Virtual Reality as a Learning Tool: How and Where to Start with Immersive Teaching

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Abstract Innovations in the field of educational technology are very prominent. The application of immersive virtual reality (VR) in teaching and learning is currently in the focus of interest of researchers dealing with education. Numerous studies indicated that there are significant potential benefits of using this technology to improve learning outcomes and students' motivation, overcome school-based and test anxiety, influence empathy, and ensure students focus on teaching content. However, there is still an issue of economic justification of investment in head-mounted displays (HMDs) and VR software for school use. Additionally, the key questions that arise from using VR in the classroom are on what theoretical basis to build immersive teaching and how to choose relevant content. The purpose of this chapter is to present a literature review of VR applications in education (with emphasis on both technological and pedagogical aspects, integration, and evaluation criteria), as well as to show the results of a small qualitative study conducted with teachers and an educational media specialist (all familiar with using VR as a teaching tool) in the Republic of Serbia.

Keywords Educational technology · Head-mounted display · Immersive learning · Immersive technologies · Technology-enhanced learning · Virtual learning environment · Virtual reality

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1 Introduction

The use of information and communication technologies (ICT) in educational contexts modified the learning environments dramatically, providing a significant challenge and continuous changes in learning approaches and instruction (Spector, 2014). Recent innovations in the field of virtual technologies have facilitated the access to VR and augmented reality (AR) to everyone, which opened up numerous opportunities for using these technologies in educational sector in order to improve the efficacy of learning (Martín-Gutiérrez, Mora, Añorbe-Díaz, & González-Marrero, 2017). However, Spector (2014) pointed out that the simple use of a new technology to replace prior practice may not be beneficial and described a smart educational technology as one that accomplishes effective, efficient, and engaging use, often in an innovative, flexible, and adaptive manner.

According to Gros (2016, p. 6), "smart education encourages a 'high-level' use of technology, utilizing it as a 'mind tool' or 'intellectual partner' for creativity, collaboration and multimedia productivity." Also, the same author emphasized that a concept of smart learning is broader but highly related to the term "technology-enhanced learning" (TEL), which is more familiar and more frequently used in Europe. The term TEL is often described only as the usage of the ICT in teaching and learning (Kirkwood & Price, 2014), and in recent years the focus was on the application of mobile devices (Zhu, Yu, & Riezebos, 2016). However, the wider conceptualization of the TEL as the intersection of technology and pedagogy would be more appropriate (Bälter, 2017). Changes in teaching methodologies and learning strategies are also required since the effective use of technological advancements goes beyond the simple application of new educational technologies in a learning environment (Kinshuk, Chen, Cheng, & Chew, 2016).

Teaching using technologies is often considered innovative per se, and usually, the success of technology integration has been based only on the extent of use (Moyle, 2010). However, Daniela, Kalniņa, and Strods (2017) asked: "Can all technologies be considered innovative?" (p. 89), and Spector (2016) emphasized that innovative and adaptive technologies have the potential to support, facilitate, and enhance learning, but only if there is evidence of those benefits that innovative technology can be considered as an innovative learning technology, as well.

Modern immersive technologies created new opportunities to turn learning into an exciting endeavor (Kovács, Murray, Rozinaj, Sulema, & Rybárová, 2015). Kinshuk et al. (2016) indicated AR and VR as examples of innovative technologies that can be used in smart learning environments to enable learning opportunities that have been very difficult (or impossible) in traditional settings. Both technologies are different but related in some characteristics and usage (Liu, Bhagat, Gao, Chang, & Huang, 2017). AR supplements the real world with virtual objects, while VR simulates a whole reality and is usually defined as a three-dimensional computer-generated environment, available in real time, which allows user interaction through different input/output devices (Boud, Haniff, Baber, & Steiner, 1999). In the educational context, VR can be defined as a collection of various technologies (hardware and software) that could be used to deliver an immersive learning experience (Hussein & Nätterdal, 2015; Liu et al., 2017).

