education sciences

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Assessment of Supporting Visual Learning Technologies in the Immersive VET Cyber-Physical Learning Model

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Abstract: Humanity faces diverse technological, societal, and sociological challenges. Digitalization is being integrated into every aspect of our lives. Technologies are developing rapidly and the ways in which we live and learn are changing. Young people are acquiring information and learning in a different way than in the recent past. Education systems are no longer keeping up with the development of technology. Education systems need to adapt and introduce technologies that motivate students and ultimately contribute to higher learning goals. To this end, we need to develop modern learning models that support education and technological development. In previous research, we developed and evaluated a state-of-the-art learning model, the CPLM. We built on this with a new study, in which we assessed the difference between the cognitive activities of attention and meditation in students during the viewing of a classical educational video, a 360° video, and an AR app on a screen. We found that the 360° video had the greatest impact on students' attention and is consequently suitable for initially motivating students in the proposed learning model. We made a proposal for a modern educational model and possibilities for further research.

Keywords: XR immersive technologies; VET education; 360° video; educational video; innovative learning method development; assessment

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Citation: Veber, M.; Pesek, I.; Aberšek, B. Assessment of Supporting Visual Learning Technologies in the Immersive VET Cyber-Physical Learning Model. *Educ. Sci.* **2023**, *13*, 608. https://doi.org/10.3390/educsci13060608

Academic Editor: Valery Vodovozov

Received: 24 April 2023
Revised: 5 June 2023
Accepted: 9 June 2023
Published: 14 June 2023

1. Introduction

Humanity faces diverse technological, societal, and sociological challenges [1]. Social, sociological, and global changes are taking place. Times of war, migration, epidemics, pollution, and scarcity in terms of resources and raw materials have presented humanity with new challenges. Technological development, the transition to a carbon-free society, the introduction of alternative fuels, and population growth will be the fundamental starting points for the future [2]. Children who start their education today will later perform professions that we cannot even imagine today or that we can only imagine in outline based on current developments [3]. We can ask ourselves how education systems can adapt to this. An education paradigm is crucial for the future. The OECD reports that education is no longer keeping up with technological development and that education is currently not taking advantage of the opportunities that the development of technologies presents. We can ask ourselves how individuals will function in Society 5.0 and what knowledge, competences, and skills they must have to be sociable, interesting, and competitive while respecting ethical and moral norms. For example, an individual must have digital literacy, mathematical skills, be able to analyze large amounts of information, and have access to healthcare. An individual must take responsibility for their actions, add value to different projects, as well as be a good negotiator and facilitator. An action-oriented approach and the ability to reflect upon one's actions in relation to goals and expectations are essential [4]. Significant attention is also being paid to Industry 5.0, which focuses on the interaction between highly skilled workers and robots to produce personalized products and services.

This builds on global trends based on the creation of the networked smart factories of the future [5]. Smart factories will enable systemically automated production processes based on individual needs, efficiency, and rapid adaptability [6]. Industrial systems are currently in a state of upheaval. The Fourth Industrial Revolution is being integrated into all areas of production and related systems. In Slovenia, the industry is still in its infancy and companies are actively investing in digitalization and Industry 4.0 systems. In Europe, the guidelines are mainly set by German companies such as Festo and Siemens, among others. The basic Industry 4.0 standard implies the digitalization of processes and a large amount of information that must be properly analyzed, evaluated, selected, and used. This already includes artificial intelligence (AI), which enables massive data analysis (MD). Currently, AI is present in data analysis in healthcare, transport systems, social networks, and other digitalized systems. An Industry 5.0 standard in the early stages of globalization has also been subject of discussion, wherein physical and virtual systems work in parallel, information is analyzed by AI, and humans collaborate with robots—essentially a highly personalized system tailored to the individual user [7].

As a result, VET education faces new and unique challenges. Scientific education should not only promote vocational training, but also support the development of engaged and knowledgeable citizens to enhance society's capacity for sustainable development [5]. Teachers who teach interdisciplinary lessons, especially those who teach robotics, face a major obstacle in this area. Faced with enormous diversity, rapid progress, and the need to constantly acquire new skills, teachers must have interdisciplinary perspectives, adaptability, a lifelong learning attitude, and sensitivity. Exploring creative approaches is essential to engage children in science and technology [8]. Technology-enabled co-creation provides opportunities to explore the engineering design process [9]. The boundaries between knowledge and technology are fluid but closely intertwined in the highly interdisciplinary field of science and technology. The mastery of digital skills, particularly technological and engineering skills, is of great importance in the fields of engineering and technology [10,11]. It is important to recognize that only well-trained teachers can effectively fulfil their role in this process. Therefore, they need to be trained in at least two key areas: problem-based and collaborative working and learning, and functional skills, especially in science, technology, engineering, and mathematics (STEM). To implement this complex educational paradigm, we need to revolutionize the way in which teachers interact with students and the way in which students interact with teachers [12]. Teachers working in the interdisciplinary field of mechatronics education face great challenges with regard to engineering and technology. Given the enormous diversity, rapid developments, and constant need for new knowledge and skills, teachers must have interdisciplinary perspectives, responsiveness, a lifelong learning approach, and adaptability. High levels of teacher competence are believed to correlate directly with learner motivation, which plays a crucial role in the educational process. Through innovative thinking, creativity, teamwork, initiative, perseverance, and effective communication, individuals can succeed in their professional and personal lives [13].

Teachers must therefore integrate a variety of modern technologies into the educational process to motivate students and achieve higher learning goals [14]. Video materials are useful and have been successfully integrated into learning processes [15–18]. However, with the development of technologies, 360 VR videos are also being successfully integrated into the classroom [19–22]. It is a challenge regarding how we integrate immersive technologies into a modern learning process and how we can adapt the learning process to these technologies. Modern technology can help us improve our spatial and visual memory, according to research [23]. As information is presented more intensely, it affects different brain centers and causes the formation of numerous neural connections [24]. Extended reality technology (XR) is rapidly evolving to enable modern pedagogical approaches and the use of immersive technologies for educational purposes. XR technologies include immersive technologies such as augmented reality (AR) and virtual reality (VR). VR refers to environments created with computer graphics that enable a person's presence and experience in virtual environments that resemble real environments. AR refers to the technological applications of computing devices that enrich and enhance the user's physical environment with additional information and virtual objects in real time [25]. With 360° videos, highly interactive and immersive learning environments such as AR and VR can be created. These technologies are becoming increasingly useful for education, as they allow users to directly experience and interact with virtual content and environments [19]. To this end, we developed and evaluated a modern learning model, which is the cyber-physical learning model (CPLM). In this study, we investigated how supporting visual technologies affect students' attention and meditation while using each technology, and how attentive or relaxed they are while using these technologies.

