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Implementation of the Modern Immersive Learning Model CPLM †

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Abstract: The digitalization of industrial processes is being driven forward worldwide. In parallel, the education system must also be transformed. Currently, education does not follow the opportunities and development of technologies. We can ask ourselves how we can integrate technologies into a traditional learning process or how we can adapt the learning process to these technologies. We focused on robotics education in secondary vocational education. The paper contains research results from a modern learning model that addresses student problem-solving using cyber–physical systems. We proposed a reference model for industrial robotics education in the 21st century based on an innovative cyber-physical didactic model (CPLM). We conducted procedure time measurements, questionnaire evaluations, and EEG evaluations. We could use VR to influence the improvement of spatial and visual memory. The more intense representation of the given information influences multiple centers in the brain and, thus, the formation of multiple neural connections. We can influence knowledge, learning more effectively with short-term training in the virtual world than with classical learning methods. From the studied resources, we can conclude that the newer approach to teaching robotics is not yet available in this form. The emerging modern technologies and the possibility of developing training in this area should be investigated further.

Keywords: VR technologies; educational robotics; education; innovative learning method development; evaluation

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1. Introduction

Consultation on the organization of the Vocational Education Center (CPI) Slovenia, Chambers of Commerce of Slovenia (CCS) and secondary schools, held in November 2018, at the National Council of the Republic of Slovenia under the theme of "The future of vocational education—participation of school, local environment and employers in Industry 4.0" was highlighted, in particular, by the use of education against serious challenges in the field of education of Industry 4.0 in the field of secondary vocational education.

The field of science and technology is highly interdisciplinary and the boundaries between individual skills and technologies are fluid, but, at the same time, they are intensively interconnected. Education does not currently follow the opportunities and development of technologies [1]. In practice, there is a large gap between traditional education and modern technologies. It is a constant challenge of how we can integrate emerging technologies into a traditional learning process, or how we can adapt the learning process to these technologies. The role of science education is, not only to develop citizens as individuals, such as through the promotion of vocational education training (VET), but also to develop an active, informed citizenry and to thus promote society's willingness to engage in sustainable development [2]. This area poses a great challenge to teachers in the interdisciplinary educational field of teaching robotics skills. The great diversity, rapid development, and need to constantly acquire new skills and competencies require a teacher who is interdisciplinary, responsive, a lifelong learner, and constantly adapting. We can ask ourselves how to increase interest in innovative ways to support and engage students in science and technology [3]. Co-designing with technology enables the learning of the engineering design process, and potentially enhances science learning by promoting knowledge integration [4].

Modern manufacturing companies invest in flexible manufacturing processes, the essential units of which are intelligent machining centers, manipulators, and industrial robots. Robots usually replace workers in areas where there are heavy loads, gasses, heat, or other harmful conditions. The factors of productivity, repeatability, quality, and global competitiveness in the market cannot be ignored. In recent decades, robotics has been integrated into many industrial processes as an indispensable part of modern, economic, and human technologies. At the same time, technology is becoming more and more integrated into daily life. Robotics is, and will be, a very important part of Industry 4.0. This consists of cyber–physical systems, robots, the Internet of Things, mass data, artificial intelligence, and other technologies [5].

An industrial robot in an automated system enables serial execution of a programmed welding process. Pedagogical robotics in secondary vocational education in Slovenia can be divided into two pedagogical types. The first type is a PBL-oriented, collaborative, discovery, competitive, and team-based learning, in which students develop mobile rescue robots for the RoboCup Rescue RMRC, a global robotics competition. Through collaborative teamwork, students learn about ideation, design, 3D modeling, electronic component development, sensor systems, and microcomputer programming. The end result is a mobile rescue robot that is unique and varies according to the requirements of the competition. The second part of educational robotics is industrial robotics. This includes frontal teaching, discussions, exercises, short training sessions, and problem-solving tasks. Later, we expand this to include project teamwork and hands-on industrial problem-solving tasks. Current trends indicate that humans and robots will work together in the production process. As we know, there are limits to what robots and humans can do. Collaboration between humans and robots will improve productivity and product quality, and ultimately lead to lower product costs [6].

There are a variety of platform approaches for using robots in education that are still based on decades-old ideas. Problem-based, constructivist, and competitive learning are cited as the most commonly observed uses of robots in education [7]. Educational robotics is often presented as a platform to achieve the following three main goals ([7,8]):

- To teach STEAM
- To develop learning skills such as scientific inquiry, engineering design, problem solving, creative thinking, and teamwork;
- To motivate students for science and engineering [9].

If we look at existing articles, we see many existing methods of modern teaching. The P3 approach (practice, problem solving, and project) [10] is very interesting, which is also used by educational robotics. We can see that VR may be implemented in many cases of educational robotics ([10–15]).

Research shows that we can use modern VR technologies to influence the improvement of spatial and visual memory [16]. As the presented information is presented more intensely, it affects multiple centers in the brain and thus leads to the formation of multiple neural connections [17].

