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Original Research

E-LEARNING, VR AND TECHNO-EDUCATIONAL STANDS AS A WAY FOR PRACTICAL OPTIMALISATION OF EDUCATION FOR THE AUTOMATION NEEDS

E-LEARNING, VR ORAZ STACJE TECHNO-DYDAKTYCZNE JAKO PRAKTYCZNA OPTYMALIZACJA EDUKACJI DLA POTRZEB AUTOMATYKI

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Abstract

The publication presents a hybrid learning approach for training in the field of automation, focused on Programmable Logic Controllers and teacher-trainer relation in the VR. In this case hybrid learning is a mix of such methods like: physical techno-educational stands (possible to be used also for distant learning), e-learning courses and Virtual Reality Learning Environment (VRLE). In this article we will present two such VRLE that can be used through web browsers 2D and/or fully immersive experience in VR. To some extent we will present here also results of our initial research on the use of VR in this context. This article gives an insight on the ways how to embed such interactive environment with traditional forms like work-based learning, simulations and e-learning courses. Such "blended" education helps to develop learning management system through the Protocol of Learning Technologies Integration (PLTI). This contribution presents results of studies conducted during hybrid workshops in Poland and Lithuania. Results show that blended learning approach can give greater motivation and satisfaction to a learner thanks to multi-modal learning environment (MMLE), moreover there are some indications that it could also enrich learning retency. This MMLE was developed in response to market demands (pilot), offered and implemented in research laboratories by the Ruhr University in Bochum (Germany) and Łukasiewicz Institute for Sustainable Technologies in Radom (Poland). Such actions are aligned with the newly adopted EU strategy to lead Web 4.0 and virtual worlds.

Keywords: Vocational Education and Training (VET), PLC, hybrid and blended learning, Virtual Reality, digital twins

Streszczenie

Publikacja przedstawia wyniki badań porównawczych prowadzonych nad zastosowaniem hybrydowych metod nauczania w obszarze automatyki z orientacją na programowanie sterowników PLC i szkolenie-trenerów w VR. W tym kontekście hybrydowe nauczanie stanowi zestaw metod takich, jak: fizyczne stanowiska techno-dydaktyczne (z możliwością prowadzenia nauki zdalnie), kursy e-learningowe i środowisko edukacyjne wirtualnej rzeczywistości (SEWR). W niniejszym artykule zaprezentowano dwa SEWR, gdzie dodatkowo autorzy rozwiązań przewidzieli możliwość nauczania w aplikacji desktopowej - poza VR. Publikacja prezentuje także wyniki pierwszych badań w zakresie używania gogli VR w kontekście edukacji zawodowej. Artykuł daje wgląd w metodykę nauczania z zastosowaniem zarówno nowoczesnych form interaktywnych, jak i bardziej tradycyjnych opartych na uczeniu się w miejscu pracy, symulacjach i e-learningu. Takie „mieszane" podejście do edukacji pozwala stworzyć system zarządzania procesami nauczania i dalszej optymalizacji, dzięki tzw. Protokołowi Integracji Technologii w Edukacji (PITE). Autorzy prezentują wyniki badań przeprowadzonych podczas warsztatów hybrydowych w Polsce i na Litwie. Wyniki badań pokazują, iż mieszane podejście może w większym stopniu przełożyć się motywację i satysfakcję dla uczestnika dzięki Multi-modalnemu Środowisku Edukacyjnemu (MMSE), co więcej pojawiły się wskazania świadczące, iż tak prowadzony proces może pozytywnie wpłynąć na poziom retencji uczenia się. To multi-modalne podejście powstało w oparciu o zapotrzebowanie rynku (pilotaż) i nawiązaną w ramach projektu

współpracę laboratoriów badawczych Uniwersytetu Zagłębia Ruhr z Bochum w Niemczech i Łukasiewicz-Instytut Technologii Eksploatacji w Radomiu. Badania weryfikacyjne prowadzono w Kolegium Koweńskim na Litwie, a w ich efekcie dopracowano założenia kursu e-learningowego i przygotowano założenia pod kolejny projekt dotyczący wirtualizacji stanowiska techno-dydaktycznego do nauki programowania robotów z przeznaczeniem do pracy w systemach inspekcji wizyjnej. Warto zwrócić uwagę, iż tego typu inicjatywy wpisują się w nowo przyjętą Strategię UE w zakresie Web 4.0 i wirtualnych światów.

