Visual Learning Technologies in the Immersive VET

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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.

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

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 researchers cannot even imagine today or that researchers can only imagine in outline based on current developments [3]. Researchers 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. Researchers 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, researchers 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][16][17][18]. However, with the development of technologies, 360 VR videos are also being successfully integrated into the classroom [19][20][21][22]. It is a challenge regarding how researchers integrate immersive technologies into a modern learning process and how researchers 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, researchers developed and evaluated a modern learning model, which is the cyber-physical learning model (CPLM).

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. Researchers learn through videos and multimedia content. Researchers 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].

Researchers 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, researchers 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. Researchers' 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 researchers used for educational 360° video. According to the sources, 360° video is widely used in education [19][31][32][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][39][40][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 researchers 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][47][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, researchers 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.

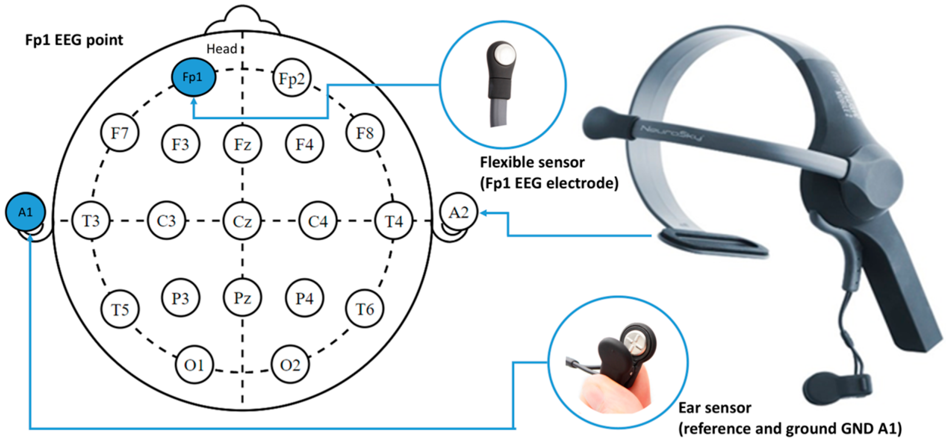

Figure 1. Electrode position based on the standard international system of electrode positions [59].

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].

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