VR is defined as a computer-generated simulation that is three-dimensional (3D), multisensory, and interactive, allowing users to explore or immerse themselves in an environment. Generally, VR is classified as high or low immersion, and depends on how much the user perceives the real world during the VR simulation ([18,19]). In low immersion VR, 3D images are displayed on a desktop screen, and the user can interact with objects in the simulation using the mouse and keyboard. While interacting with the desktop VR, you can still perceive the real world vividly. High-immersion VR, on the other hand, refers to a full-immersion simulation where users wear an HMD and interact with the virtual world through consoles. This type of simulation isolates users from the real world and enhances the sense of presence. Users feel like they are acting in the real world because the 3D images of the HMD are very realistic [20]. The area in which virtual reality (VR) technology can be used effectively is, among others, the area of education and in the development of memory. VR technology has a very important impact on spatial and visual memory [17], and, at the same time, it is a relatively affordable technology where we do not need physical equipment in certain cases, but can limit ourselves to virtual education [10]. Several studies have shown that virtual labs improve science learning in terms of conceptual knowledge, procedural knowledge, practical skills, self-efficacy, and perceptions of science ([21,22]).

In science education, researchers have used VR labs to improve understanding of science concepts and develop scientific implications [23]. Several studies have found that the desktop VR improves students' knowledge gain and retention ([24,25]). Researchers suggest that the immersive environments of VR promote a generative process by providing a realistic experience that leads to an enhanced sense of presence [20]. This, in turn, leads to high levels of engagement, motivation, and deep cognitive processes [26]. Although the technology of VR holds promise for learning and education, the question of how teachers incorporate an immersive VR science lab into traditional classrooms and how students learn in this context remains unanswered [27]. In the last decade, immersive technologies have become much more affordable and viable for educational applications [28].

Cyber–physical systems (CPS) are the core concept of Industry 4.0 for building smart factories [29]. CPS are highly interconnected and integrated intelligent systems that consist of technically interacting networks of physical and computer-based components [30]. As an important part of Industry 4.0, it encompasses the applications of many innovative technologies such as prefabrication, automation, 3D printing, virtual reality, augmented reality, unmanned aerial vehicles (UAV), sensor networks, and robotics for repetitive or uncertain operations [31].

The goals of Industry 4.0 were outlined in Action Plan High-Tech Strategy 2020 for Germany [32], the German equivalent of Japan's Science and Technology Basic Plan [33]. Both involve a top–down, government-led approach and collaboration between industry, academia, and the government sector. Industry 4.0 advocates for smart factories, while Society 5.0 aims for a super intelligent society. Although both visions advocate the use of CPS, the scope of its use differs. In Industry 4.0, CPS is to be used in the manufacturing environment, while in Society 5.0 it is to be used throughout society [34]. The development trend is toward Society 5.0, where both Industry 4.0 and Society 5.0 are based on the creation of increasingly sophisticated "cyber-physical systems" characterized by their reliance on embedded, decentralized, real-time computation in a network of heterogeneous physical objects [35]. The Japanese government, through its "Society 5.0" initiative, is attempting to use new technologies to create a "super intelligent" cyber–physical society that is more human-centric than our current information society [36]. In our case, we will focus on the didactic model.

Cyber training means training in VR space, and physical space means learning skills on the physical objects of training. How to achieve better learning goals using cyber training, what kind of learning environment is suitable and what teaching approaches should be used by the teacher to motivate young people towards engineering and technology has been a fundamental research question. We conducted questionnaire evaluations, procedural duration measurements, and EEG evaluations of the proposed modern learning model. In this way, we compared the current way of education, developed a relevant learning model and introduced innovative learning strategies and systematically evaluated and all proposed scientifically. Our main hypothesis was that cyber–physical training will be effective in improving procedural time in robotics training.

The highlighted points are crucial for the progress of the society as a whole. We have studied how modern pedagogical and didactic methods in the educational process affect students, their inner productive motivation, procedural skills, and other skills of modern society, as well as the skills that young people need in the 21st century. The great diversity, rapid development and need to constantly acquire new skills and competencies require teachers to be interdisciplinary, responsive, lifelong learners, and constantly adaptable, especially in the areas of training in industrial robotics, mobile robotics, and automated systems. The rapid development of technologies opens up new opportunities in education. Therefore, we must incorporate them into the educational process to educate young people to become responsible individuals with personal and professional values for a common prosperous future.

2. Materials and Methods

2.1. Cyber–Physical Learning Model

The cyber–physical learning model (CPLM) is derived from the standard educational model, that follows classical educational paradigm and is dominantly used in VET schools to teach STEM subjects. The standard model consists of a lecture where theory is presented and then the problem is simulated by the teacher. Students then receive a task, which they have to solve using a computer simulation. The teacher then evaluates the task solution for each student and gives feedback. Only then are students given a physical task that they must solve using the given tool.

The cyber–physical learning model extends this classical approach using VR technology with motivational VR movies about the topic to get students motivated and interested. We again used VR technology before the physical task to further deepen the understanding of the presented task. In this step we do not just show a movie, but provide hands-on VR experience for the tools and task and give the students the opportunity to try and solve the task. Such a VR experience helps students to understand underlying concepts, and it has already been shown by research to be effective [10,17,20].

For the implementation of the proposed CPLM, we selected a robotics class from a VET school. In this class, students learn about industrial robots, which enables the serial execution of a programmed welding process. In our case study, the student must program the industrial robot for the purpose of basic linear welding, where the student does not set any welding parameters, but sets and programs the robot's welding procedures. Figure 1 presents the proposed learning model with the procedure's steps.