We studied the use of different technologies in the modern educational process with a PEEG device to assess students' attention and meditation while using a traditional educational video, a 360° educational video, with AR technology on a smartphone as well as the VR technology. We sought to fulfill the following research gap: despite the increasing use of augmented reality in education and the growing popularity of 360° videos, there is a significant research gap when it comes to understanding their impact on teaching and learning compared to traditional video formats. While individual studies have examined the effectiveness of traditional video content or the benefits of AR, there has been limited systematic comparison between these technologies with 360° video. Based upon this, we set our research objectives. The main objective of this study was to investigate the effectiveness and didactic value of 360° video, traditional video, and augmented reality in education. A comprehensive analysis of these three modalities will reveal their unique capabilities, learning outcomes, and pedagogical implications. Based upon this, the following research questions were formulated: how do traditional video, 360° video, and augmented reality differ in terms of student attention in education? What are the practical challenges and constraints associated with integrating classic video, 360° video, and augmented reality into educational environments, and how can these obstacles be overcome to maximize their educational potential? The findings will contribute to evidence-based pedagogical practice and inform future technological developments, ultimately paving the way for transformative and immersive learning environments. Based upon the above, we hypothesize the following:

H0: *There is no significant difference in student attention between the use of 360° video and an AR app in education.*

H1: *(alternative hypothesis): There is a significant difference in student attention between the use of a 360° video and an AR app in education.*

2. Theoretical Framework

Teachers need to be interdisciplinary, responsive, lifelong learners, and always flexible due to the fact that their work involves great diversity, rapid development, and the need to constantly acquire new skills and abilities. In the current age of digital technologies, there is a wealth of information and an abundance of audio and visual stimuli. Information is accessible through the Internet and various social networks, as well as through various multimedia devices such as smart cell phones, tablets, PCs, and laptops, which are not only used to listen to music also present visual content and other related information. We learn through videos and multimedia content. We can use technology and knowledge for educational and professional purpose. The question is how can interest in innovative approaches and student engagement in science and engineering be increased [26].

We can refer to the European Digital Skills Framework (DigCompEdu), which provides tools to improve citizens' digital skills. In the fields of education, training, and employment, the need has emerged for a common reference framework that defines what it means to be digitally competent in a digitized global environment. The framework aims to raise the level of digital literacy among citizens, support the development of digital literacy strategies, and plan education and training initiatives based upon digital literacy for specific target groups. DigComEdu provides a common framework for defining and describing key areas of digital literacy at the European level [27].

Robotics is used in numerous industrial processes and is an essential component of contemporary, economically feasible, and humane technologies. Likewise, robotics technology is increasingly finding its way into everyday life. Industry 4.0, including robotics, the Internet of Things, crowdsourcing, artificial intelligence, other cutting-edge technologies, and cyber-physical systems have a significant role to play in the future. According to current trends, humans and robots will work together during the production process and consequently they can increase productivity, improve product quality, and reduce production costs. Applications in which humans and robots can work together are limited [28,29].

As a VET school that trains people for the industry, we must integrate robotics technology into the curriculum. In the mechatronics technician training, industrial robotics is taught as part of the robotics (RBT) course, and in the mechanical engineering technician training, it is taught as part of the automation and robotics (AVR) course. Educational robotics in secondary vocational education can be divided into two pedagogical strands.

The initial focus of educational research is on problem-based and cooperative approaches designed to promote competition. The goal is to engage students in team-based learning in which they actively participate in the development of mobile rescue robots for the RoboCup Rescue World Robotics Championship RMRC. Throughout the process, students are exposed to various aspects including ideation, design, 3D modeling, electronic component development, sensor systems, and microcomputer programming. The result is a customized mobile rescue robot tailored to the specific requirements of the competition. The next phase of robotics training focuses on industrial robotics. This phase includes problem-based assignments as well as traditional teaching methods such as frontal lectures, discussions, exercises, and short training sessions. These theoretical components are reinforced by project or research-oriented work and practical problem-solving tasks based on real industrial challenges. Our study focused on this particular aspect of robotics education.

Video content accompanies young people at all stages of their lives. They follow videos on various social networks as well as create video content to express themselves creatively. For this reason, educational videos are also important for educational process [16,17,30].

Due to the growing availability of technology, 360° video is increasingly being used for educational purposes. Certain 360° cameras such as the Insta360 X3, InstaOne RS, Gopro Max 360, and others like them are affordable and provide high-quality 360° videos, but there are limitations including the angle of capture and the limited lighting conditions. Professional 360° cameras such as the Insta360 Pro 2 allow high-quality 8K 360° videos. This is the camera we used for our educational 360° video. According to the sources, 360° video is widely used in education [19,31–33].

The fundamental idea behind Industry 4.0 is using cyber-physical systems (CPSs) to create smart factories [34]. CPSs are technologically interactive networks of physical and computer-based components that are highly interconnected and integrated [35]. Prefabrication, automation, 3D printing, virtual reality, augmented reality, unmanned aerial vehicles (UAVs), sensor networks, and robotics are just some of the cutting-edge technologies that are being deployed as key components of Industry 4.0 [36]. Although both ideologies support the use of CPSs, the extent of this use is different. CPSs are to be used in the production environment in Industry 4.0, while Society 5.0 calls for its use on a global scale [37]. CPSs are more frequently used for educational and training purposes [38–41]. One area in which VR technology can be effectively used is in education and memory development.