The term VR has been used to describe a lot of different technologies, such as online virtual worlds, massive multiplayer online games (MMOs), simulations, flight or surgery simulators, Cave Automatic Virtual Environment (CAVE) systems, as well as a wide range of HMDs (Jensen & Konradsen, 2018). Usually, VR involves full immersion by using the HMD and a six-degree-of-freedom (6-DOF) input controller to manipulate the environment (Robertson, Card, & Mackinlay, 1993). In the literature, immersion is related to the sense of presence (or to the experience of "being there") which should be the main goal of virtual environments design, as well (Cummings & Bailenson, 2016). However, Robertson et al. (1993) conceptualized nonimmersive VR (3D environments on a computer screen that can be directly manipulated using a keyboard or a mouse) as an alternative form of VR. Nowadays, the term "desktop VR" is more frequently used instead of "nonimmersive VR" since immersion also refers to an intellectual or emotional involvement, not only to the sense of presence in a specific space/environment or location (Freina & Canessa, 2015).

Currently, the use of VR in education is far from mature, and the main question still is what is appropriate and beneficial to teach with this educational technology and how to teach it (Liu et al., 2017). In this chapter, we argue that the immersive teaching and learning can be potentially considered innovative and effective, as well as that VR should be one of the various technologies included in a smart learning environment.

2 Literature Review

For more than half a century, technologies related to VR have been under development (Olmos, Cavalcanti, Soler, Contero, & Alcañiz, 2018).

Merchant, Goetz, Cifuentes, Keeney-Kennicutt, and Davis (2014) emphasized that immersive VR was beyond the reach of schools, and there were a lot of problems that disabled the mass use of this technology in education (e.g., the high cost of HMDs, many users experienced discomfort and motion sickness, and the instructional design of virtual learning environments was poor). However, desktop-based VR found its use in K-12 and higher education settings, and many educators have integrated those technologies (such as simulations, games, and virtual worlds) into their instruction practice. The same authors conducted a meta-analysis and examined a total of 13 studies in the category of games, 29 studies in the category of simulations, and 27 studies in the category of virtual worlds. The results showed that games, simulations, and virtual worlds were effective and had a positive influence on learning outcome. Still, games showed higher learning gains than simulations and virtual worlds.

Graziano (2017) pointed out Second Life as the most mature and popular virtual world used in education, and the TLE TeachLivE™ lab as one of the best-known simulations of classroom experiences for training pre- and in-service teachers. Nebel, Schneider, and Rey (2016) indicated that there is a growing interest of researchers and teachers for software (especially for educational videogames and serious games), and they emphasized that commercial videogames could be utilized as educational tools, as well. Also, the same authors analyzed the educational use of Minecraft and concluded that this game offers tremendous qualities regarding creation, collaboration, and distribution as well as that it has already been in worldwide use on various educational topics. Currently, a teacher-friendly platform Minecraft: Education Edition and virtual lab simulations Labster are more and more in use for learning in formal educational settings.

According to Freina and Canessa (2015), two main types of immersive VR are CAVE systems and HMDs.

The CAVE is a room-based fully immersive VR system invented in 1992. The side walls (as well as the floor and ceiling) of a cubic room are made of projection screens. The participant is wearing a special pair of goggles to obtain a stereoscopic view of the virtual environment. Different input devices can be used to provide interaction between participants and the system (the user can point out, select, or drag and drop virtual objects). The potential use of CAVE has been explored in various domains including education, but the actual application was often limited to research projects (Muhanna, 2015).

Ivan Sutherland created the first HMD and head tracking system in 1968, and since then (thought continuous development), this technology emerged from limited use in specialized fields and research laboratories to a low-price commercial device (Liu et al., 2017). The argument that immersive VR can be used for simulation-based learning (where students can learn and practice new skills in a secure and interactive environment) with the potential to revolutionize education has been discussed for decades (Jensen & Konradsen, 2018). However, the HMDs had no significant and large-scale application in educational settings until now (Stojšić, Ivkov Džigurski, Maričić, Ivanović Bibić, & Đukičin Vučković, 2017). Nowadays, the situation has changed due to success of the first developer version of Oculus Rift in 2013 which led to a new generation of better-quality and consumer-priced VR goggles (Jensen & Konradsen, 2018). The Oculus Rift was the first affordable and comfortable computer-assisted HMD with a wide field of view. The development of Google Cardboard (which uses a smartphone and a cheap cardboard/plastic VR headset) in 2014 enabled massive commercial use of immersive VR for the first time in history, and through Google Expeditions Pioneer Program (that started in 2015), millions of students worldwide began to use this technology for learning in their classrooms (Stojšić et al., 2017).