In step 1, students were presented with a motivational 360 VR video (Figure 2). The video was shot with an Insta 360 VR camera and shows the learning space with a MIG/MAG welding robot and the use of robotic welding in 360 VR technology. The VR motivational film can be viewed by students using a smartphone headset or VR glasses. An example can be seen in Figure 2, which shows the learning robot cell for training MIG/MAG robot welding. The cell contains the industrial robot, Kuka KR 5 ARC HW, a welding source with associated equipment, and a two-axis welding table that allows the manipulation of welders.

In step 2, we conducted a pre-test with a questionnaire and a lecture. This was followed by step 3, in which we showed and simulated a problem on the projection screen in front of a whole student learning group. The robot applications can be simulated with the simulation software Kuka Sim Pro and programmed directly with the offline programming software Kuka Office Lite. Successfully performed exercises in a simulation environment are a prerequisite for performing exercises on an industrial robot. In step 4, students have to perform and solve their own simulated practice problems. At that point, we used an EEG device to measure the maximum attention level of a single student (CG and EG), as shown in Figure 3.

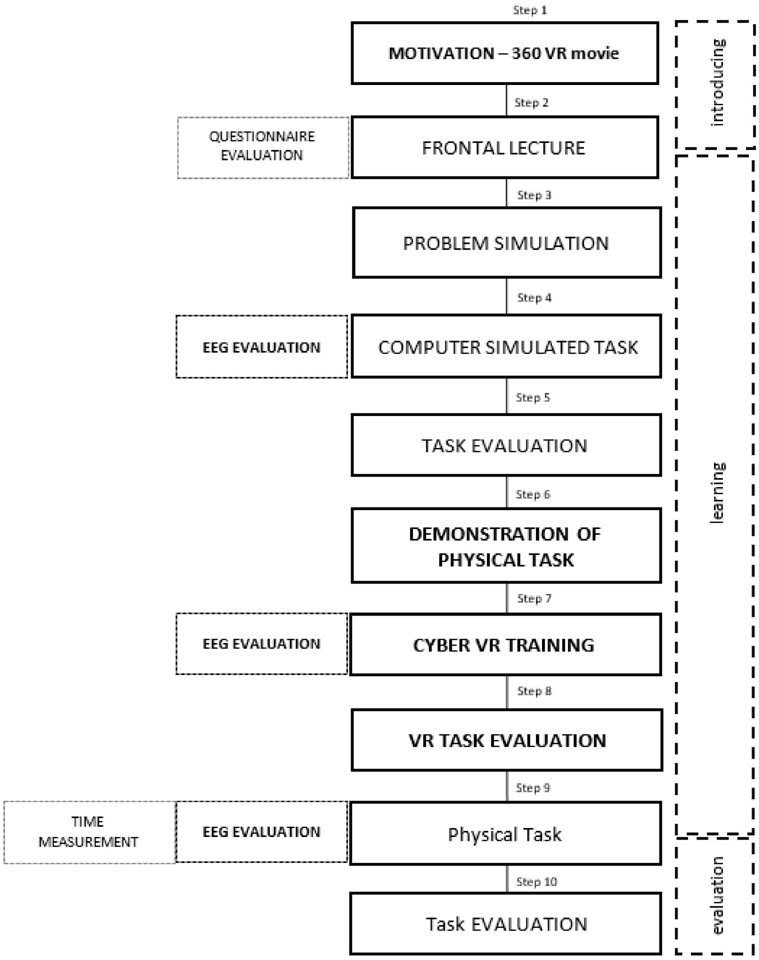

Figure 1. Cyber–physical learning model—concept of modern teaching model.

Figure 2. Motivational 360 VR movie example.

Figure 3. Lab PC problem solving simulation.

This was followed by a task evaluation, in which we assessed students' procedural knowledge in a simulation environment. In step 6, we demonstrate the learning process in a physical learning environment with the goal to students visualize the concept. This was followed by step 7, in which the cyber training VR was conducted using Oculus Rift VR goggles to achieve optimal learning outcomes, as shown in Figure 4.

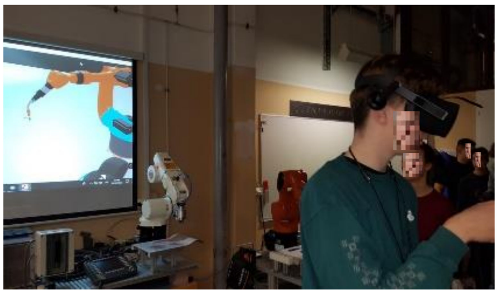

Figure 4. Cyber VR training.

Step 8 is devoted to assessing students' procedural knowledge in VR. This was followed by step 9 where students complete a physics task. This step also includes EEG evaluation of attention and timing measures of the procedural tasks. We concluded with step 10, in which we assessed each student's procedural knowledge with a post-test questionnaire.

Figure 5 shows the learning robot cell for training MIG/MAG robot welding. The cell contains the industrial robot Kuka KR 5 ARC HW, a welding source with associated equipment, and a two-axis welding table that allows the manipulation of welders.

Figure 5. Lab learning robot welding cell.