Słowa kluczowe: kształcenie zawodowe, sterowniki PLC, hybrydowe i mieszane formy kształcenia, wirtualna rzeczywistość, cyfrowe bliźniaki

1. Introduction

On 11th July 2023 European Commission has adopted a new strategy on Web 4.0 and virtual worlds to steer the next technological transition. Four key strategy pillars of this strategy were indicated. Two of them are about empowering people, reinforcing skills and supporting an European Web 4.0 industrial ecosystem. Strategy states that specialists in virtual worlds are essential and stakeholders should cooperate to set up a talent pipeline and support further skills development. European citizen's panel has provided 23 recommendations including those on human-centricity, education, awareness-raising and skills on how to use Virtual Worlds. This is a strong signal that modern and comprehensive learning paths with combined methods and VR are needed, especially in the leading branches like automation and machinery, automotive, food processing, chemistry and energy where Programmable Logic Controllers (PLC) are widely used (IRA, 2021, pp.5). PLCs are mostly used in the automation and machinery sector (79%), so in above mentioned context, it is crucial to improve ways to prepare industry professionals for the challenges of digital transformation and Industry 4.0. This is even more important in RIS (Regional Innovation Scheme) countries like Poland, Lithuania or Slovakia.

That is why project PLC-Centered VR-training for Industry 4.0 was developed (VR-PLC). In that project existing training PLC techno-educational stand was augmented and virtualized as we have created a digital twin of technological transport stand. Together with German colleagues we have developed a virtual simulator of a physical simulator. Upskilling with the use of such digital twin in Virtual Learning Environment is supported by 2D version, hybrid workshops (to test tools) and e-learning course delivered by European Institute of Innovation and Technology (EIT Manufacturing) via Skillsmove.eu platform.

The aim of this project was to design attractive way of learning with the use of elements of gamification and microcredentials (digital badges) admitted by EIT-M. Thanks to use of gamification learners gain the feeling of control, feedback, sense of achieving goals and feeling of progress (Świtalski W., Łódź 2019).

Our institute was previously involved in the development of other VR Learning Environment (VLE) while leading Erasmus+ project called "Collaborative VR Platform for e-learning: Teaching Communication". Two VR rooms were created with adoption of some classrooms functionalities like: screen for presentation, whiteboard, sticky notes, etc. (Stępnikowski A.W., ed. 2023). Due to those experiences we had a chance to implement new EIT-M project in 2023 called PLC-centered VR-Training for Industry 4.0: Train the trainer enabling interaction mode between teacher/trainer and the trainee. In addition we have also put a virtualized visual inspection robot arm to the techno-educational stand. Such innovative, highly accessible VR-PLC platform can empower workers and reinforce skills enabling acquisition of vocational and digital skills.

The rationale for carrying out the project was the need for optimization of the up- and re-skilling of VET and higher education students (I phase) and professionals (II phase) and make easier access to education for adults. Another reason was to disseminate digitalization processes in companies (ia. in Poland only 11% of companies are highly digitalized compared to an average of 26% in the EU). Such solutions will be also delivered by Mazovia EDIH project consortium (Łukasiewicz-ITEE is a partner there).

