

# VR-PLC as an answer to industry training needs in digital competences of programming logic controllers (PLC)

Rozwiązania VR-PLC jako odpowiedź na potrzeby szkoleniowe przemysłu w zakresie kompetencji cyfrowych programowalnych sterowników logicznych (PLC)

**Słowa kluczowe:** edukacja ustawiczna dorosłych, potrzeby szkoleniowe, rzeczywistość wirtualna (VR), kompetencje cyfrowe programowalnych sterowników logicznych (PLC).

**Streszczenie:** Z przeprowadzonej analizy wybranych źródeł przedmiotu badań wynika, że programowalne sterowniki logiczne (PLC) są istotną częścią niemal wszystkich operacji linii produkcyjnych w zakładach przemysłowych. Analiza treści literatury skłania do szerszego poszukiwania optymalnych metod kształcenia w obszarze nauki programowania sterowników PLC (także w związku z ich rosnącą popularnością). Celem artykułu jest weryfikacja hipotezy, iż konieczna jest zmiana modelu kształcenia kompetencji cyfrowych programowalnych sterowników logicznych (PLC) wynikająca z rozwoju technologicznego oraz nowych możliwości, jakie niesie za sobą wirtualna rzeczywistość (ang. *Virtual Reality* – VR) dla pracowników przemysłu metalowo-maszynowego (w dobie tzw. czwartej rewolucji przemysłowej). Niniejszy artykuł stanowi przyczynek do badań w tym obszarze, ukazując rezultaty sondażu diagnostycznego przeprowadzonego wśród przedstawicieli kadry zarządzającej przedsiębiorstw sektorów metalowo-maszynowego, motoryzacyjnego i elektronicznego, gdzie wymagane jest programowanie sterowników PLC. Badanie zostało przeprowadzone w ramach projektu pn. *Szkolenia VR zorientowane na programowanie PLC dla Przemysłu 4.0 (VR-PLC)* realizowanego przez konsorcjum złożone z następujących członków EIT-Manufacturing: Sieć Badawcza Łukasiewicz – Instytut Technologii Eksploatacji w Radomiu (Ł-ITEE) w partnerstwie z Uniwersytetem Zagłębia Ruhry w Bochum (lider) oraz Litewskie Stowarzyszenie Przemysłu Maszynowego (LINPRA).

W artykule ukazano rezultaty ankiety przeprowadzonej w lutym 2022 na celowo dobranej grupie respondentów wśród przedstawicieli kadry zarządzającej czternastu przedsiębiorstw (będących członkami Radomskiego Klastra Metalowego (RKM) oraz Litewskiego Stowarzyszenia Przemysłu Inżynierskiego (LINPRA)). Zebrane odpowiedzi dają wgląd w nastawienie osób zarządzających przedsiębiorstwami do kształcenia z wykorzystaniem technologii wirtualnej rzeczywistości. Istotną była koncentracja na gotowości i oczekiwaniach związanych z zastosowaniem rozwiązań VR w doskonaleniu zawodowym pracowników w kontekście kompetencji cyfrowych dotyczących programowania sterowników PLC. Autor artykułu jest koordynatorem zespołu projektowego Ł-ITEE, a uzyskane wyniki badań posłużą praktycznie przy planowaniu efektów uczenia się w ramach warsztatów i programie szkoleniowym z zastosowaniem VR.

**Key words:** continuous education of adults, training needs, virtual reality (VR), digital competence of programming logic controllers (PLC).