VR technology has a significant impact on spatial and visual memory [24], and it is cost-effective because, in some cases, no physical equipment is needed and we can limit ourselves to virtual instruction [42]. Studies have shown that virtual labs improve the learning of technical content in terms of conceptual knowledge, procedural knowledge, and the understanding of practical content [43,44]. Researchers have implemented VR instructions to improve students' understanding of scientific concepts and engineering scientific development [45]. Several studies have shown that VR training improves students' knowledge [46–48]. AR is one of the most advanced information visualization technologies, in which the existing environment is visualized and overlaid with digital information to create enriched information about the real environment. With the development of this technology, AR has added a new dimension to possibilities in education [49]. Based on a review of various articles, we can see that the use of immersive technologies for learning, education, training, and teaching is rapidly increasing [50].

Electroencephalography (EEG) technology enables psychophysiological measurements that capture the relationships between mental and physical processes by measuring the electrical activity generated by the synchronous activity of thousands of neurons [51]. EEG is considered a non-invasive method of measuring the electric field of brain activity. Electrodes attached to the head record the voltage potential around a group of neurons. The technology is over a hundred years old and is used in various applications. It can record a wide range of cognitive activities, such as reading patterns [52], behavioral patterns [53], interactive behavior [54], activities in gaming [55], and activities in e-learning [56], measure motor skills [53], classify visual and non-visual learners [57], etc. The usual use is also to measure the attention (A) and meditation (M) of students for educational purposes [58].

Figure 1 shows the international standard model for placing 10–20 EEG electrodes on a person's skull. The International Electrode Placement System is the standard for the placement of EEG electrodes on the skull and the placement of transcranial magnetic stimulation (TMS) for cognitive neuroscience and psychiatric treatment studies.

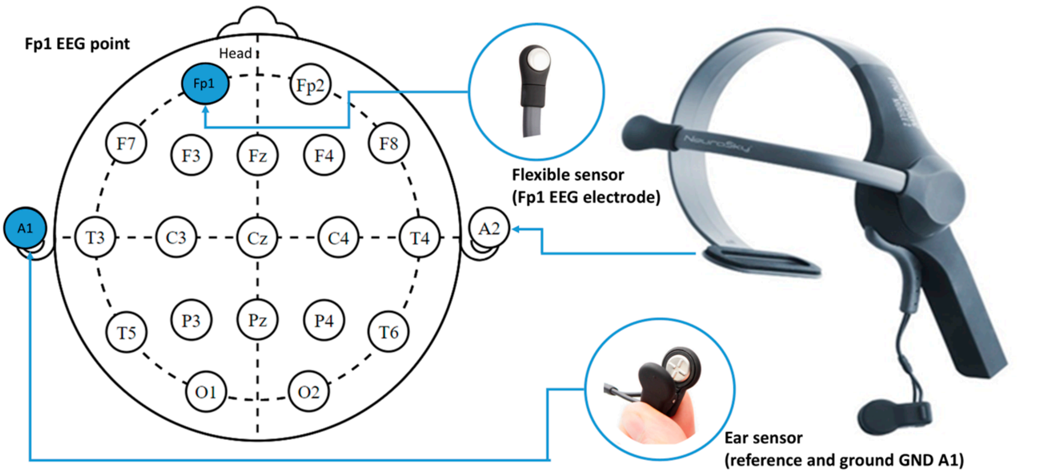


Figure 1. Electrode position based on the standard international system of electrode positions [59].

The key to TMS studies is the reliable placement of sensors on the head to perform measurements in a specific area of the cerebral cortex. A system with 10–20 sensors is useful because it is inexpensive and provides reliable measurements in specific areas of the cerebral cortex [60]. In this technique, the electrodes are precisely placed on the person's skull. This method requires a correlation between the positions of the electrodes on the skull and the underlying brain structures [61]. The device used is one of the simple PEEG measuring devices. It was used to measure the anterior part of the skull at measuring point Fp1.

Different brain waves can be measured, such as alpha, beta, gamma, delta, and theta waves. The oscillations of EEG signals at different frequencies represent the activity of the neurons [62]. The frequency bands include the following waves: delta (<4 Hz), theta (4–7 Hz), alpha (8–12 Hz), beta (13–30 Hz), and gamma (>30 Hz) [63,64]. Variation in the beta waves is related to attention (focus), while variation in alpha waves is related to meditation or relaxation [65]. Mindfulness is the behavioral and cognitive process of selectively focusing on a discrete aspect of information, whether it is a subjective or objective perception, while not focusing on other details [65]. In contrast to mindfulness, meditation is an unchanging and self-regulated cognitive activity in which the mind is relaxed and calmed [66]. Meditation represents a person's mental state rather than their physical state and refers to a reduction in active cognitive processes in the brain [67]. This means that a higher level of relaxation makes a person more active and less stressed. Higher levels of meditation can increase the listener's attention and absorption of information if the levels of attention and meditation are optimal for learning [68]. With the development of the brain–computer interface, more thought has been given to how PEEG can be integrated into the field of education. As reported in the literature, simple portable EEG (PEEG) devices provide sufficiently reliable measurement results and can be used to evaluate the pedagogical model [59,69].

3. Related Work

In the field of educational science, we investigate the impact of integrating technology into modern pedagogical and didactic approaches on students' intrinsic achievements, motivation, innovativeness, and various other learning outcomes. The impetus for these investigations came from our research on improving educational goals through the use of modern technologies. Specifically, we wanted to identify appropriate learning environments and apply appropriate pedagogical approaches to effectively engage young people in technology and engineering. To provide a framework for industrial robotics education in the 21st century, we conducted a study focused on determining the feasibility and methods for integrating modern technologies into existing robotics education processes.

In our previous research and articles, we compared the state of the art in robotics education, developed appropriate modern learning environments and innovative teaching strategies for it, and systematically evaluated all proposed approaches. In our related research, we asked whether modern technologies, such as VR, can be used to improve learning objectives, increase the effectiveness of education, training, and procedural skills, and whether modern technologies can be used to motivate learners for training [70,71].

The research focused on robotics education in VET (17–19-year-old students) and the use of modern technologies to achieve optimal educational outcomes. We compared the current robotics training method with modern learning supported by cyber-physical systems, an assessment questionnaire, and measurements of selected cognitive parameters with an EEG device. We systematically and scientifically developed innovative learning strategies for these learning environments.