The results of the project – after validation workshops in Kaunas College and AGH University of Kraków - met a positive feedback, especially with regard to motivation and insight into functionalities of PLC programming, some remarks were given also in the context of teaching and previous experiences with VR in the educational context.

a) b)

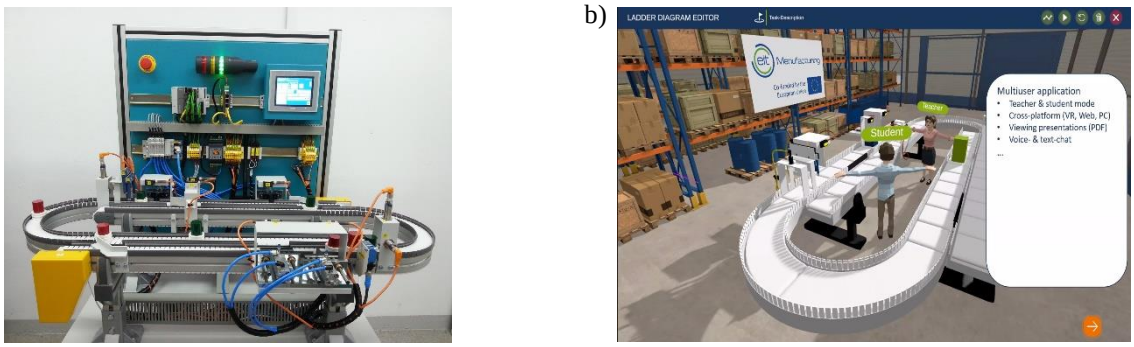

Fig. 1. Examples of VR-PLC functionalities: a) physical stand, b) digital twin in the VR Learning Environment

2. The concept of the blended learning with the use of VLE

The multilevel concept of the holistic remote training of PLC programming was founded already a few decades ago. Initially the main idea was to deliver a simulator (techno-education stand) to program the physical device in a chosen language and see how it reacts and moves in real-time. It was also about demonstration how relatively low costs of the training are and such stands were produced for VET and teaching centers. When the remote mode was enabled, it was possible to program the machine without actual presence of a trainee. That was also case at our Institute as we have developed few such stands for robotics and learning ladder diagram. After a few years it appeared that this concept can be further developed with other solutions like e-learning course (PLC languages, basic and advanced instructions, etc.) and VR technology (Fig. 2). In terms of functionality, such blended approach offers greater attractiveness and accessibility which contributes to a better learning retention level. This also allows to reduce travel time, cost and impact on the environment. In 2023 additional modules were developed in order to prepare VR-PLC trainers – both in Skillsmove.eu e-learning course (leadership, interculturality, teaching methods, etc.) and in VLE. Each module can be also certified in this learning platform after finishing a learning path (each one includes several learning nuggets). Such learning platform reflects a competence and could be understood as a microcredential and/or electronic badge.

Theoretical knowledge serves as an introduction and shows broader contexts. Skillsmove.eu platform also provides on-line tests for instant feedback on knowledge acquisition alternating with 3D experiences for practical use of gained knowledge. Learning paths and virtual training have passed the EIT-Manufacturing quality control process to ensure professional adequacy. The main VLE functionalities are:

- adequate virtualization of a physical stand,
- access to a simplified version to perform most basic tasks with a limited number of sensors and actuators,
- possibility to be used in the desktop version through a web browser – WebGL 2.0 standard (mouse and keyboard are used so no VR headset is needed). That gives possibility to be used by people with problems with VR motion sickness,
- learner's progress in particular levels of VLE is recorded and sent back to the supporting learning platform where it is marked as completed in the system,
- in 2023 an multi-axis robotic arm for visual inspection was added (to show some more functionalities),
- an avatar of a trainer also has appeared enabling more interactive and engaging way of learning.

There are several engaging elements of the VLE as learners can interact with the digital stand, view supporting texts and get familiar with actuators and sensors, ia. by blocking a light barrier with their hand. Set of those methods we call multi-modal learning environment (MMLE).