**Abstract:** Analysis of selected sources of the subject of research on PLCs show that they are an important part of any automated shop floor operations across all manufacturing industries. To better prepare industrial professionals for the challenges of the digital transformation up- and reskilling of their existing workforce is essential. Literature analysis show that there is a need for broader searching of optimal educational methods in the area of digital competencies of programming logic controllers (PLC), also in the aspect of their growing popularity. The aim of this article is to verify hypothesis that there is a need to change the model of shaping digital competencies of PLC programming occurring due to technological development and new possibilities that Virtual Reality bring for metal-machinery industry workers (in the context of Industry 4.0). For that this article aims to be initial contribution to research in that field showing results of diagnostic survey conducted among managers of companies from branches of metal-machinery, automotive and electronics where is a need of PLC programming. This research was undertaken within the project *PLC-Centered VR-Training for Industry 4.0 (VR-PLC)*<sup>1</sup> realised by consortium consisted of following EIT-Manufacturing<sup>2</sup> members: University of Ruhr-Bochum (leader) and Lithuanian Engineering Industry Association (LINPRA) and Łukasiewicz Research Network – Institute for Sustainable Technologies (Ł-ITEE)<sup>3</sup>. This article shows results of a survey conducted on group of respondents (Łobocki 2011, pp. 175) in February 2022 among fourteen managers of industry companies from Poland and Lithuania. Answers collected from enterprises associated within Radom Metal Cluster (RKM) and Lithuanian Engineering Industry Association (LINPRA) gave us an insight to companies readiness and expectations connected with the use of VR in employees vocational upskilling. What mattered was the focus on readiness and expectations connected with the use of VR solutions in workers professional upskilling in the context of digital competencies of programming logical controllers PLC. Author of this article coordinates Ł-ITEE team in VR-PLC project and gained results of research will be applied practically while planning learning outcomes designed for workshops to be conducted for industry workers in Poland and Lithuania with the use of VR headsets.

## Introduction

PLCs are an important part of any automated shop floor operations across all manufacturing industries. They are frequently used not only in industry automation and OEM machinery sector (79%) but also in food industry (70%), automotive (69%), chemistry (53%), energy (48%) and building automaton (41%) or transport (31%) [IRA 2021, pp. 15]. For better preparation industrial professionals for the challenges of the digital transformation up- and reskilling of their existing workforce is essential. For that VR-PLC project aims at creation of comprehensive workshops on the role of PLCs and industrial automation with regards to Industry 4.0 and bringing initial knowledge and skills in that field. For that, existing training PLC standards will be augmented with virtual representation (so called digital twins), enabling remote and simulated workshops. Through a train-the-trainers approach professionals develop the skills necessary to drive innovation in their companies.

<sup>1</sup> Source: <https://www.ide.ruhr-uni-bochum.de/vrplc/> [access: 11.03.2022]

<sup>2</sup> European Institute for Innovation and Technology (EIT) – Manufacturing, source: <https://eitmanufacturing.eu>.

<sup>3</sup> Source: [https://plaza.eitmanufacturing.eu/PROMISE/PRIVATE/PLAZA/my\\_plaza.aspx](https://plaza.eitmanufacturing.eu/PROMISE/PRIVATE/PLAZA/my_plaza.aspx) [access: 18.03.2022]

Teaching communication and soft skills in the VR environment is a purpose of Ł-ITEE next EU project called (in short) COViR, financed from Erasmus+ programme<sup>4</sup>.

We can also observe that there is higher demand for PLC/PAC with distant access through PLC to all devices in machine (IRA 2022, pp. 14). VR/AR solutions will be popularised in industry (...) enabling conduction of comfortable trainings. VR training market in Poland is however only in the early phase of growth. There are only singular companies delivering such VR solutions (IRA 2022, pp. 21). In the VR-PLC and its continuation (VR-PLC Trainers) we want to explore possibilities of PLC programming education with the use of Virtual and Augmented Reality.

Through a train-the-trainers (TtT) approach professionals develop the skills necessary to drive innovation in their companies. TtT has great learning retention estimated for about 80–90% relatively high are also assessed VR solutions – at the level of 75% (Stępnikowski A. 2022). Mixing those methods can lead us to great educational results. That is why our institute together with partners from Germany and Lithuania have undertaken project funded from European Institute for Innovation and Technology (EIT-Manufacturing) called PLC-Centered VR-Training for Industry 4.0 (VR-PLC) and is planning to submit continuation for VR-PLC trainers.