2.2. Methods

Our research focused on the teaching of educational robotics in vocational education at the upper secondary level (students 18–19 years of age) and the use of modern technologies for the purpose of achieving optimal educational outcomes. We compared the current way of training in robotics against modern learning supported by cyber–physical systems, questionnaire evaluations, and EEG evaluations. We systematically and scientifically promoted innovative learning strategies for these learning environments. The research was conducted with a control group (CG, n = 15) and with an experimental group (EG, n = 15). We measured the procedural time of robot welding programming and defined it as auxiliary time. In control group we had 15 students following the traditional learning method with frontal lecture, guided computer simulation, standalone computer simulation, interpretation and demonstration on an industrial robot, and training and problem-based tasks. We divided the empirical research into three steps. In the first step, we evaluated the questionnaires on student motivation, pre-knowledge, spatial orientation, and attitude to VR technologies. In the next step, we measured the procedural time of the given problem-solving task, the provided a method for educational robotics teaching with the CG and the proposed modern didactical learning method with an experimental group (EG). In the third step, we measured the EEG responses under different circumstances to prove that VR stimulations are more intense and we can improve procedural knowledge.

In our research, the students needed to program the industrial robot for the purpose of basic linear welding (LLE, low level exercise) and angle welding (HLE, higher level exercise). The students did not set any welding parameters, but they programmed the robot welding procedures. In this case study, the fixing of the material to the welding table was the preparation time. The programming and setting of the industrial robot were part of the auxiliary time, as well was the execution of the auxiliary task. The robot had good repeatability, so the focus was on programming skills and basic welding settings. Technological time, in our case study, meant the weld that we programmed.

In secondary level vocational training (training program for mechatronics and mechanical engineering technicians), we teach robotics in the learning modules of AVR (automation and robotics) and RBT (robotics); welding with industrial robots is also part of the curriculum. The reference sample included 30 students. The research was carried out using the classical approach of education with the CG (n = 15) and the second part was done with the EG (n = 15) based on the introduction of a modern teaching model for educational robotics.

3. Results

3.1. Questionnaire Evaluation

In Table 1, we can see the results of student motivational assessments for CG and EG. In Q1, we can see that the onset of current motivation about learning new knowledge and technology in CG and EG was very similar and not significantly different. In Q2 we can see that technology motivates students to explore and acquire new knowledge, in this case EG was slightly more motivated. In Q3 we can see that students were interested in robotics technology; in this case, CG was slightly more motivated. The same was true for Q4. In Q5, we can see that EG wants to gain more knowledge and skills in welding with industrial robots than CG. Based on the given answers, we can assume that technology motivates students' education.

Table 1. Students motivation evaluation results.

	Mean CG	Stdv CG	Mean EG	Stdv EG
Q1 Current motivation to learn about new knowledge and technologies	3.80	0.68	3.87	0.83
Q2 Technology motivates me in researching and acquiring new knowledge	3.67	0.98	3.93	0.70
Q3 I am interested in robotics technology	4.33	0.72	3.87	0.74
Q4 I want to learn new robotics technology skills	4.00	0.85	3.73	1.16
Q5 I want to gain knowledge and skills of welding with an industrial robot	3.73	1.22	4.00	1.00

In Table 2 we can see the results of the prior knowledge of CG and EG. In Q5, we can see that the prior knowledge of CG and EG in setting up and programming an industrial welding robot is very low and at about the same level. Thus, in Q5, if we evaluate the prior knowledge of setting up and programming an industrial welding robot, we can see that it is similar for CG and EG. and not at a high level. In Q6, we see that CG has a fairly high level (x = 3.71) of knowledge regarding setting up and programming industrial welding robots, compared to CG (x = 3.47). If we compare this with Q5, we can see that procedural knowledge is lower in both groups (CG and EG).

Table 2. Students pre-knowledge evaluation results.

	Mean CG	Stdv CG	Mean EG	Stdv EG
Q5 I know the procedures for setting up and programming an industrial welding robot	2.27	1.22	2.33	0.98
Q6 I know setting up and programming an industrial welding robot	3.71	1.07	3.47	0.83
Q7 I can program the basic movements of an industrial robot	4.14	0.86	3.27	1.28
Q8 I can set and program the peripheral units of an industrial robot	3.27	0.88	2.93	1.10

In Q7, we can see that CG has a higher knowledge about programming the basic movements of an industrial robot, consequently there is also a higher score for CG in Q8.

In Table 3, we can see the assessment of students' spatial orientation. The spatial orientation was checked so that we can compare whether the spatial orientation is related to the orientation in the VR environment. We can see that the students had quite good spatial orientation (Q9). Both groups (CG x = 4.33, EG x = 4.13) had very good spatial orientation. We can conclude that this also affects the results of VR CPS training. Consequently, in Q10 we can see that they can imagine objects in three dimensions. In Q11, we can see how many students have already performed the visualization technique. With Q12 we checked how they navigated the map and in Q13 if they liked to play games in their childhood that involved assembling smaller parts. Lastly, in Q14, we checked if they could imagine the movement of an industrial robot in space.

Table 3. Students spatial orientation evaluation.

