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The Use Of Virtual Reality, Augmented Reality, And The Metaverse In Education: The Views Of Preservice Biology And Mathematics Teachers

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This research aims to analyse the views of preservice biology and mathematics teachers regarding the use of virtual reality (VR), augmented reality (AR), and the metaverse in education. The participants of the research consist of 24 pre-service biology and mathematics teachers. The views of preservice teachers on the use of VR, AR, and the metaverse in education were analysed on the benefits of using VR, AR, and the metaverse in education, with what subjects/modules they can be best associated, and what would be needed to make it most effective. The preservice biology and mathematics teachers demonstrate that the utility of VR, AR, and the metaverse in education is beneficial for increasing the quality of learning and improving the existing teaching methodologies. Preservice teachers believe that these technologies are effective for teaching subjects that require more visual material, such as organs, cells, ecosystems, geometry, and the geometry of space or solid bodies. Moreover, the preservice teachers draw attention to the need for infrastructure and well-informed individuals (students, preservice teachers, teachers) for VR, AR and the metaverse. The results provide value for pre-and in-service training, teacher training and designing the teaching environments for the future.

Keywords: Virtual Reality, Augmented Reality, Metaverse and Preservice Teacher

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INTRODUCTION

The concepts of information and computer technologies, frequently discussed nowadays, are the indicators of how our future lives are going to evolve and develop through technology. Accordingly, in the near future, we are to experience and incorporate in our lives, rapidly emerging exponential technologies such as cloud and edge computing, high-speed mobile internet data, big data, artificial intelligence, robotics, nanotechnology, internet of things, biotechnology, 3D printing and extended reality (Misra, Roy & Mukherjee, 2021; as cited in Mystakidis & Christopoulos, 2022). Also, Mystakidis (2022) indicates that the exponential technologies which are on a constant and rampant high-speed growth, will expand even more when two or more of these technologies combined and their effects and results will increase even more.

Apart from leading to the fourth industrial revolution, also referred to as "Industry 4.0", these exponential technologies will bring in great social, economic and educational changes (Penprase, 2018; Mystakidis, Papantzikos & Stylios, 2021). Indeed, it is clear that an educated workforce will be necessary to satisfy the new ways of work, service and life that brought about by this unstoppable development. That is why individuals need to be equipped with suitable digital competencies during their school, university and even vocational education (Abe, Abe & Adisa, 2021; as cited in Mystakidis & Christopoulos, 2022). As such, researchers have stated that for the current teachers who will be educating the incoming generation of students, digital sufficiency and digital literacy, essential for the knowledge society, are indispensable necessities (Fernández-Batanero, Montenegro-Rueda, Fernández-Cerero & García-Martínez, 2020). Because of that, teachers-to-be have to rapidly attain digital sufficiency and follow new technologies. Also, Michos and Hernández-Leo (2020) explain that the digital and technological sufficiency of teachers is crucial both for them to conduct compatible teaching that prepares the students for the future life and work environment and also for a professional career development allowing the use of up-to-date technologies. As for Mysatikidis and Christopoulos (2022), they argue that the teachers' positive attitude toward technology is critical for any new learning/teaching technique integrated with technology. However, Wurdinger and Allison (2017) state that if teachers consider their working conditions to be worsening, they could react negatively against the incorporation of technology into education.

As a matter of fact, assuming that the teachers who were raised by traditional pedagogical tools and models are already prepared to utilize new technologies in education, would not be highly realistic. That is why, starting from preservice teachers who are currently in the preservice teacher education programs, all teachers need to be trained regarding the use of future technologies in education through pre-and in-service training. In this context, knowing the preservice teachers' views regarding the current educational technologies and determination their mindsets are of importance. The purpose of this research is to analyse the views of preservice teachers regarding the use of virtual reality, augmented reality, and the metaverse in education.

Virtual Reality, Augmented Reality and the Metaverse in Education

There is a need for an educated workforce, qualified to meet the social and economic conditions and lifestyles brought about by the rapid development of technology and equipped with suitable technological and digital competencies. After the adoption of computers, the internet and mobile devices in the recent past and with the advent of the age of computing platforms using technologies such as virtual reality (VR) and augmented reality (AR), training on the use of these technologies is a necessity (Mystakidis, Fragkaki & Filippousis, 2021).

VR is an artificial medium created by computer software that allows the user to accept it as a real medium, by the way it is presented to the user (Boz, 2019). The purpose of VR is to project the three-dimensional (3D) virtual world and to mislead the visual, auditory and tactile senses by providing conditions similar to reality but that are not real. Standard computing tools and devices such as glasses and stereo headphones, pieces of clothing or gloves that detect motion, are required to achieve that. That is how an individual can interact with three-dimensional objects, see and touch, from the moment they enter the virtual world (Boz, 2019; Mystakidis, Fragkaki, & Filippousis, 2021). Through the employment of VR technology in education, potentially dangerous or expensive experiments can be conducted; fieldwork can be done from inside the classrooms; experiments normally requiring an animal or a specific material can be done; a virtual object or a being can be examined as if it were real; operations, experiments, applications, solutions, activities, media or meetings can be watched and performed (Boz, 2019).