Working with PLCs is becoming an even more important skill for shop-floor workers in the context of digitalization and Industry 4.0. In this projected an international consortium consisting of Ruhr-University Bochum, Łukasiewicz Institute for Sustainable Technologies (Ł-ITEE), and LINPRA, the engineering and technology industries association of Lithuania, builds a workshop format for up-skilling of these workers on virtual PLC techno-educational stands to make them and their companies ready for the digital transformation.

Important elements of that VR-PLC project are about attractive way of learning such as use of gamification and open badges given by the consortium and EIT-Manufacturing. Gamification gives to learners (feeling of) control, feedback, sense of achieving goals (progress) and collecting badges.

### **Assumptions for the research on the learning PLC programming**

Even before the corona period, companies had strong incentives to invest in automation to remain competitive in a changing world of work, most of which led to the vanishing of middle-skill occupations. In the post-corona period, such motives will be stronger, as businesses will aim to gain a competitive Edge through offering pandemic-proof work environments, services and products. Up- and reskilling of workers is essential both for the individuals and their companies to continue innovation and tackle the digital transformation. VR-PLC education has the potential to break down the huge barriers that traditional learning has always

<sup>4</sup> Source: <https://covir.eu> [access: 28.02.2022]

struggled with which is even increased by the pandemic), through experiential learning. LITEE has developed PLC stands for upskilling of industrial professionals in six variants. Together with a teaching methodology and learning content these stands teach Polish professionals on PLC programming on different use-cases like liquid level and pressure control. This project will expand the available research content to cover topics necessary for Industry 4.0, like the OPC-UA communication standard and connecting PLCs to the Internet of Things. To broaden the impact and remove the necessity to have physical access to the PLC stands this project builds a digital twin of the stands that can be viewed and interacted with in the Virtual Reality. All learning content and access to the virtual test stands will be made available to the EITM GLP. To streamline the process for further VR workshops in EITM workshops the implementation will be kept highly modular. Future projects can then build upon and extend these building blocks to ensure a consistent, high-quality experience. The innovative, highly accessible VRPLC platform will create a new market for interactive vocational and continuing education enabling acquiring vocational and digital competences.

Arguments for the research on the learning PLC programming are expressed by branch experts *ia. in Automation Market Informant (IRA)* being a special attachment to "Automation, parts and applications" (APA), they include:

- 1) **Growing PLC popularity** even in the age of COVID-19 pandemia, where we can still witness constant development and increase of needs for PLCs. COVID has fostered automation of production processes and it is observed with declared greater financment for automation plans and increase of interests in automation and robotics (IRA 2022, pp. 12);
- 2) there is **higher demand for PLC/PAC with distant access** through PLC to all devices in machine (IRA 2022, pp. 14);
- 3) **VR/AR solutions will be popularised in industry** (...) enabling conduction of comfortable trainings. VR training market in Poland is however only in the early phase of growth. There are only singular companies delivering such VR solutions
- 4) **global sales of VR/AR devices will increase volume** in the next years above the level of 25 mln pieces annually (IRA 2022, pp. 21–22).

## Results of the survey

According to newest survey for managers from industry conducted within the EIT-M project „VR-PLC” in February 2022 in Radom (Poland) we can define some shortages and needs from the metal-machinery sector, mainly SMEs. South part of Mazovia region is a traditional cradle of that branch and here, in the city Radom and around it Radom Metal Cluster (RKM) is functioning with 32 members and partners. Representatives from medium and high level managers of eight RKM companies (25% of members) have filled up this survey on the PLC trainings. According to that survey results (Metal Cluster Survey – MCS 2022) we can say that:

- 1) companies mainly think about workers future skills mainly when it goes to technological development, increase of quality demand and of competition (93%