This study was conducted with a control group (CG, n = 15) and an experimental group (EG, n = 15) in the field of educational sciences. The focus of this study was to evaluate the procedural aspects of robotic welding, including the setup and programming time. The control group consisted of 15 students who underwent the teaching process using traditional teaching methods that included frontal lectures, guided and independent computer simulations, interpretations and demonstrations on an industrial robot, and problem-based training and assignments. The cyber-physical learning model (CPLM) extends the classical approach with VR technology to motivate and interest students. VR experience helps students understand underlying concepts and it was already shown by the research that is effective [24,45,72]. Figure 2 presents the proposed learning model and its step-by-step procedure.

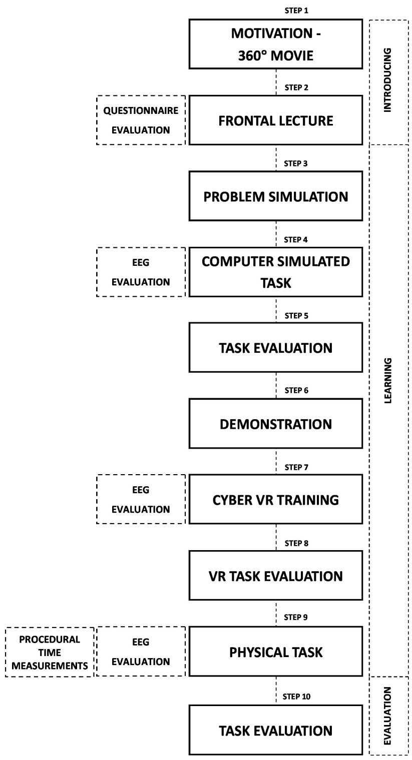


Figure 2. Cyber-physical learning model—concept of the modern teaching model [71].

The empirical research was divided into three steps. In the first step, an evaluation questionnaire was used to investigate participants' motivation, background in the field, spatial orientation, and attitudes toward VR technologies.

Based on the responses, we concluded that technology motivates learners to acquire new skills. We assessed the spatial orientation of CG and EG and found that, in our case, EG had better spatial orientation. We then used a Smith–Whetton questionnaire to determine the actual spatial orientation and found that, in this case, EG also had better spatial orientation. We also examined whether the VR technology was of interest to the learners, whether the VR technology motivated them to use new skills and technologies, and whether they had used the VR technology in the past. We found that the VR technology motivated them to use new skills and technologies.

In the next step, we measured the procedural time for solving problems with the classical method and with the proposed modern learning method. We measured the processing time for the low-level procedural knowledge exercise (LLE) and the high-level procedural knowledge exercise (HLE) on robot welding with the classical method and the proposed learning method. We also determined the students' overall learning success (SLS: high–H; medium–M; low–L). We found that the measured procedure time had a lower average value when CPLM was implemented. Compared to CG, the average LLE procedure took 3.68% less time and the average HLE procedure took 1.80% less time. Based on the time measurements, we can hypothesize that the CPLM approach influences the duration of problem solving. The procedural knowledge required for welding with an industrial robot is acquired faster and more effectively through a short training session in a virtual environment than through conventional learning techniques.

In the third step of developing the modern learning model, we used an EEG device to measure students' attention and meditation as they perform computer-based problem-solving and problem-solving in a cyber-physical system using the CPLM modern learning model. The measurements show that the attention is 5.94% higher in the VR environment than in the computer environment, but the results are not statistically significant at this stage. The mean meditation score in the VR environment is slightly lower than the measured score of computer-based problem-solving, which can be explained by the fact that it is a virtual environment and the students are less relaxed at the beginning of the test. As we explored in the literature, higher levels of meditation increase students' attention and their ability to better understand information. When levels of mindfulness and meditation are higher, learners are in an optimal state for learning [73]. Based on EEG measurements and article analyses, we can say with a high degree of probability that the VR environment increases students' attention so that they are ready to optimally absorb information under the given circumstances.

In the following part of this article, we will focus on different supporting visual technologies for educational purposes. The 360° videos are part of the modern CPLM learning model. Therefore, we were interested in the difference between a traditional educational video and a 360° video on a screen from the perspective of students' cognitive activities. However, as AR technology is also part of XR immersive technologies and will be included in the CPLM model, we were interested in how this technology also affects the cognitive activities of students, namely in terms of attention and meditation.

4. Materials and Methods

Our research focused on the teaching of educational robotics in vocational education at the upper secondary level (students aged 17–19) and the use of modern technologies to achieve optimal educational outcomes. We teach robotics on the AVR (automation and robotics) and RBT (robotics) learning modules in vocational training at the secondary level (training modules for mechatronics and mechanical engineering technicians); the welding of industrial robots is also on the curriculum. We compared the way in which robotics is taught today with the use of the new immersive learning model. For these learning environments, we promoted methodologically and scientifically innovative learning methods. This study was conducted with an experimental group (EG, $n = 15$). To test and prove the thesis, we decided to use a simple EEG device, the Mindwave Mobile 2. The device was used to measure attention and meditation in different given situations. The measurement time was 150 s. We selected a group of 15 EG students and measured their EEG activity while (a) watching an educational video; (b) watching a 360° educational video; (c) using AR on the smartphone with the AR robotics app; and (d) using a CPS and a VR robot simulator. During the measured EEG responses, we evaluated the mean values of attention and mediation in the different given environments and assessed the mean values of the measured EEG responses.

The educational video was edited with the software tool Da Vinci Resolve (Figure 3). We used a variety of raw video shots with a smartphone or downloaded from various video content channels. For off sound, we used an external USB microphone and Windows Dictaphone software. For the background music, we used Royalty Free Music.