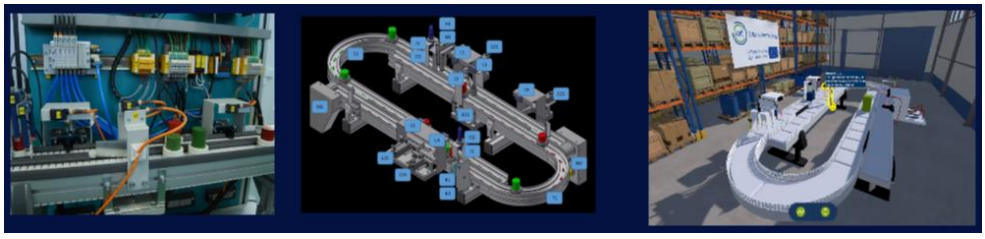

Fig. 2. Visualisation of blended learning approach (physical, HMI and VR)

3. Implementation and conducted research

In the beginning of 2022 Łukasiewicz-ITEE and LINPRA (Lithuanian Association of Industry Engineers) have conducted a survey for managers from metal-machinery and automotive industries with regard to training needs and methods (n=16). Only 16% of participants (namely from two companies) were experiencing training with the use of VR while 64% of asked medium- and high-level managers indicated that it would be an interesting offer. There were also some differences even between countries here as in Poland e-learning was mentioned as more used form that in the Lithuania (77% vs 58%). 1/3 of respondents stated that it takes too much effort to go to the training. Last but not least, the less desired educational form were long-lasting formal vocational upskilling conducted for over 1 year (Stępnikowski A.W. 2022).

Bearing that in mind, during two years of our projects 39 unique learning nuggets were developed in three languages: English, Polish and Lithuanian (resulting in 89 nuggets in total structured in 17 learning paths). Based on the assumptions of the previously tested program for physical stand in the e-learning platform we have added other elements such as: digital twins, PLC learning languages, basic and advanced instructions, function blocks and an introduction to robot programming. Additionally there are "educationnal" nuggets for trainers of trainers like: training methods and forms in VR, trainer personalities, training cycle, diversity and sustainability aspects. This context of sustainability for the use of VR and AR was elaborated i.a. based on the developments of research on the effectiveness of training on professional maintenance (X-Wei L., et all, 2022). The Learning Management System (LMS) Moodle was used while VR elements were planned for Oculus Quest 2 standalone. As it was mentioned few levels of practical tasks in the field of programming were also developed in the VLE (Fig. 3). Those theoretical and practical elements were developed and tested during physical workshops and training in Radom, Kaunas, Kielce, Lublin and Krakow (over 100 learners and about 30 teachers and VET trainers).

Fig. 3. Virtualization of the ladder diagram programming

Here are results of research conducted by us in Lithuania in 2022 and 2023. They were submitted to EIT-M as these effects were part of the final report. First pilot workshop took place on October 2022 in Kaunas Kolegija (Lithuania) with 40 participants (HE students from robotics and automation faculty and industry managers). A survey was conducted and in its results VLE was indicated as an easy tool to be used (55%) with intuitive user interface (60%) and VR experiences felt realistic (50%). For most of respondents (80%) it was easy to navigate in the environment. This workshop was successful thanks to showing different options of learning PLC programming. Those learners however – in general – as students did not feel prepared to work on real PLCs, which also might be a result of an (over)simplification of the VLE. The second Lithuanian workshop took place in 2023 and was dedicated to VET and higher education teachers and trainers/instructors. It was a verification of the methods of programming but also of train-the-trainer module. Research survey was conducted among participants (n=26). It appeared that most of them were satisfied with the content, interactions and outcomes of a workshop (75%), similar number of participants were assessing VR experiences positively (70%). Fewer positive opinions were given on e-learning content (60%) and that could be also due to the fact that nuggets in Lithuanian language were still in the revision phase. 60% of participants see a potential in the use of VR in VET training and it is worth to mention that only 25% of them had previous experiences with VR. It is interesting to compare respondents indications on the usability of VR in the VET training, namely:

- 65% indicates that they could be used for training on complex machines;
- 60% states that VR could be useful in the maintenance and repair simulations (training sessions for maintenance tasks);
- 60% indicates that it could be used widely for training of individuals geographically dispersed;
- 55% state that it could be used for simulation of high-risk scenarios;
- 45% indicates that VR could be used for virtual labs experiments (chemical or physical experiments in controlled VLE);
- 40% states that VR is a good tool for real-time feedback and assessment;
- 25% indicates that VR could be used for soft skills training (e.g. communication and leadership).