- each). Other factors contributing to that are: changed customers demand and increasing product complexity (both 86%). Among 7 factors the less indicated one was company growth (42%) and applying legal norms and standards.
- 2) Key sources of information about employees training needs are taken from: individual/personal contacts (86%, in Poland 94%), suppliers trainings/information (78%, in Poland 88%) and trade fairs (78%). Among 9 information sources the less indicated ones were: other employees (64% in general, while in Poland 86%), Internet (57%), social media (28%) and abroad visits (36%, while in Poland 63%).
  - 3) There some **employees already engaged** in informal on the job trainings (86%) and sector-specific trainings – often offered by producers (78%) and e-learning (58%, in Poland 77%). Among 8 forms of employee engagement in trainings **the less indicated one was trainings with the use of VR (used only by 16%, namely by two companies). That is to be connected with answers for another question regarding problems with training offers** where we can see that in most cases trainers are theorists (71%), subject of trainings is not adequate to the needs (71%) and training costs are too high (64%). Following that managers indicate that there are no proper training possibilities (63%), too much technological requirements (43%) and it takes too much effort to go to the training (28%).
  - 4) Managers from industry indicate that in the future, in the context of workers trainings they would desire following forms of training and upskilling: sector specific courses, including those offered by producers (86%) and informal trainings on the job (86%), than there is e-learning (78%, in Poland 86%), personal – soft skills (71%) and language courses (both 71%). For employees it would be also interesting to participate in the **trainings with the use of VR (64%) and initial vocational trainings**. In the case of VR-PLC TRAINERS we will try to cover those most important areas like essence from producers trainings in form of advanced PLC programming nuggets together with soft-skills and VR issues that will be integrated into Training of VR-PLC Trainers programme.
  - 5) **The less desired training/educational forms** were long-lasting formal vocational upskilling (over 1 year courses in schools) mentioned by 50% and lectures with only 21%.
  - 6) Regarding the **specific training needs and knowledge required for programming PLCs and Industry 4.0** managers indicated that the most desired ones are: assessment of the technical efficacy of mechatronic systems and devices (78%), using service manuals and documentation (71%) and interpreting of PLC instructions – so called „basic instructions“ (64%). Next topics were indicated by 57% managers regarding the way of locating damages in mechatronic systems, connecting existing mechatronic systems with the Internet of Things. Half of managers pointed out necessity of trainings in the field of using software for programming mechatronic devices.
  - 7) In the potential situation of flexible access to free of charge PLC trainings managers would be eager to send most employees (around 10) for trainings

regarding the functioning and use of basic instructions (71%) and on the topic of verification of the correctness of functioning of programmes for mechatronical devices (66%). On the 3rd place they've pointed out equal willingness (63%) to send workers for trainings on:

- a) software use in programming,
- b) modification of programmes for controlling mechatronical devices based on „assumption graph” of desired processes and
- c) localisation of damages in mechatronical devices and systems
- d) connecting existing mechatronic systems to the IoT.

The importance of trainings/upskilling of workers in the field of PLC programming industry managers have indicated mostly employees aged between **25–45 years old (78%) and 19–24 years old with 71%** on average but surprisingly 78% indications were made alone in Polish companies. Polish specificity was also visible with regard to apprentices aged 15–18 years old indicated by 55% managers in Poland but in the same time characterised with very low (lack of) interest in Lithuanian companies, probably due to weaker traditions of employing juvenile workers (apprentices within so called dual system). Significantly smaller indications were pointed for employees aged **46–60 years old with 42%**. Only one company (7%) have indicated that is willing to upskill workers aged 60+ (precisely in the scope of 60–65 years old).

Few managers gave also additional comments mentioning that: „such VR PLC trainings” (..) „*can be useful for workers*” and that „*VR solutions in the process of learning the programming or even testing software for developing real machines are very desired technology*”.