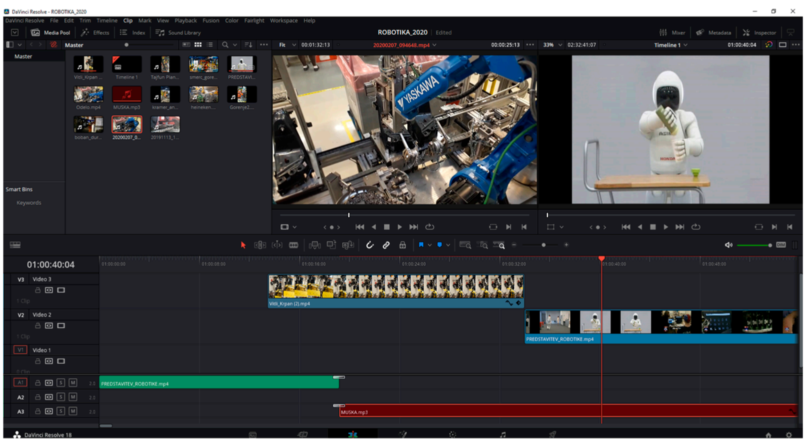


Figure 3. Editing an educational video in the Da Vinci Resolve software.

The 360° video was edited using the software tool Insta360 Studio (Figure 4). We used 360° video recordings made with an Insta360 Pro and an Insta360 X2 camera. We have to take care of the right lighting conditions when shooting and use the right methods in editing to stitch the 360° videos together.

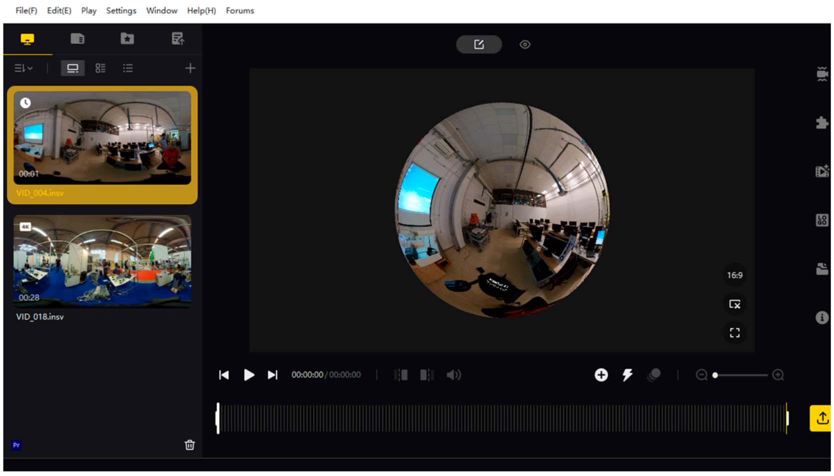


Figure 4. Editing the 360° educational video in Insta360 Studio software.

We used the AR application RobotStudio AR (Figure 5), which provides an enriched graphical experience with different industrial robots and pre-built robotic cells.

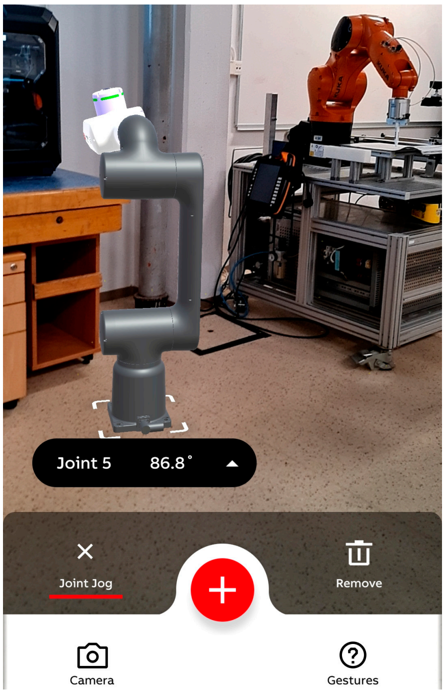


Figure 5. AR app RobotStudio AR.

The EG is relatively small, but this can be justified by the fact that it is a pilot study. In the VET class, we are limited by the number of students, space, and time frame. We are also limited in terms of technical equipment. The survey was conducted during class, at a time when we had several classes in a row. It should be noted that the survey was conducted in the robotics lab. It is also important to consider the different times at which the measurements and surveys were conducted. Some surveys were conducted in the morning, whilst others were conducted in the afternoon. Students may therefore have been more or less tired due to previous cognitive activities, which should be considered in the context of the obtained results. The individual's current motivation and mood, the temperature of the room, and the time of the school year in which the survey is being conducted can also influence the results. This makes a difference in terms of whether the survey is conducted at the beginning of the school year or towards the end, when students are already saturated with information, tired, and consequently expecting a holiday. Another limitation could be the ethical dilemma of students not wanting to participate or having problems with the use of technology in the classroom. With VR and 360° videos, virtual reality sickness can occur, which manifests in the form of discomfort, eye pain, headache, stomach upset, nausea, vomiting, pallor, sweating, fatigue, drowsiness, disorientation, and apathy. Other symptoms include postural hypotension and vomiting [74].

We sought to answer the research question by determining how the use of each technology affects student attention and meditation, and incorporated the results into the development of a modern learning model. We measured student's A and M values while they used classic on-screen video, 360° on-screen video, and an on-screen AR app. The results were tabulated and analyzed using a *t*-test.

5. Results

Assessment of Different Visual Learning Approaches with Brainwave Measurements

Table 1 shows A and M mean values measured while watching an educational video (EV-A, EV-M), a 360° video (360 V-A, 360 V-M), and while using an AR application (AR-A, AR-M). The recording time of the cognitive activities was 150 s, and the measurements were scalable measurements in millivolts. The measured mean of A and M when viewing the educational video is EV-A = 56.22; and the measured mean of EV-M = 57.68. The measured mean of A and M when viewing a 360° video is 360 V-A = 63.17; the measured mean 360 V-M = 51.89. The measured mean of A and M when using the app AR is AR-A = 53.04; and the measured mean of AR-M = 57.04. As we have written previously, meditation is a cognitive activity in which the mind calms down. Therefore, due to a higher level of relaxation, the person is more cognitively active and less stressed.

Table 1. Education video attention (EV-A); education video meditation (EV-M); 360° education video attention (360 V-A); 360° education video meditation VR (360 V-M); augmented reality attention (AR-A); augmented reality meditation (AR-A)—scalable measurements in millivolts.