The new HMDs can be grouped into three categories: 1. PC/console-based (or desktop-driven VR) headsets (such as Oculus Rift, HTC Vive, Windows Mixed Reality devices, and PlayStation VR); 2. mobile-based (MVR or smartphone-driven VR) headsets (such as Google Cardboard-type devices [including View-Master VR, Nearpod VR, and Merge], Daydream View, Samsung Gear VR, etc.); and 3. standalone VR devices (such as Oculus Go, Lenovo Mirage Solo, VIVE Focus, ClassVR, and similar).

Freina and Ott (2015) conducted a systematic review of papers published during 2013 and 2014 related to the potentials of use of immersive VR for educational purposes. Most of the analyzed articles focused on pre-university (high school) and university learning settings (particularly in the field of teaching science and medical subjects), as well as adult education and training. The results showed that immersive VR has some advantages: it could give an opportunity to experiment with the situations and objects that have some limitations in real life (e.g., different time periods, physical inaccessibility, lack of access, or it is highly dangerous to access, ethic problems, etc.), could offer practice and training in a safe environment, could increase the learner's involvement and motivation, could support different learning styles, and could facilitate content understanding and memorization.

In a comprehensive review of the literature, Jensen and Konradsen (2018) analyzed 21 articles reporting on experimental studies of the use of new HMD devices in education and training published since 2013. All of included studies were based on the idea that immersion has a positive impact on the learning outcomes. The findings showed various situations where HMDs can be useful for skills acquisition (including cognitive skills, psychomotor skills, and affective skills) and that learners generally had a positive attitude toward the use of immersive VR technology. Reported drawbacks and barriers included cybersickness symptoms, lack of appropriate software, technological challenges, and the possibility that the immersive experience could distract students from a learning task. Also, the authors emphasized the need for further research on the use of HMDs but in an authentic educational context (not laboratory-style experiments).

According to Cochrane (2016) and Stojšić et al. (2017), the most suitable and affordable option for implementing immersive VR in educational settings is MVR since schools computers in most cases do not meet the Oculus Rift or the HTC Vive demands. The VR headsets based on a smartphone are suitable for classroom use and investing in such HMDs is economic (Olmos et al., 2018). Moro, Stromberga, and Stirling (2017) compared performances between two HMDs (desktop-based Oculus Rift and mobile-based Samsung Gear VR) in a study where 20 participants were allocated to one of two headsets in order to complete a lesson and test (which evaluated the transfer of knowledge) on spine anatomy. The results showed that the test scores in both groups were the same, but participants in the mobile-based VR group experienced more cybersickness symptoms (especially disorientation and blurred vision). The authors concluded that all participants perceived the VR lesson as more engaging and fun and that the affordable MVR could be just as suitable as the more expensive desktop-based VR for teaching medical and health science (since cybersickness symptoms did not drastically influence the perceived usefulness of this learning tool and students' enjoyment).

In the past, the high price of HMDs was one of the biggest entry barriers for using immersive VR in educational settings. Today with low-cost MVR HMDs that issue seems solved, especially in schools in which BYOD (bring your own device) model is allowed (Olmos et al., 2018). Vishwanath, Kam, and Kumar (2017) demonstrated that MVR (with the Google Cardboard-type viewers) could be successfully integrated in low-resource educational settings with positive impact (deeper level of students' engagement with the learning materials).