### Summary and main discoveries of the MCS survey

Conducted survey is the pioneering venture in scale of East European countries but it is expected that many others will follow as it is foreseen that in the next years global sales of VR/AR devices will increase volume above the level of 25 mln pieces annually while VR trainings markets are only at the early phase of growth with only singular companies delivering such virtual/augmented reality solutions. All that tendencies show that VR/AR trainings should be explored in a broader range and that explains the need for in-depth researches in that area.

Managers from industry companies of metal-machinery, automotive and electronical branches from two countries (7 companies each) have confirmed that:

- There is no interest for long-lasting formal-school based courses;
- Employers look for cheap and flexible trainings that are not overloaded with theory;
- There is a gap in the field of VR trainings (they are not in the offer and are not recognized yet by employess);

- VR trainings are desired together with e-learning courses and soft skills development (it seems that our project can cover that areas).

There are some small differences with regard to substantive and practical areas of PLC trainings that managers find useful in Poland and Lithuania but they are not crucial. Some aspects like localisation of damages in mechatronic systems are more desired in Poland (68,5%) than in Lithuania (57%), while the assessment of the technical efficacy of mechatronic systems and devices (65%) is more important in Lithuania (87%) than in our country (71%), but generally those differences can be connected with particular companies specificity. It seems that in Poland individual contacts are more important as a transmission belt for spreading the news on training offers and possibilities (94% in Poland vs 71% in Lithuania) but due to small sample of chosen companies it can't be seen as meaningful. It is worth mentioning that in the creation of the course program, the approach of MES – Modules of Employable Skills is used (Symela, 1999). That is due to the fact that learning path consist of competences (confirmed with micro-credentials and namely badges) and they consist of minimum three or four learning nuggets. In that way, easily such learning of competencies can be turned into modules.

VR-PLC project is funded by EIT Manufacturing. EIT Manufacturing is an Innovation Community within the European Institute of Innovation & Technology (EIT) – that connects the leading manufacturing actors in Europe. Fueled by a strong interdisciplinary and trusted community, EIT-M will add unique value to European products, processes, services – and inspire the creation of globally competitive and sustainable manufacturing. Results of all EIT-M projects (learning nuggets and learning paths) are going to be placed in special learning platform [www.skillsmove.eu](http://www.skillsmove.eu). It is worth to mention that for all developed learning nuggets (short „portions” of knowledge or skills) there is a also designed learning path as sets of minimum three learning nuggets can be combined into one competence – even if they were developed within different projects. That is a new approach that can be associated with *Council Recommendation on a European approach to micro-credentials for lifelong learning and employability* that is planned to be introduced soon by European Commission.

## References

1. Łobocki M. (2011), *Metody i techniki badań pedagogicznych*, Wydawnictwo Oficyna Wydawnicza Impuls, Kraków.
2. Maddox T. (2017), *The science of VR/AR/MR „Training for retention”: Training is only half of the story...and not even the most important half*, LinkedIn .
3. Stępnikowski A. (2022), *Guidebook for Training of SDG Trainers*, OECD, Warsaw-Paris, (in the process of being published).
4. Symela K. (1999), *The principles of implementation and evaluation of modular programmes in training of adults*. MoLSP, ILO, ITeE, Warsaw-Geneva-Radom.

5. *Informator Rynkowy Automatyki edycja 2021*, „Automatyka, podzespoły, aplikacje”, Warszawa 2021.
6. *Informator Rynkowy Automatyki edycja 2022*, „Automatyka, podzespoły, aplikacje”, Warszawa 2022.

### Internet sources

7. <https://www.lde.ruhr-uni-bochum.de/vrplc/> (access: 28.02.2022).
8. <https://www.skillsmove.eu> (access: 27.02.2022).
9. <https://eitmanufacturing.eu> (access: 18.03.2022).
10. <https://covir.eu> (access: 28.02.2022).

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