N	EV-A	EV-M	360 V-A	360 V-M	AR-A	AR-M
1.	64.25	52.56	58.22	74.18	50.11	59.35
2.	59.85	49.91	78.71	41.35	83.09	55.53
3.	79.69	32.64	79.73	35.64	62.85	54.19
4.	63.00	54.61	45.29	51.42	47.07	58.90
5.	45.57	57.40	75.20	47.77	60.47	83.08
6.	77.40	79.20	54.68	42.33	78.53	59.90
7.	37.02	74.87	45.81	52.29	13.69	46.30
8.	79.27	39.63	75.23	41.25	54.00	49.87
9.	37.22	71.70	55.83	45.66	59.18	47.64
10.	62.13	58.38	56.34	60.78	60.72	57.37
11.	64.34	59.73	70.60	53.32	52.07	63.88
12.	52.80	51.43	57.88	52.48	39.36	33.95
13.	23.64	53.45	73.58	44.69	37.11	36.20
14.	58.31	63.93	47.19	58.70	35.70	59.85
15.	38.78	65.75	73.23	76.47	47.93	52.54
StD	16.29	11.63	12.03	11.30	16.85	9.08
Mean	56.22	57.88	63.17	51.89	53.04	57.04

Figure 6 shows a graphical representation of the brainwave measurements. Based on the measurements of 360 V-A, a 360° video was increased by 11% compared to EV-A when watching a normal educational video, and by 16.03% compared to AR-A when using the screen AR app. Interestingly, EV-M = 57.88 and AR-M = 57.04 are relatively equal, while the relatively low value is 360 V-M = 51.89. It should be noted that all measurements with relatively high A and M values and consequently all technologies are useful for training. At this stage, the results are not statistically relevant. We performed a *t*-test to analyze whether there are statistically significant differences between the measurements of EV-A, EV-M, 360 V-A, 360 V-M, AR-A, and AR-M.

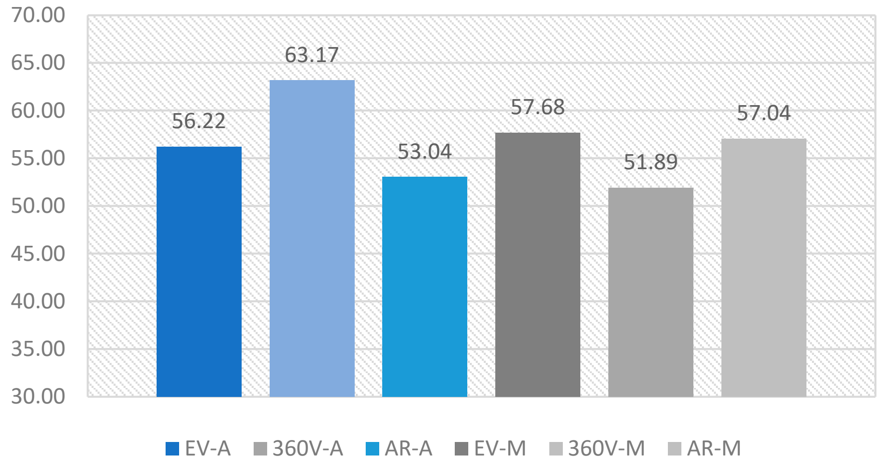


Figure 6. Graphical representation of the mean values—brain wave measurements A and M.

As we can see from Table 2, the kurtosis coefficient K for the measured intention values (EV-A K = −0.65, 360 V-A K = −1.76, AR-A K = 1.14) indicates the normal forms of flattery, whilst the curvature coefficient S (EV-A S = −0.32, 360 V-A S = −0.10, AR-A S = −0.42) indicates a large number of the principal measured values. The mean value EV-A (x = 56.22) is lower than 360 V-A (x = 63.17), but the standard deviation 360 V-A is lower (s = 12.03). The correlation between the values is high (r = 0.73) and not statistically significant (p = 0.79). Looking at the coefficient t, which indicates the statistical differences, we find that the difference between EV-A measurements and 360 V-A is not statistically significant (t = −1.33, p = 0.20). The mean value of 360 V-A (x = 63.17) is also higher than that of AR-A (x = 53.04), and the standard deviation here is lower than 360 V-A (s = 12.03). The correlation between the values is high (r = 0.44) and statistically significant (p = 0.094). Looking at the coefficient t, which indicates the statistical differences, we find that the difference between the EV-A measurements in 360 V-A is statistically significant (t = −2.65, p = 0.019).

Table 2. *t*-test paired sample correlation results EV-A, 360 V-A, and AR-A.

	EV-A	**360 V-A**	**AR-A**
Min	23.64	45.29	13.69
Max	79.69	79.73	83.09
StD	16.29	12.03	16.85
Mean	56.22	63.17	53.04
K	−0.65	−1.62	1.14
S	−0.32	−0.10	−0.42

Pair	n	r	Sig. p	t	Sig. P 2-tailed
EV-A 360 V-A	15	0.73	0.79	−1.33	0.20
360 V-A AR-A	15	0.44	0.094	2.65	0.019

As we can see in Table 3, the kurtosis coefficient K for the measured intention values (EV-M K = 0.13, 360 V-M K = 0.50, AR-M K = 5.40) indicates a distribution that is more peaked than normal, and a distribution of AR-M K = 5.40 indicates that the distribution is excessively peaked. The curvature coefficient S (EV-A S = −0.17, 360 V-A S = 0.96, AR-A S = 1.94) indicates a large number of smaller measured values. The mean value EV-M (x = 57.68) is higher than 360 V-A (x = 51. 89), but the standard deviation 360 V-A is lower (s = 11.30). The correlation between the values is lower (r = 0.25) and not statistically significant (p = 0.35). Looking at the coefficient t, which indicates the statistical differences, we find that the difference between EV-M measurements in 360 V-M is not statistically significant (t = 1.60, p = 0.13). The mean value of 360 V-A (x = 51.89) is lower than that of AR-M (x = 57.04), and the standard deviation here is lower in AR-M (s = 9.08). The correlation between the values is high (r = 0.087) and not statistically significant (p = 0.75). Looking at the coefficient t, which indicates the statistical differences, we find that the difference between the EV-M measurements and 360 V-M is not statistically significant (t = −0.65, p = 0.52).