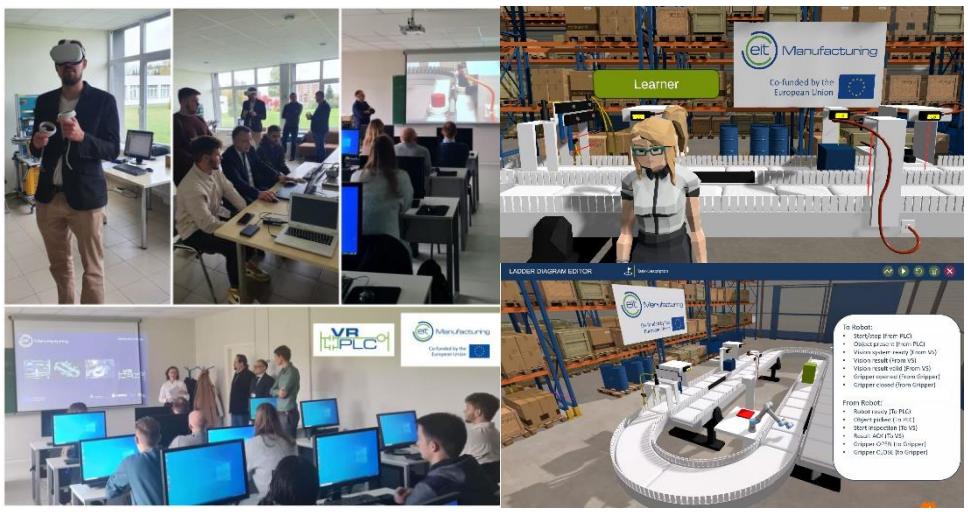

Fig. 4. Pictures from the Lithuanian workshop in 2022 and visualization of the VLE

4. Conclusions

In accordance with the new strategy on Web 4.0 and virtual worlds to steer the next technological transition, research organisations need to build support for skills development for virtual worlds at regional and national levels while EIT's role is to boost EU's virtual technological capacity. It is worth to remind that "re-skilling" is one of four main pillars of this strategy. VR-PLC project with its continuation (train-the-trainer) was contributing to this policy. The main goal of the concept was to virtualize existing techno-educational stand of a technological transport in order to foster skills acquisition on PLC programming by blending learning methods. Authors are presenting hybrid workshop with the use of VLE and Skillsmove.eu e-learning platform. Two validation workshops conducted in Lithuania by researchers from our institute and Ruhr University of Bochum have confirmed that mix of learning methods is the good way to support learning process (70% shared positive opinions). Each element (short lecture, physical stand, e-learning, VLE) has covered other PLC programming aspects. Emphasis was placed on different aspects of PLC and it have received positive feedback from the most of 66 participants (75%). This overall results were a function of quality of trainers work and program content with strong focus on the originality level and intensity of the transmission - including dynamics adapted to participants feelings and expectations (Stępnikowski A.W. ed., 2023, pp. 55). Trainers were innovative Meta VR Trainers (Sałata E., Bojanowicz S. eds. 2017). Participants were not so enthusiastic about e-learning course (54%) – due to translation problems and some lacking functionalities. Those issues were solved after pilot workshops.

During all of those events in Lithuania and Poland each time a few people felt dizzy due to the motion sickness in VR (ca. 5-10%). This problem is less experienced while sitting, yet longer periods of time (over 15-20 minutes) in VLE increases the likelihood of that risk. After 30 minutes learner should take a break. That is also an important obstacle in wider dissemination of VLEs as they should to be supported by other methods, preferably hybrid. New opportunities are rising - especially for maintenance training - with the use of AR.

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