The use of pre-made (off-the-shelf) VR apps and content is prominent in research studies dealing with the educational use of MVR. For example, Minocha, Tudor, and Tilling (2017) pointed out the potential application of 360° photospheres and videos for educational purposes. They also investigated the use of Google Expeditions app in primary and secondary school science and geography (the research included both students and teachers). As a result, the authors identified 10 affordances of using this app: 1. 360-degree visual authenticity (accurate physical representation of the space, spatial relationships, sense of spatial presence, etc.), 2. 360-degree navigation, 3. 3D view, 4. emphasis (teachers can highlight certain aspects of a scene), 5. first-person perspective, 6. in situ contextual information, 7. simulations (perceived benefits such as realism, image detail, and ability to see the connection between elements), 8. single-user handling (not being conscious of others, sense of control, and sense of immersion), 9. synthesis (educators can use more than one expedition, as well as other resources), and 10. visualization (perceived benefits such as authenticity, sense of scale, sense of space, etc.).

The possibility that users (e.g., researchers, teachers, and students) can create their own VR content has become a reality (Martín-Gutiérrez et al., 2017; Stojšić et al., 2017). The game engine Unity was often used for creating immersive educational environments in research studies (see Freina & Canessa, 2015; Hussein & Nätterdal, 2015; Moro et al., 2017; Vega, Rose, Eckhardt, Tahai, Humer, & Pietroszek, 2017). Also, the popular VR creation tool CoSpaces Edu, commercial 360° cameras, as well as apps for making 360° panoramas (such as Street View, Cardboard Camera, and similar) were often mentioned in the literature (Stojšić et al., 2017). Cochrane et al. (2017) proposed a framework for designing MVR learning environments and described two projects (Mesh360 and Augmenting the Classroom) that aimed to enhance learning in higher education. The idea and concept of WebVR (instead of downloading and using apps, the VR content is available in a web browser) could be potentially useful to facilitate creation and distribution of educational VR experiences. A-Frame is an easy-to-use framework for creating WebVR apps without diving into technical details, and it supports embedding HTML elements (such as videos and images) inside a VR environment (Prins, Gunkel, & Niamut, 2017).

Virtual learning environments can be created using the VR technology, but a clear pedagogical model (or framework) is required to inform the design and use of the systems (Fowler, 2015). The questions covering relevant pedagogical frameworks (that could support the implementation of VR in the classroom) and integration and evaluation models need to be addressed as well.

Liu et al. (2017) suggested three key theoretical bases for applying VR in education:

1. *Constructivism* – puts students at the center of the learning environment and the activities and interactions keep challenging learners' prior experience, as well as promoting the construction of new knowledge. Instructional strategies (extended

from this theory) such as situated learning, experiential learning, and collaborative learning are appropriate for teaching and learning with VR.

2. *Autonomous learning theory* – refers to self-directed learning where learners pick their learning targets and choose how to achieve them. However, students' self-control and an ability to use the feedback from a teacher or the environment are required. The VR technology can provide a suitable learning environment for autonomous learning and practice, since students can check their learning outcomes and receive real-time feedback from the environment.
3. *Cognitive load theory* (CLT) – refers to limitations in human working memory during mental activities (e.g., thinking, problem-solving, etc.). The VR learning environments can be highly realistic with multiple modalities of information, but the rich simulation may induce split-attention effect (students ignore the real learning objective, focusing only on a specific stimulator) and overload (when mental load exceeds the capacity thus negatively affecting learning outcomes).

Pantelidis (2009) pointed out that it is not appropriate to use VR with every teaching material and instructional objective and proposed a ten-step model to determine when to use VR in education. This model emphasized the importance of considering the specific characteristics of objectives (steps 1 and 3), determining the reasons to use VR for selected objectives (type of immersion and interaction needed, as well as what are the main advantages of application) (steps 2 and 4), choosing appropriate VR equipment and the virtual environment design (steps 5 and 6), and using the evaluation cycle (steps 7, 8, 9, and 10).