Table 3. *t*-test paired sample correlation results EV-M, 360 V-M, and AR-M.

	EV-M		**360 V-M**		**AR-M**
Min	32.64		35.64		46.30
Max	79.20		76.47		83.08
StD	12.03		11.30		9.08
Mean	57.68		51.89		57.04
K	0.13		0.50		5.40
S	−0.17		0.96		1.94
Pair	n	r	Sig. p	t	Sig. P 2-tailed
EV-M 360 V-M	15	0.25	0.35	1.60	0.13
360 V-M AR-M	15	0.087	0.75	−0.65	0.52

6. Discussion

There is a need for a discussion on how technology can be introduced into education in an appropriate way. In our previous research and articles, we compared the state of the art in robotics education, developed the appropriate modern CPLM learning model and innovative teaching strategies for it, as well as systematically evaluated all proposed approaches. In our related research, we asked whether modern technologies such as VR can be used to improve learning objectives, increase the effectiveness of education, training and procedural skills, and whether modern technologies can be used to motivate learners for training [70,71]. To complement the CPLM learning model, we tested various assistive visual technologies such as learning videos, 360° videos, and the use of the AR environment. We measured A and M cognitive activities with an EEG device and systematically compared the results in the context of the learning model. Based on the measurements of 360 V-A, the 360° video was increased by 11% compared to EV-A when watching a normal educational video, and by 16.03% compared to AR-A when using the screen AR app. From the results, it can be concluded that 360° videos are suitable for the purposes of introductory motivation in the CPLM learning model. When we watch a video, we do not use our hands, but mainly our eyes and ears, and as a result, certain cognitive activities take place. The difference is in a 360° video, where we have to move the PC mouse with our hands to move in a 360° space, and in an AR application, where we have to move our fingers on the screen to interact with the AR environment. This can influence the cognitive activities and the measurement results.

Especially with the use of immersion technologies, we need to consider that the time required to use VR glasses, the impact on the psychosomatics of the individual, and the risk of eye injury if used improperly can be problematic. The question is that of how can individualized learning be incorporated in order to minimize the negative effects. The appropriate time at which the VR environment can affect an individual's psychosomatics has not been fully explored. One study investigated the use of a VR environment during an extended period of time. It found that individual users experienced migraines, nausea, and anxiety. These problems mainly occurred at the beginning, but with long-term use, participants gradually overcame the negative side effects and initial discomfort [75]. In the future, the aforementioned topic of discussion should be investigated in more detail. In practice, learners inappropriately use a PC or a smartphone for educational purposes, and the same applies to VR technologies. To deliver education with modern technologies, we propose the concept of micro-trainings limited to 5–10 min. In this way, we reduce the impact on the individual's psychosomatics, the strain on the eyes, and in the long run, also the cognitive load for the individual.

There are many options for further research in the future. One option for research could focus on the use of interactive videos in education [76,77], comparing interactive videos with traditional and 360° videos and using them in an immersive didactic model. For this purpose, it is possible to use a 3D smartphone adapter or view a 360° video through VR glasses. The use of holograms in education is also an interesting area of further research [78]. For immersive content and video, motion capture suits [79] can be used to capture motion in real time, perform various cyber animations, and incorporate the concept of meta-humans [80]. For combined training in the future, new opportunities are opening up for scientific research into the use of meta-humans. Additionally, the use of computer games for the purpose of problem-based training in conjunction with cyber-physical systems could be a good combination for further research and integration into the training system. This research could be performed with newer VR glasses such as the Oculus Quest 2, Pico, or HTC Vive. Simple smartphone adapters could be used to replace the head-mounted display. Another very interesting area is the more detailed exploration of augmented reality (AR) in education. The technologies are developing rapidly and offer good user experience and many educational opportunities. In our case, the research can be performed with more advanced devices such as the Microsoft Hololens 2, Vuzix Blade, and Vuzix M, among others. Another interesting area of research is the use of music for educational purposes [81] and integrating it into VR learning environments [82]. Yet another interesting area of research is the integration of AI with cyber-physical systems and the possibility of developing personalized tutoring systems for education in cyber-physical environments. In the future, we can investigate whether there is a difference between orientation in space and orientation in virtual space, or whether students with better spatial orientation orient better in virtual space. We can also ask whether this has an impact on faster knowledge acquisition. An EEG device with multiple measurement points could be used to measure cognitive activities and the captured measurement signals could be analyzed in more detail. Heart rate, facial expression, and eye activity can be measured along with cognitive load so that the content of the cyber-physical learning system can be tailored to the individual learner. Another important aspect is the impact of the cyber-physical system on short- and long-term memory, which needs to be further investigated in the future. Future studies should investigate how cognitive load changes over time in a cyber-physical environment and which measurement tools are more suitable for measuring cognitive load in virtual environments. As such, different cognitive load (ICL, ECL, and GCL) could be measured in a virtual environment.

It is important to introduce new technologies into the educational process, considering the above recommendations regarding time constraints. At the same time, it is very important to also maintain learning through traditional written sources [83]. Throughout evolution, our brains have adapted to reading written sources and therefore processing information differently than when reading screens. Let us not forget handwriting, which is also a very important factor in education and personal development [84]. We propose an educational system (Figure 7) in which we balance different approaches by delivering part of the education with traditional written resources and another part with electronic written resources and closed and open hypertexts combined with modern online classrooms or massive online open courses (MOOCs). Students who take an MOOC have cognitive interests, but they are also motivated to achieve goals such as certification and improving their professional skills [85]. However, we must be aware that large groups of students from the same university may perceive the same e-learning platforms used in the teaching and assessment process completely differently, as shown in one of the studies [86]. We can combine these with collaborative learning tools, e.g., using smartphones as learning tools and AI learning and assessment tools for tutoring students. In the case of distance learning, deep and meaningful learning (DML) in distance education should be an essential outcome of quality education [87]. In the third part of modern education, we propose to use the above-mentioned modern technologies such as 360° video and XR immersive technologies to further influence learners' motivation and achieve higher learning goals.