As for AR technology, it places virtual objects with augmented components into our real world and allows us to see these objects next to those in the real world, in the same dimension. AR technology consists of the real-time combination of the image of the medium in which we are physically present, and the visual or auditory data produced digitally (Hazneci, 2019). Azuma (1997) refers to AR as a technology where virtual objects are blended with the real world, while at the same time real and virtual objects are in interaction with each other. To use the AR technology, an internet connection, smart glasses, smartphones or tablets and AR applications installed in those devices are necessary. After that, the device is held onto the visual designed for AR and once the device detects the object/visual, the new three-dimensional image appears (Boz, 2019). Through developments in recent years, the use of AR technology has become easier and thus can be conveniently used from secondary school to university (Akçayır & Akçayır, 2017). Through the use of the AR technology in education, the students can walk around in places relevant to what they learn, visit museums, botanical gardens or zoos in other countries, stand inside geometrical shapes, utilize tools and machines with simulations, observe their surroundings as if they were in someone else's body and thus can internalize and feel what their teachers have taught them (Erbaş & Demirer, 2015).

Mystakidis, Fragkaki and Filippousis (2021) mention that AR and VR technologies will be able to ameliorate students' learning process and the quality of learning by improving their episodic memory and that these fundamental digital technologies will have a wide impact on daily life, communication-interaction, job-profession and teaching-learning. The concepts of VR and AR are known to be crucial components of the metaverse, an umbrella term containing numerous digital technologies within (Damar, 2021). Dionisio, Burns III and Gilbert (2013) define the metaverse as the concept of a three-dimensional virtual world that allows the interaction of the real and virtual worlds and Jeon and Jung (2021) note that it is a platform on which both online teaching and learning activities, as well as educational activities such as learning, communication and empathy, take place. The metaverse could also include blockchain technology, artificial intelligence, cloud and edge computing, cryptocurrencies, machine vision, and all virtual world applications under the domain of extended reality, like AR and VR (Damar, 2021).

Fernandez (2017) mentions that the teachers who will educate the students –the digital natives, play a significant role in the use of virtual world applications like VR, AR or the metaverse in teaching. Accordingly, it is the teachers who know in what fields the students need more help, in what topics or class modules these technologies can be more conveniently used and how to best complement such a learning experience while teaching (Fernandez, 2017). As a result, the question of how to train the teachers and preservice teachers to become competent, both in their fields and also digitally, should be analysed by multifaceted research and solutions should be developed

RESEARCH QUESTION

How do preservice biology and mathematics teachers view the use of virtual reality, augmented reality, and the metaverse in education?

Sub-Questions

1. What are the preservice biology and mathematics teachers' views on the benefits of the use of virtual reality, augmented reality and the metaverse in education?
2. What are the preservice biology and mathematics teachers' views on which subjects/modules can be best associated with the use of virtual reality, augmented reality, and the metaverse in education?
3. What are the preservice biology and mathematics teachers' views on what is needed to enable the effective use of virtual reality, augmented reality and the metaverse in education?

RESEARCH METHODOLOGY

This research, which evaluates preservice teachers' views on the use of VR, AR, and the metaverse in education, uses a basic qualitative research design. In basic qualitative research, researchers focus on the process and aim to understand it (Merriam, 2013). In this research, the focus is on the technologies of VR, AR, and the metaverse that will quickly enter our lives, specifically on their applications in education, their benefits, with what fields/modules they can be most associated with, what would be required for their effective use, and understanding the process of making them a common practice, for instance by looking at the preparedness of teachers and students.

PARTICIPANTS

The research was conducted with 24 senior-year preservice teachers' students pursuing a degree in biology and mathematics teaching programs at a state university in Ankara, the capital of Turkey. Among the preservice teachers, 12 of them pursue biology for teaching and the other 12 pursue mathematics for teaching. 18 of the preservice teachers are female and 6 of them are male.

The preservice teachers were determined by easily accessible and purposive sampling methods. With regards to easily accessible sampling, the preservice teachers were chosen among those who are pursuing their studies in the same institutions as the researchers. As for purposive sampling, they were chosen among final-year students, given their larger knowledge and experience in education. Due to the rather little-explored and newly emerging nature of the subject matter, the number of participants was decided considering that the views given by the students were satisfactorily varied. We will refer to the preservice teachers as PT1, PT2, etc. to protect their privacy.