According to Vishwanath et al. (2017), MVR could be integrated in the curriculum in four different ways: 1. to demonstrate actual real-world phenomenon (this is applicable when there is or can be made VR content exactly on the selected topic), 2. to illustrate abstract concepts, 3. to compare and contrast (e.g., students can be asked to compare different ecosystems, climates, landscapes, cultures, systems of government, etc.), and 4. to arouse interest. There is also a need for an evaluation framework appropriate for learning activities with VR, and the SAMR model (see Puentedura, 2013, 2015) is often recommended (Graziano & Daley, 2017; Romrell, Kidder, & Wood, 2014). This model includes four levels of technology integration (substitution, augmentation, modification, and redefinition), and for each level, explanation, examples, and questions are provided to support teachers in implementing educational technologies (Puentedura, 2013, 2015). Lessons and activities created using VR technology should be above the substitution level of the SAMR in order to be recognized as potentially innovative.

In the literature, health issues (such as cybersickness) are often related to the use of immersive VR. However, in the context of mental health treatment, VR is a powerful tool well suited for exposure therapy (Maples-Keller, Bunnell, Kim, & Rothbaum, 2017). VR exposure therapy (VRET) is a relatively effective treatment that can reduce anxiety and phobia symptoms (Parsons & Rizzo, 2008). School phobia is related to diverse events associated to school (such as to be bullied or criticized in front of the class, having to speak in public or do exams, etc.), and the use of VRET is an important tool to reduce the intensity of school-related fears

(Gutiérrez-Maldonado, Magallón-Neri, Rus-Calafell, & Peñaloza-Salazar, 2009). Examination-related anxiety is a serious problem in education and can affect students' academic results. The VRET offers several advantages over in vivo exposure and permits the design of various exam situations (such as adjusting the difficulty of the test or adapting the virtual environment more closely to the learner's situation in real life) (Alsina-Jurnet, Carvallo-Beciu, & Gutiérrez-Maldonado, 2007). Also, the VRET can be helpful for reducing public speaking anxiety of students, and VR smartphone apps for mobile HMDs provide the possibility of treatment in a home environment (which could be relevant for students who do not seek treatment) (Stupar-Rutenfrans, Ketelaars, & van Gisbergen, 2017).

3 Method

To capture authentic and in-depth information, we conducted a small exploratory qualitative study regarding teachers' experience and reflections on their use of immersive technologies in the classroom.

3.1 Participants

We used purposeful sampling and invited 12 teachers (whom we had previously established collaboration with) to participate in this research. The selected teachers met two required criteria: (a) demonstrated a passion for innovative teaching and (b) already used VR as a teaching tool in the classroom. For the first criterion, participants provided us with their lesson plans and online links to their materials (such as presentations of eTwinning projects they participated in, blog posts about their teaching innovations, video and photo materials from their classrooms, etc.). The second criterion assured us that teachers could provide a useful data about the integration and usage of VR in schools. However, only six teachers (from six different public schools in the Republic of Serbia) agreed to participate. Due to such low response rate, we invited an educational media specialist (responsible for the integration of VR and teacher training in a private school), and he responded positively.

The participants were given pseudonym names to protect their privacy. Toni (the educational media specialist) had 2 years of working experience with the educational use of VR. He had trained and supervised more than ten humanities and science teachers (in a private school where he works) on the use of different VR devices (HTC Vive, Samsung Gear VR, ClassVR, and Google Cardboard). For a summary of the teachers' demographic information, see Table 1.

Table 1 Teachers' profiles

Teacher's name	Gender	Years of teaching	Type of school	Subject	Immersive teaching experience
Sanja	Female	3	Primary	Geography	1 year (MVR)
Marko	Male	14	Primary	Geography	1.5 year (MVR)
Jagoda	Female	28	High	Mathematics	6 years (desktop VR and recently MVR)
Ana	Female	24	Primary	Mathematics	4 years (desktop VR)
Maja	Female	16	Primary	Chemistry	6 months (mobile AR/VR)
Mira	Female	10	Primary	1–4 grade teacher	2 years (mobile AR/VR)

3.2 Data Collection and Analysis

This study was carried out in the first term of the 2017–2018 school year. We used reflective writing as a method (see Chretien, Goldman, & Faselis, 2008; Jasper, 2005; Schön, 1983; Yesilbursa, 2011) to collect data from the selected teachers. A Microsoft Word template was created and sent via e-mail to all potential participants. The participants were asked to write reflections on their prior teaching with VR, as well as to provide their prepared lessons plans and other related materials. Also, we created an online questionnaire (through Google Forms) to obtain demographic data.