	Mean CG	Stdv CG	Mean EG	Stdv EG
Q9 I have a good spatial orientation	4.33	0.72	4.13	0.92
Q10 I can imagine objects in three dimensions	4.40	0.74	4.27	0.70
Q11 In the past, I have already performed the visualization technique	3.53	1.19	3.00	1.41
Q12 I find it hard to get lost, it is simple to navigate the map	4.13	0.92	3.80	1.08
Q13 As a child I like to play games that involved assembling smaller parts into assembly	4.27	0.88	4.53	0.83
Q14 I imagine the movement of an industrial robot in space	4.13	0.64	4.13	0.83

We improved the assessment of spatial orientation using the Smith and Whetton questionnaire, as shown in Table 4. In Q15, we can see that EG had 100% success in evaluating image rotation. The result of combining image orientation and shape in Q16 was also better with EG. The results of EG were also better in question 17, in which we evaluated what pattern we can design to acquire the cube shown in the image.

Table 4. Students spatial orientation—Smith and Whetton questionnaire evaluation.

	CG Success (%)	EG Success (%)
Q15 Which image rotation is correct?	93.75	100
Q16 Which group of shapes can we combine to get the desired shape?	18.75	75.00
Q17 Which pattern can we design to get the cube shown in the picture?	43.75	50.00

Finally, as we can see in Table 5, we evaluate students' attitudes towards VR technologies. With Q18, we evaluated whether VR technology interests students. With Q19 we evaluated whether VR glasses motivate students to acquire new skills. With Q20, we determined if students want to use VR technology in the classroom. We were also interested in whether students had used it in the past, which was evaluated with Q21. Q22 is a similar question, we were interested to see if students had used VR glasses for teaching purposes before. Since it is now common to use VR glasses to watch 360 VR movies, this was evaluated with Q23. In Q24, we found that students had not yet undergone VR robot welding training.

Table 5. Students attitude to VR technologies.

	Avg CG	Stdv CG	Avg EG	Stdv EG
Q18 VR technology interests me	4.20	0.77	3.60	0.63
Q19 VR glasses motivate me to learn about new knowledge and technologies	3.60	1.06	3.27	1.44
Q20 I want to use VR technology in my learning	3.47	1.30	3.36	1.65
Q21 I have used VR glasses in the past	3.87	1.55	2.60	1.80
Q22 I have already used VR glasses for educational purposes	2.27	1.53	1.80	1.26
Q23 I have already used VR glasses to watch 360 VR movies and cartoons	1.87	1.30	3.36	1.65
Q24 I provided VR-training of robotic welding	1.00	0.00	1.00	0.00

3.2. Procedural Time Measurements

We measured the time for providing the learning procedure of the classical method and with the proposed learning method. We measured the time of the programming procedure for the low-level exercise (LLE) and the higher-level exercise (HLE) for robot welding using the classical method and the proposed learning method. We also determined a student's overall learning success (SLS, High—H, Medium—M, Low—L), a parameter that describes the student performance, and compared it to the measured time of the exercise.

In Table 6 we can see the procedure measurements for CG and EG in the case of LLE and HLE. One of the things we were interested in was how student overall learning levels affected their performance in the problem-solving exercise. For CG, we had four students with low SLS, seven students with medium SLS, and three students with high SLS. We can see that the high-level students also had shorter execution times for LLE and HLE on average. However, this was not always the case, and some students had low or medium SLS levels but were good at vocational–technical subjects. This was confirmed by student #10. In EG, we had four students with low SLS, eight students with medium SLS and four students with high SLS.

In Figure 6, we see an average measurement of the procedural time of problem solving with CG and EG for LLE and HLE. We can see that most EG times are lower and were in the range of times measured using the classical method, CG. It can be observed that the average value of the measured time was lower in the case of CPLM implementation. The average procedure time of LLE was 3.68% lower than CG and the procedure time of HLE was 1.80% lower than CG. Based on the time measurements, it can be said that the CPLM method affected the scheduling time for procedure setting and programming of basic robot welding. With a short training session in the virtual world, we can influence knowledge of robot training faster and more efficiently than classical training methods.

Table 6. Time procedure measurements of CG and EG, for LLE and HLE.

n = 15 CG	Time CG LLE	Time CG HLE	SLS (L, M, H)	n = 15 EG	Time EG LLE	Time EG HLE	SLS (L, M, H)
1.	06:38:11	07:59:30	M	16.	05:26:38	07:45:17	M
2.	05:57:32	06:01:21	M	17.	04:57:32	05:56:12	L
3.	07:12:45	07:59:05	M	18.	06:55:13	06:59:26	M
4.	04:47:09	05:33:54	H	19.	05:12:42	06:27:27	L
5.	06:01:23	07:55:02	H	20.	06:14:24	07:01:23	L
6.	05:46:32	06:02:22	L	21.	04:42:32	05:48:18	H
7.	05:30:22	06:05:53	M	22.	04:56:16	06:25:10	M
8.	05:02:26	05:45:23	L	23.	04:59:56	05:25:52	M
9.	05:37:33	05:10:44	M	24.	04:26:52	07:10:48	M
10.	05:20:32	06:02:33	L	25.	05:10:32	05:55:06	M
11.	05:38:55	05:57:10	M	26.	05:22:15	06:33:22	H
12.	05:49:31	06:22:55	H	27.	06:32:31	06:59:15	M
13.	06:22:55	05:59:01	M	28.	04:48:38	05:24:04	H
14.	06:11:04	06:55:57	L	29.	05:26:04	06:04:45	M
15.	06:23:11	06:56:35	M	30.	06:19:29	06:44:02	L
mean	05:53:20	06:27:10		mean	05:40:10	06:20:58	