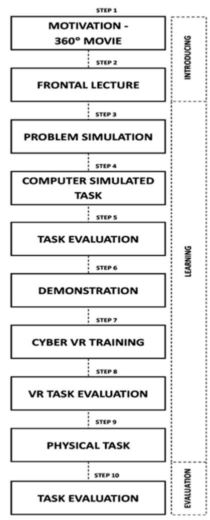
Standard Education ⟺	**E-Education** ⟺	**Immersive Education**
Frontal lectures Discussion Debates Written learning sources Books Written and verbal assessment Hand writing	Blended learning Online classroom E-learning materials Education video Interactive video Books with QR codes Open and closed hypertext Massive open online courses Collaborative learning software New generation learning management software AI tutor systems AI evaluation systems Flipped classroom Distance learning DML	360° education video Interactive educational virtual tours XR technologies, CPLM 
Problem-based learning, collaborative research team work, micro-training, gamification		

Figure 7. A proposal for a modern educational model.

One of the studies notes that, after the COVID-19 pandemic, more attention has been paid to the efficiency of technology than to effectiveness. The earlier technological development of e-learning was a promotional measure to encourage potential users to adopt and use e-learning. However, the recent technological development of e-learning was the essential foundation of education, as it was the only way to continue education under the conditions of x COVID-19-related quarantine and lockdown [88].

7. Conclusions

As we can see in Figure 6, the measurements of 360 V-A were increased by 11% compared to EV-A when a normal educational video was watched and by 16.03% compared to AR-A when the app AR was used. We can see that the attention measures show greater attention with the 360° video than with an instructional video and AR app. However, the results are not statistically significant. The conclusion is that the results are statistically significant when we compare 360° video and AR apps. We need to look at these results in a broader context. In previous research, we found that the modern CPLM learning model improved students' procedural knowledge regarding all the limitations and recommendations. Therefore, with the above limitations of EG and the limitations of the research, we can confirm hypothesis H1 and claim with high probability that there is a significant difference in students' attention when 360° videos and an AR app are used in the classroom.

The results show that the students' procedural knowledge improved. Since the 360° video is part of the overall model, we can say with great certainty and with all limitations that the 360° video has an impact on students' motivation and consequently on the acquired knowledge. In the future, we need to expand our research to a larger group of students and minimize the impact and limitations of the study. We may also ask what the survey results would be if 360° videos were viewed with VR glasses or a 3D headset VR for a smartphone. The results would likely be different if we used the AR glasses Hololens. These are goals for future research.

Education has had to adapt to the development of civilization, culture, and technology. Theoretical and methodological developments have produced new approaches in key areas of educational history [89]. A paradox has arisen in the integration of modern technologies into education. We used to limit the time children spent looking at screens; now we want to put screens right in front of them. Is technology is a problem or a tool? Elon Musk has publicly expressed that no one wants a screen strapped in front of their face [90]. These are some of the reasons to study the field, evaluate it, and set guidelines for education in the future.

In the past, the development of technologies has influenced socio-technological developments. The first breakthrough came with the development of electronic semiconductor components and transistors, which led to the development of personal computers [91], and later to the development of computer-controlled machines and robots [92]. The development of personal computers has grown exponentially since the development of the first PCs. The speed and power of the devices have increased, while at the same time, the sizes of the devices have significantly reduced. Electronic information and communication technologies have begun to have a significant impact on individuals' daily work and leisure time [93]. The development of technologies has also affected the development of education. The paradigm of humanism or the paradigm of holistic cognition is the basis for the genetic integration of the knowledge, skills, competencies, moral imperatives, and social values that contribute to the effective development and socialization of individuals. The role of the teacher in the modern world has been to guide the knowledge intended for learners in the context of mass information. The teacher's professional activity does not aim to be the sole source of specialized information, but rather aims to help learners find the necessary information, analyze it, appropriately evaluate it, and form their own opinions and ideas [94].

At the same time, in addition to their expertise, we need to prepare students for daily life by guiding them in the constant search for new goals and by teaching them the importance of ethical norms and personal values that form the basis of their actions. Professional ethics, attitude towards work and work tools, professional communication, and initiative are essential for professional performance. These have been mentioned by Slovenian employers as essential soft and cross-cutting skills for future employees. Technical skills are not essential as they can be learned and applied in professional practice. There will be many challenges in the field of education in the future. Education systems will have to adapt to future developments, which will be a challenge for all social partners, education staff, and learners.

To summarize the message of *The Little Prince*: creative people dream with open eyes, seek new experiences, ask interesting questions, observe others, and confront their opinions with their own beliefs. As they progress towards the goal of being a student, they transform into adults—responsible people who are curious, honest, and try not to deviate from their values. Let us use the time we have to have new experiences and adventures, let us think free of mental templates, let us be joyful and curious. We live in a time of rapid change, global upheaval, and migration. In order to remain competitive in the labor market, we must constantly educate ourselves, seek out new knowledge and insights to gain the experience that forms the basis for new knowledge. Thus, let us work together and succeed in uncovering and creating new knowledge on our journey to the world of modern technologies and education.

Author Contributions: Conceptualization, M.V., I.P. and B.A.; methodology, M.V., I.P. and B.A.; software, M.V., I.P. and B.A.; validation, I.P. and B.A.; formal analysis, M.V., I.P. and B.A.; investigation, M.V.; resources, M.V.; data curation, I.P. and B.A., writing-original draft preparation, M.V. and I.P.; writing-review and editing, M.V., I.P. and B.A.; visualization, M.V.; supervision, I.P. and B.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the research standards and ethics of Institute of Contemporary Technology, Faculty of Natural Science and Mathematics, University of Maribor (FNM_ICT) and approved by the Ethical commission for studies involving humans (1_2022).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: This research was a part of Matej Veber thesis from Ph.D. Program in Educational Technique. The authors would like to thank the Slovenian Research Agency (ARRS).

Conflicts of Interest: The authors declare no conflict of interest.

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