. The experimentations conducted with plant operators highlighted, through the analysis of user experiences, exactly the points of attention described above and the need for an adaptation to users' needs.

2.2 An Adaptive Learning in the Described Context

Making use of virtual or digital learning environments as discussed in the previous paragraphs opens up doors towards a trend that could be very relevant for this research: adaptive learning, a way of personalised learning in the sense that tailors the learning content towards the needs of the user. It should be here emphasised that personalised and adaptive learning are not interchangeable terms: fully personalised learning experiences also focus on tailoring learning methods to user preferences and content towards user interests, variables that cannot be changed in this research, whereas adaptive learning focuses on tailoring the content to what students need to know.

New technologies, such as VR, have the potential to allow for many ways to improve an adaptive learning experience and to overcome some of the current challenges. Some relevant affordances include [6]:

- assisting in determining a student's strengths and weaknesses; adapting the amount of instruction to the proficiency of the student;
- creating multiple lessons to target student needs and interests;
- delivering media rich instructions;
- providing teachers or instructors with data based results and analytics about student performances.

In general, adaptive learning programmes try to keep learners inside the "flow channel" [7], defined as a perfect balance between anxiety and boredom in relations with skill and challenge. In this zone, the exercises are not too difficult as to make learners anxious, but not too simple that they become bored. A nice view on how to create flow in games is proposed by Chen [8], who states that three conditions need to be met: the system needs to be intrinsically motivating, to offer the right amount of challenge as mentioned earlier and to provide the player the sense of being in control. These three conditions should be ensured in the VR simulator programmes.

There are roughly four categories of adaptive learning environments [9]:

- content discovery: adaptive techniques are used to present individual learners with personalised content during a course, possibly from other sources;
- interaction level: learning content and the course are not adapted, but the user interface and the interaction with it are tailored towards user preferences;
- course delivery: the way the course is set up, is tailored towards user needs.
- adaptive collaboration: learning processes requiring communication or collaboration are supported.

From a preliminary survey conducted in railway and process industries appears that the adaptive course delivery is the most appropriate type. It can ensure that at the end of the training each participant has the same knowledge by tailoring the offered content towards the gaps of knowledge that need to be filled for each trainee.

3 Challenges to Face for Introducing an Adaptive VLE

Implementing VLE for educational purposes also comes with challenges, namely technological and pedagogical.

3.1 Technological Challenges

Probably the most important challenge in this case is to improve the VR environments in terms of setting the scene and the experience. On the one hand, this means that the accuracy and the reaction speeds of the VR applications should be improved, and the delay of the visuals should be reduced. Currently, this causes some users to become nauseous or feel dizzy, comparable to the effects of motion sickness. On the other hand, this also includes adding more types of feedback such as smell and haptic feedback.

The second relevant challenge is to shape the experience in such a way that it allows for natural and intuitive interactions with the VR environment. A very complicated aspect indeed, because every user is different.

3.2 Pedagogical Challenges

First, finding the correct teaching strategy and matching the content is always challenging. It is widely accepted that VR (but also Augmented Reality) can enhance learning experiences if implemented correctly but the manner in which it does is always case-dependent.

Another common issue occurs while using VR especially for the first time is that of cognitive overload. This phenomenon occurs when people receive too much information or choices interfering with their short-term memory, distracting them from their original thought process [10]. Especially in VR environments, where multisensory information is used to increase the sense of presence, this can affect learning outcomes if this information is repetitive or redundant.

Finally, closely related to the latter point, there is the challenge of reducing the difficulty of using the technology. This makes longer their learning curve for mastering their own process and emphasises the need for well-thought out content that can easily adopt for their own learning needs [11].

4 Conclusions

The opportunities and the challenges discussed in previous paragraphs, despite the different scales and/or level of detail entailed in the transport and process industry, appear to be common related to the adoption of VR for operator training and learning activities. The choice of the adaptive VLE appears to be the right solution, above all where operators with different levels of skills are involved in the training. The more experienced ones resulted to be more confident in their perceptions and knowledge than in the technological tools developed for training and re-training (that is also one of the recognised sources of occupational accidents and operational errors). On the other hand, the adoption of a collaborative environment will allow to take advantage of their experience to improve the simulations and enhance the learning experience of less skilled operators, thus overcoming in an effective way the so-called technological transfer between generations of workers.

Application of the principles here described are under development, both in the field of train maintenance (VRE for train doors maintenance) and for the process field (VRE for control room and field operators communications and interventions in case of emergency).

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References

1. Mikropoulos, T., Natsis, A.: Educational virtual environments: a ten-year review of empirical research (1999–2009). Comput. Educ. **56**, 769–780 (2011). https://doi.org/10.1016/j.compedu.2010.10.020
2. Dalgarno, B., Lee, M.J.W.: What are the learning affordances of 3-D virtual environments? Br. J. Educ. Technol. **41**, 10–32 (2010). https://doi.org/10.1111/j.1467-8535.2009.01038.x
3. Fowler, C.: Learning activities in 3-D virtual worlds. Br. J. Educ. Technol. **46**, 412–422 (2015). https://doi.org/10.1111/bjet.12135
4. Jacobson, J.: Authenticity in immersive design for education. In: Liu, D., Dede, C., Huang, R., Richards, J. (eds.) Virtual, Augmented, and Mixed Realities in Education. Smart Computing and Intelligence. Springer, Singapore (2017)
5. Monferini, A., Konstandinidou, M., Nivolianitou, Z., Weber, S., Kontogiannis, T., Kafka, P., Kay, A.M., Leva, M.C., Demichela, M.: A compound methodology to assess the impact of human and organizational factors impact on the risk level of hazardous industrial plants. Reliab. Eng. Syst. Saf. **119**, 280–289 (2013). https://doi.org/10.1016/j.ress.2013.04.012
6. Crosbie, J., Kelly, G.: Behav. Res. Methods Instrum. Comput. **25**, 366 (1993). https://doi.org/10.3758/BF03204527
7. Göbel, S., Wendel, V.: Personalization and adaptation. In: Dörner, R., Göbel, S., Effelsberg, W., Wiemeyer, J. (eds.) Serious Games. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-40612-1_7
8. Chen, K.C., Jang, S.J.: Motivation in online learning: testing a model of self-determination theory. Comput. Hum. Behav. **26**(4), 741–752 (2010). https://doi.org/10.1016/j.chb.2010.01.011
9. Paramythis, A., Loidl-Reisinger, S.: Adaptive learning environments and e-learning standards. Learning **2**, 181–194 (2003)
10. Bolisani, E., Scarso, E., Padova, A.: Cognitive overload in organizational knowledge management: case study research. Knowl. Process. Manag. **25**, 223–231 (2018). https://doi.org/10.1002/kpm.1579
11. Liu, D., Bhagat, K.K., Gao, Y., Chang, T.W., Huang, R.: The potentials and trends of virtual reality in education. In: Liu, D., Dede, C., Huang, R., Richards, J. (eds.) Virtual, Augmented, and Mixed Realities in Education. Smart Computing and Intelligence. Springer, Singapore (2017). https://doi.org/10.1007/978-981-10-5490-7_7