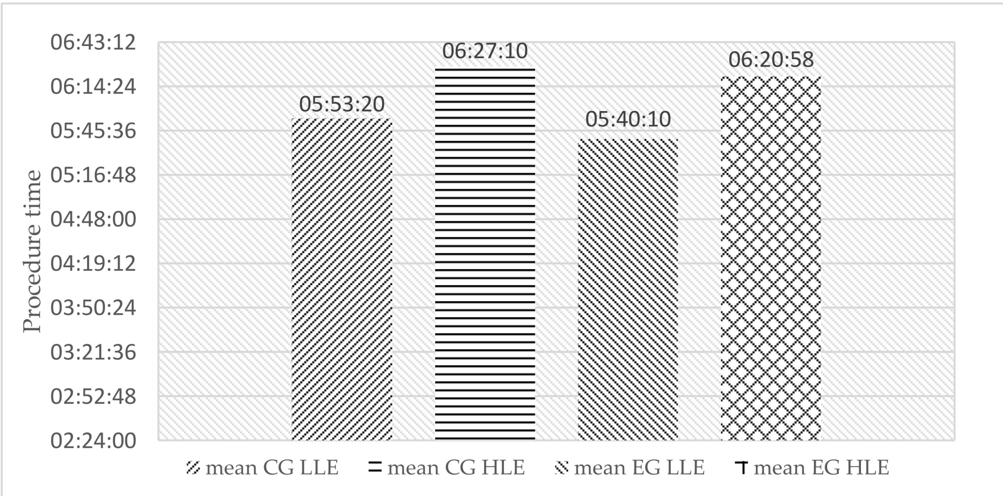

Figure 6. Time measurement of procedure time CG and EG, LLE and HLE.

3.3. Evaluation of CPLM with Brainwave Measurements

It is a challenge to perform brainwave experiments in a classroom. EEG equipment is becoming portable and miniaturized, and with simple preparation it is possible to get accurate brainwave information [37] to improve student performance [38]. The electroencephalogram (EEG) is a widely used non-invasive method for monitoring the brain. An EEG device uses forehead electrodes to detect brain electrical waves and electronics to process signals and transmit data via Bluetooth communication to a laptop, tablet, or smart phone. It uses a signal processor and communication unit to send data to a communication channel [39]. EEG has been used in the field of educational research to evaluate and monitor the effectiveness of traditional and modern teaching methods or to develop feedback-based systems. The EEG detects human brain waves based on selected characteristics of α, β, δ and θ waves. The variations in β waves in an EEG are strongly correlated with attention and α waves are strongly correlated with meditation [40]. Attention is the behavioral and cognitive process of selectively focusing on a discrete aspect of information, whether viewed as subjective or objective, while ignoring other perceptual information [41]. In contrast to attention, meditation is an intentional and self-regulated focusing of attention to relax and calm the mind [42]. Meditation does not represent a physical state, but rather a mental one, of an individual and refers to a reduction in active mental processes of the brain. That is, a higher level of relaxation indicates that an individual is more relaxed and less stressed [43]. There are different cognitive aspects that can be measured with EEG devices [37], such as reading context [35], presentation patterns [37], interactive behavior [35], edutainment [44], e-learning [45,46], motor skill acquisition [47], and promoting performance [48]. We can measure different brain waves, such as alpha, beta, gamma, delta, and theta waves.

A device was used to measure attention and meditation in various given situations. In order to check and prove the theory, we decided to use a simple EEG device, the Mindwave Mobile 2. We selected a group of 15 EG students and measured their EEG activity while watching relaxing videos, while working on a personal computer where they performed a simulation problem solving, and while using a VR system and a robot VR simulator. During the measured EEG responses, we evaluated the average values of attention and meditation in the different given environments and assessed the average value of the measured EEG responses.

In Table 7, we see the measures of attention (CPS-A) and meditation (CPS-M) during the computer problem-solving robotics simulation task and the VR environmental problem-solving task (VR-A, VR-M). Students performed the computer problem-solving robot simulation task during measurements with an EEG device. The time of recording the cognitive activity was 150 s. In the pilot group of students who solved computer problems, we measured a mean value of attention of 43.38 and a mean value of meditation of 54.27. The time recording cognitive activity was 2.5 min. In the pilot group of students solving computer problems, we measured an attention mean of 43.38 and a meditation mean of 54.27. Then, we included the VR environment and measured the same parameters in the immersive environment and with the simulated VR task. As we already noted, meditation is a cognitive activity to relax and calm the mind, and consequently, a higher level of relaxation makes a person more active and less stressed. In the pilot group of students using a VR learning environment, we measured a mean score of attention of 51.44 and a mean score of meditation of 53.36.

Table 7. Computer problem solving attention (CPS-A), computer problem solving meditation (CPS-M), attention VR (VR-A) and meditation VR (VR-M)—scalable measurements in millivolts.