Miles and Huberman (1994) pointed out that "Qualitative data can be reduced and transformed in many ways: through selection, through summary or paraphrase, through being subsumed in a larger pattern, and so on." (p. 11). We used pattern coding to find common themes in the data. The identified related segments in participants' statements were used to demonstrate the particular theme.

4 Findings

The participants' statements were categorized into four themes: support, integration, perceived impact and benefits, and barriers and limitations.

4.1 Theme I: Support

All the participants dedicated special attention to the question of support (or the lack of it). The initiative and students' support (who through BYOD approach provided and used their own mobile and/or VR devices) were crucial for Sanja, Marko, and Mira to start using immersive technologies in teaching. Jagoda, Ana, and Maja saw themselves as the main factor in introducing new technologies into the teaching process. Sanja also emphasized the support of her school colleagues (with whom she organized exemplary classes using VR viewers), as well as the support of the principal who provided additional ten Google Cardboard headsets (she bought the first ones at her expense). Maja pointed out the significant support of her international colleagues (whom she cooperated through eTwinning and similar international projects), and a complete lack of support from the colleagues and managers in her school, and emphasized that she did everything "in a makeshift manner and at her expense." Marko and Ana indicated that they did not have any support of their schools for buying HMDs, while Ana stated that she tried (but in vain) to find help for creating her own educative VR contents. Jagoda (who saw herself as an innovative teacher with extensive experience with using ICT for educational purposes) pointed out the lack of society support for innovative teachers and the lack of parent support (because many of them oppose the use of modern technology in classes).

Toni emphasized that he was always the available support for teachers in his private high school. He indicated that the teachers were most frequently very reserved at the beginning of the training and without previous personal experience with VR/AR technologies. However, in the end, the majority of them started applying those educational technologies in their teaching. He described the process this way:

> Upon completing their training, the teachers have the opportunity to use all available VR/AR technology in school. Since there are a limited number of VR devices, there is a table where the teacher can reserve the HMDs (ClassVR or HTC Vive) for his or her class. Every teacher also received a short manual for each of the headsets and concrete examples for his or her subject. I always helped them in preparing their initial classes.

4.2 Theme II: Integration

Only Jagoda and Maja stated that they had technical and organizational problems in the process of integration, while Mira emphasized that the implementation of mobile AR (MAR) and MVR into the teaching process was easy.

Geography teachers described different ways they used MVR. Sanja wrote that she used 360° panoramas and video materials for covering regional geographic contents (grades 6 and 7) but always combining them with other mobile apps and online tools (e.g., QR codes, associations games, online blank maps, formative quizzes, or writing a blog post about a particular country or city). Marko wrote that he used pre-made apps (such as Titans of Space® Cardboard VR and similar) for covering mathematical geography and astronomical contents (grade 5) as an additional activity in classes along with his presentation and quiz. Sanja also emphasized what novelties the VR technology enabled in her teaching:

> Thanks to VR, children have the opportunity to learn in an interesting manner about distant places of the world (that they would probably never have a chance to visit). In this way, they can individually explore those remote spaces and analyse them together in the end. The entire class is directed towards students exploring.

Mathematics teachers Jagoda and Ana reported using desktop VR and mainly 3D mathematics simulations. Ana pointed out that VR helped her when she wanted to show real life mathematics examples (such as volume and surface calculations of actual objects and buildings). Jagoda wrote about her experience with SLOODLE (Second Life + Moodle), which was not always positive, so she started using Minecraft: Education Edition while she began using MVR through BYOD concept.

Maja and Mira reported using BYOD concept. Maja wrote that she used available mobile, AR, and VR apps and integrated them based on the examples of good practice from her international colleagues. Mira stated that she used MAR more, particularly with group projects where her students created posters and used the HP Reveal app and platform to make them interactive. She indicated that she used MVR apps occasionally in order to present the abstract concepts in a simpler manner.