N	CPS-A	VR-A	CPS-M	VR-M
1.	42.41	41.63	49.62	40.44
2.	56.33	39.07	65.03	53.41
3.	42.82	52.92	47.81	73.74
4.	48.52	52.30	59.57	53.64
5.	45.74	66.17	49.06	46.65
6.	46.13	59.81	57.03	45.03
7.	48.87	79.07	50.87	54.47
8.	39.66	42.40	79.31	58.70
9.	40.18	57.88	40.41	45.33
10.	55.68	58.10	59.59	70.47
11.	51.13	42.35	71.20	64.09
12.	57.28	39.38	51.73	52.55
13.	75.22	52.34	38.65	42.65
14.	38.53	49.11	38.97	40.46
15.	37.20	39.12	55.27	58.78
StD	9.88	11.51	11.56	10.38
Mean	48.38	51.44	54.27	53.36

In Figure 7 we see the measurements represented graphically. Based on the measurements, we can see that attention in the VR environment is 5.94% higher than in the computer problem-solving environment; however, the results are not statistically verified at this stage. The mean value of meditation was slightly lower than for computer problem solving, which can be justified by the fact that it is an immersive environment and students are less relaxed at the beginning of a test.

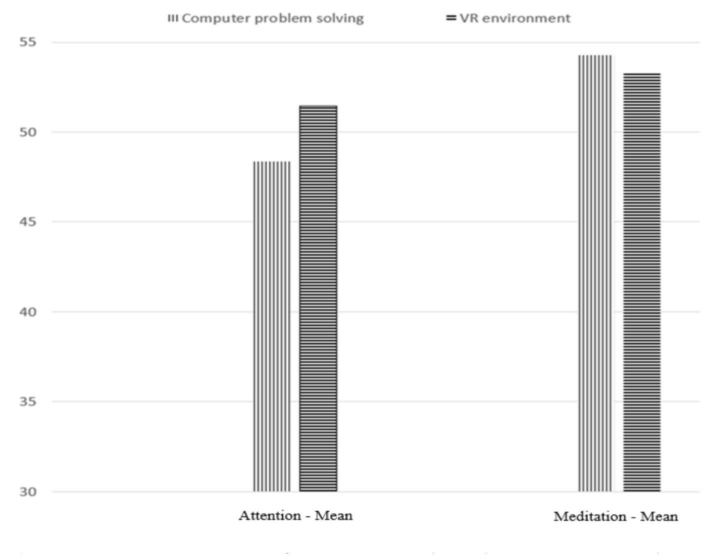

Figure 7. Measurements of attention and meditation mean values.

As we have researched, higher levels of meditation can increase students' ability to pay attention so that they can better absorb and process information. When attention and meditation are high, learners are in an optimal state for learning. Based on EEG measurements and analyses of the articles [37–39,43,45–51], we can claim with greater probability that VR increases student attention so that they are in an optimal state for learning. As we can see in Table 8, we performed a *t*-test to examine whether there were significant differences between the measures of attention and meditation means in a computer environment or in a VR environment. Kurtosis coefficient K for the attention measures (CPS-A K = 2.79, VR-A K =0.78) tells us that the distribution of the measures peaked, and the skewness coefficient S (CPS-A S = 1.44, VR-A S = 0.94) tells us that the distribution of the measures was right asymmetric. Coefficient K of the meditation readings (CPS-M K = 0.18 VR-M K = 0.43) shows us that there were peaked readings, and the skewness coefficient S (CPS-M S = 0.61, VR-M S = 0.59) shows us that there was a right-asymmetric distribution of readings.

Table 8. *t*-test paired sample correlation results from computer problem-solving simulation vs. VR environment.

	CPS-A	**VR-A**	**CPS-M**	**VR-M**
Min	37.20	39.07	38.6	50.44
Max	75.22	79.07	79.3	70.47
StD	9.88	11.51	11.5	10.38
Mean	48.38	51.44	54.2	53.36
K	2.79	0.78	0.18	0.43
S	1.44	0.94	0.61	0.59

Pair	n	r	Sig. p	t	Sig. P 2-tailed
Attention Computer Problem Solving (A-CPS) Attention VR (A-VR)	15	0.02	0.94	−0.79	0.44
Meditation Computer Problem Solving (M-CPS) Meditation VR (M-VR)	15	0.49	0.06	0.31	0.75

The mean of CPS-A (x = 48.38) is lower than VR-A (x = 51.44), but the standard deviation VR-A is higher (s = 11.56). The correlation between the groups is very low (r = 0.02) and is not statistically significant (p = 0.94). The mean CPS-M (x = 54.27) is higher than VR-M (x = 53.36), and the standard deviation VR-M (s = 10.38) is lower. The correlation between the two groups is high (r = 0.43), but is not statistically significant (p = 0.06). Looking at coefficient t, which indicates the statistical properties of the differences rather than their practical significance, we find that they are not statistically significant when comparing the measurements CPS-A and VR-A (t = −0.79, p = 0.44). The arithmetic mean of the CPS-A results (x = 48.38) is lower than VR-A (x = 51.44). The effect is small (d = −0.79). When comparing the CPS-M and VR-M measurements, it was found to be statistically insignificant (t = 0.31, p = 0.75). The arithmetic mean of the CPS-M results (x = 54.27) is higher than VR-M (x = 53.36). The effect is medium (d = 0.31). Thus, we can conclude that the VR environment has a greater effect on the state of meditation than on attention.

4. Discussion

Society is facing challenges in these modern times. Technology is developing rapidly and with the development of technologies, education also needs to be developed. This is a challenge for the education system and for all social partners.

The cyber–physical learning model is derived from the standard education model, which follows the classical education paradigm and is predominantly used in VET schools to teach STEM subjects. Based on these findings, we proposed the innovative CPLM learning model. The model is universal and can be used in all educational settings. We successfully tested it using educational robotics and can claim with high probability that it is effective based on a questionnaire evaluation, procedural time measurements, and EEG evaluations.

As we can see, the questionnaire evaluation shows that participants are motivated to acquire new knowledge and they are interested in robotics. Previous knowledge was not extensive, which is good and allowed us to carry out a more efficient learning process. We also wanted to see if there was a relationship between orientation in VR space and spatial orientation. We found that students who have better spatial orientation are better and more focused in the VR space and therefore take less time to adjust to a virtual space. We also found that the VR technologies are very interesting for students, which we found has an effect on motivation. We also found that most students had not yet used VR technology for educational purposes.

Next, we measured procedural time of LLE and HLE for CG and EG and compared the case with SLS. We found that training in the VR learning environment affected the reduction in execution time of the exercise, for both LLE and HLE, which was also the goal of the modern learning model. The actual time of the entire implementation of the educational process is increased by the training time in the VR environment. Essentially, the technology influences a faster perception and memorization, which we also recognized during an evaluation of the articles [10–18]. We also supported the learning model using EEG measurements to show attention increases in the VR environment compared to the computer problem-solving simulation, while the value of meditation is lower in the VR environment. We can attribute this to the new environment which is a very intense experience.

Research has shown that modern VR technologies can influence the improvement of spatial and visual memory [16]. As the presented information is presented more intensely, it affects multiple centers in the brain and, thus, the formation of multiple neural connections [17]. However, we need to discuss how to introduce technologies in an appropriate way. The timing of the use of VR glasses, the impact on the psyche of individuals, and the risk of eye damage with some use are all controversial. We can ask how we can incorporate individual learning to minimize the negative effects. On the one hand, VR helps with environment in subjects with brain damage [50]. However, the extent to which VR can affect an individual's psychosomatics is not well understood. Therefore, we need to pay attention to its use this needs to be studied in the future. Just as we can misuse a PC or a smartphone, the same is true for VR technologies. The results from the simple EEG measurement device are satisfactory, but, in the future, we can upgrade this to a more complex and accurate multi-point EEG device. The development trend towards LMS 4.0 or core learning technology system (CLTS) and next generation digital education environments (NDGLE), which we will focus on in the next stage of our study is on going [51]. It can be concluded that it is not enough to develop a modern learning model, and it must also be integrated into a modern learning environment.

Based on the research conducted, it can be concluded with high probability that the proposed CPLM learning model is effective and useful. If we want to implement Society 5.0, we need to introduce technology into education along with all other approaches. The proposed approach will be useful for a future society that will become digital and increasingly virtual. Nevertheless, this is only a fraction of the mosaic of the future, but are modest steps in preparation for Society 5.0.

5. Conclusions

The purpose of this study was to investigate the feasibility of developing a modern learning model that includes cyber–physical systems and make use of the field of educational robotics in the context of research. The assessment was conducted in a population of 30 students (15 EG, 15 CG) and was limited to VET students. Future studies should be conducted in other general education courses and assessments should be conducted in a larger experimental group. Measurements were conducted during class time, so we were constrained by time, student interest, and current mental state. VR technology can cause individuals stress when first used because it is a new experience that is very intense (possibility of nausea). We used the Oculus Rift VR HMD (head mounted display). Therefore, in the future, it is necessary to conduct research on HMDs with more processing and graphical power (Oculus Quest 2, HTC Vive, etc.). In the future, CPS VR needs to be researched and implemented in combination with AI and a smart classroom. Right now, blended learning, which is a combination of traditional teaching, written resources, modern online classrooms, and an immersive environment, are used. As education aims to personalize individual learning, AI would adapt individual learning knowledge and technologies according to prior auditory knowledge. In the future, we will explore AR (augmented reality) technologies, which are rapidly developing and enabling new educational opportunities and research in education [52]. It is necessary to investigate the negative effects of the use of modern technologies on individuals and to determine the maximum permissible duration of their use as well as the possible negative effects on individuals for educational purposes. Future research should also examine the use of the learning model in a larger experimental group and over a longer period of time. Further research could focus on more detailed brain functions and explore the use of a simple EEG meter for secondary vocational education purposes. For EEG analysis, we used a simple EEG device that gave us satisfactory results. In the future, research can be undertaken with more powerful and complex EEG meters with multiple measurement points. There is also an interesting possibility of studying mirror neurons in conjunction with VR CPS training [53]. We need to consider the current concept of a "meta-human" and the possibilities of CPS to incorporate them into modern education [54]. However, written sources and a classical pedagogical approach should not be neglected ([55,56]). Thus, the challenge for the future is to find a balance between classical education, the use of written sources, and the use of modern technologies.

Since the identified problems are crucial for the progress of society, we studied the development of a modern learning model under the influence of modern CPS and pedagogical and didactic methods in the educational process, considering the constraints and limitations of technology users. Students need to be prepared for the near future. New pedagogical concepts can help them to prepare for it.

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