Reviewing the written reflections (as well as provided lesson plans), we found that teachers reported the limited use of immersive technologies (only with certain teaching contents, through group work activities or as a part of project-based learning) and together with other teaching tools.

Toni indicated that it could be hard for teachers to cope with using VR headsets in classes. However, he emphasized that the Avantis, a company that produces ClassVR, made the process of classroom integration easy. Also, he pointed out that other (public) schools could relatively easily introduce the VR technology if they have a stable Internet connection (since students could use their own appropriate mobile devices).

4.3 Theme III: Perceived Impact and Benefits

In sum, all the teachers stated that every single activity is important for making the class successful and that VR/AR is just one of many tools they use. Due to that, Mira emphasized that she could not really evaluate to what extent VR (individually) contributed to the educational results but that her students were enjoyed by it. Similarly, Sanja indicated that "each time the students saw VR glasses on the desk the thrill was immense since they knew what was coming." Sanja and Ana noted that when using the immersive technology, an oral analysis and a systematization of the covered material are desired (and necessary) at the end of the class.

The teachers' perceived benefits of introducing immersive technologies in teaching were better students' motivation (Sanja, Marko, Ana, and Maja), the classes became more interesting (Sanja, Maja, and Mira), the students acquired the matter easier (Sanja, Marko, and Ana), better learning outcomes (Marko and Jagoda), the feeling of thrill (Sanja and Mira), longer memorization of the acquired knowledge (Sanja), and better attention in class (Jagoda).

Sanja and Mira emphasized that VR has great potential when different subject contents need to be correlated or for the STEM (science, technology, engineering, and mathematics) learning concept. Toni concluded:

> When teachers master the use of VR HMDs, they organize their application more frequently and creatively. After a while of training, they usually told me that their students were more motivated to learn and more focused on the contents being taught in class.

4.4 *Theme IV: Barriers and Limitations*

All of seven participants pointed out certain limitations, as well. They mostly wrote about those they were facing personally in their schools, while some wrote about general limitations that could be related to the entire educational system of the Republic of Serbia.

Reported personal perspective limitations were the availability of school-owned devices and the lack of investments in educational VR/AR content and apps (Marko, Ana, and Maja), the stability of the Internet connection in school (Sanja and Toni), the lack of easy-to-use authoring tools for creating VR experiences (Marko and Maja), and increased time needed for class preparation (Sanja indicated that it takes 4 h, on average).

General perspective barriers included the poor knowledge of teachers about immersive educational technologies, as well as the prevailing lack of motivation of teachers to introduce innovations and improve the teaching process (Maja, Mira, and Toni), and the teachers' fear of other teachers and parents (who oppose the use of new technologies and mobile devices in classes) (Jagoda).

Marko emphasized that "The main obstacle is the equipment because we do not have enough Google Cardboard viewers and smartphones in my schools. Luckily, my students always bring their own (whenever needed)," while Toni indicated: "In my opinion, the main obstacle is the teachers' lack of familiarity with the VR technology. It is necessary to train the teachers and motivate them to apply immersive technologies in classes."

Sanja concluded that it is possible to overcome all limitations since "if you have a motive and will to bring the world to your students (in the classroom) and make them love your subject then no obstacles truly exist."

5 Discussion and Conclusion

Smart education describes a concept of personalized and seamless learning in a digital age (Zhu et al., 2016), and since VR extends the learning experience, it could be one of many technologies integrated into a smart learning environment (Hoel & Mason, 2018). However, integration will require educators' time and effort to learn how to use VR as tool for teaching, and school leaders will need to navigate the purchasing decisions (the current offer of HMDs and VR educational apps creates an overwhelming choice), training sessions for teachers and students, as well as to monitor curricular implications (Johnston, Olivas, Steele, Smith, & Bailey, 2018).

The HMDs can be used as a medium to access virtual environments and simulations, but learning might occur only if particular VR content (or experience) is efficient and effective (Jensen & Konradsen, 2018). Olmos et al. (2018) emphasized that the VR technology is not a limiting factor anymore but rather the quality of experiences, and if we find a way to design and develop useful immersive educational content supported by the adequate teaching methodologies, "a new stage in educational history will be given birth" (p. 103). According to Johnston et al. (2018), "Adapting the VR technology means that educators will need to decide where and how the VR applications fit." (p. 416).

Our study has several limitations. The number of participants was very small, and generalizability of the results is limited. Only six public school teachers and an educational media specialist (employed in a private school) took part. Also, the teachers reported their subjective perceptions of benefits of using VR, which were not objectively measured. Still, these limitations are often associated with the educational qualitative research.

We used reflective writing as a method since this approach could be helpful in triggering teachers' in-depth thinking about their teaching practice (Yesilbursa, 2011). Four main themes in the participants' statements were support, integration, perceived impact and benefits, and barriers and limitations.

Support was one of the key factors related to the use of immersive technologies in educational settings. All dimensions of support (student-teacher, teacher-teacher, teacher-media specialist, teacher-principal, teacher-parent, and teacher-community) were indicated. Also, the teachers reported the lack of formal training opportunities in the area of the use of VR in education. Therefore, proper preparation and training for pre- and in-service teachers should be organized (Graziano, 2017; Liu et al., 2017; Olmos et al., 2018; Stojšić et al., 2017).

The teachers included in this research reported using MVR (and MAR) based on the BYOD model of integration for specific learning targets, usually through group learning activities or in project work context. Our participants indicated that the off-the-shelf VR experiences have to be matched with the curriculum and lesson goals, as well as well combined with other tools. Similarly, Minocha et al. (2017) stated: "the most effective use of VR will be when it is combined with other technologies such as videos, podcasts, wikis, blogs or forums, and mobile apps" (p. 10). We believe that the new low-cost stand-alone HMDs (together with MVR), WebVR-based approaches (for designing and delivering VR educational content), and new easy-to-use authoring tools (such as Google's Tour Creator) will greatly facilitate the integration process. Prins et al. (2017) pointed out that social WebVR could be utilized for remote participation in the classroom, as well. The new VR technology seems well suited to the context of constructivism theory and active and simulation-based learning (Jensen & Konradsen, 2018). Learning objectives and constructivist instructional strategies should be the starting point for teachers, and the evaluation framework such as the SAMR model (see Puentedura, 2013, 2015) could be also used for designing (innovative) lessons with the VR technology. Liu et al. (2017) divided the use of VR in education into four (not mutually exclusive) types: observational learning (immersive experiences could enable a deeper understanding of learning content, as well as various time and spatial perspectives), operational learning (VR environments could be used as a safer training platform for tactile and kinetic learning), social learning (VR offers the potential for interaction and cooperation in the simulated environment and could overcome the limits of physical distance which is suitable for distance and blended/hybrid education), and academic research (the VR technology is able to simulate different science and engineering experiments and could decrease the risk and cost burden).

According to the participants, the immersive technologies are useful and have potential to bring innovations in the teaching process. The teachers reported using VR combined with other teaching tools, and they did not measure the effects of this technology alone on learning results. Consequently, they indicated benefits mostly in motivational aspects of learning.

Half of the teachers stated the lack of school-owned mobile and VR devices as an important limiting factor, and two teachers reported the lack of easy-to-use authoring tools. Olmos et al. (2018) emphasized limited available educational VR contents (both provided by publishers and created by teachers) as the main bottleneck for the real implementation of this technology in school settings. Also, the problems with the Internet connection in the classrooms, restrictive school regulations, and health and safety issues (like cybersickness), among others, are still present disadvantages and limitations (Stojšić et al., 2017).

VR differs from other ICTs, but it can be connected with various educational technologies and linked to teaching and learning with computers and mobile devices. Easy integration is necessary since in a smart learning environment, heterogeneous devices have to be successfully interconnected and combined to support adaptation and personalization (Gros, 2016). The VR technology enables unique benefits and access to immersive visual and kinesthetic experiences previously not possible in traditional classroom and lecture hall settings (Johnston et al., 2018). However, utilization of VR as a teaching tool is strongly associated with educators' ability to integrate immersive technologies into their pedagogical toolkit and instruction practice (Graziano, 2017; Graziano & Daley, 2017).

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