DATA COLLECTION TOOLS

For the data collection, firstly a semi-structured interview was considered, however, due to the restrictions caused by the pandemic, the survey method, a supportive data collection tool, was used to obtain the data (Marshall & Rossman, 1995). First of all, a draft survey containing five open-ended questions was created by scanning the literature. The draft survey was sent to two field experts on mathematics and biology education for their views. In consideration with expert views, two questions were removed from the survey: "How could virtual reality, augmented reality, and the metaverse be used in education?" and "Until now, which VR, AR, or metaverse technologies have you used?" These questions were removed because these technologies were deemed too recent (first question) and the preservice teachers may not have had enough experience with the subject (second question). After that, the survey was reformatted and became the final version. The structured survey consists of two parts. The first part contains the demographic information of the participants (major, gender, etc.). In the second part, there are 3 open-ended questions, which are considered as sub-questions to determine the views about the use of VR, AR and metaverse in education.

DATA COLLECTION PROCESS

After the survey form was finalized, it was put in a format to be filled out online through Google Forms. The link to the survey form was sent to the preservice biology and mathematics teachers after their contact details were obtained. Research data was collected from the preservice teachers who confirmed the participation form within the survey. The participants were told that they could leave the research any time they wished should they feel any discomfort due to the survey questions or any other reason. The survey took approximately 10 minutes to complete.

DATA ANALYSIS

The research data was subjected to content analysis. During the content analysis, words or phrases that covered a theme or themes were counted. We aimed to explore the facts and hypotheses on the conceptualization of the topic through our interpretations (Silverman, 2001).

To this goal, the survey was filled out electronically through a special data collection form website, whose data was transferred to a Microsoft Excel file. Afterward, the data obtained was transferred to the digital medium of Microsoft Office/Word 13, to be evaluated. Next, the participants' answers were read several times. After the reading, the researchers came together to codify one of the 24 responses, while the other responses were codified separately by researchers. After this process, researchers came together again to come up with the finalized codes. These codes were described to form themes. After that, frequency and percentage distributions for the codes and the themes were calculated.

TRUSTWORTHINESS

Due to the highly subjective nature of qualitative studies, reliability is crucial to establish. The notion of trustworthiness becomes significant here. For the purpose of reliability, to make the results obtained by this research accurate and repeatable, the survey questions were mentioned explicitly. In qualitative research with a high level of subjectivity, trustworthiness as a parameter of persuasiveness, is beneficial for internal validity and the results' consistency with reality (Arastaman, Öztürk Fidan & Fidan, 2018). Moreover, in order to minimize the partiality during the research, the content analysis and codification were conducted by different researchers using the "analysis by different researchers" method. In research, the reliability of the coding made for the same data by different codifying researchers was calculated by the formula "accordance/ (accordance + discrepancy) x 100". The consistency between the codifying researchers was 95%. Analyses, where this value is over 80%, are accepted as reliable (Miles & Huberman, 1994). Moreover, to increase the descriptive quality of the research, the expressions used by the participants regarding the codes can be seen in the findings.

During the process of data collection, an informative text above the survey was provided to the participants to let them know about the purpose and process of the research, and that the participation is on a voluntary basis, allowing them to leave at any time if they wish so, and their privacy was protected. A participation consent form was signed by the participants. Moreover, necessary institutional permission was obtained to conduct the research, while ethical principles were also respected.

FINDINGS OF THE STUDY

Our research evaluates the views of preservice teachers regarding VR, AR and the metaverse. The findings obtained from the analysis of the data are given in the following sections for each of the three sub-questions:

1) **The Preservice Biology and Mathematics Teachers Views on the Benefits of the Use of VR, AR, and the Metaverse in Education**

The preservice biology and mathematics teachers' views on the benefits of the use of VR, AR, and the metaverse were grouped under five themes. Table 1 contains the codes under each theme and their frequency and percentage values:

Table 1

Distribution of Views Regarding the Benefits of the Use of VR, AR, and the Metaverse in Education.

Theme	Code	f	f_t	%
Popularizing up-to-date teaching technologies	Providing awareness for new technologies	2	3	4
	Allowing the creation of virtua classrooms	1		
Supporting methods of teaching	Enabling the display of cases/experiments hard to conduct	5	16	20
	Allowing extramural activities (trips, fieldwork, etc.)	4		
	Enriching learning methods anc materials	4		
	Enabling modelling	2		
	Allowing intraclass activities	1		
Improving the quality o learning	Allowing permanent learning	9	49	61
	Allowing meaningful learning	8		
	Allowing effective learning	1		
	Allowing easy learning	3		
	Enabling the concretization of abstract concepts	16		
	Allowing the teaching and learning of 3D objects	4		
	Allowing learning through experience	3		
	Enabling student-based activitie	3		
	Preventing the misunderstand of concepts	2		
Increasing the eagernes to learn	Increasing the students' attent and motivation	8	9	11
	Making the lesson more fun	1		
Decreasing teaching cos	Saving time in teaching	1	3	4
	Saving money in teaching	1		
	Saving labour/effort in teaching	1		
	Total		80	100

According to Table 1, preservice teachers' have evaluated their views on the benefits of the use of VR, AR and the metaverse in education, under the following themes: “Popularizing up-to-date teaching technologies” (f=3, 4%), “Supporting methods of teaching” (f=16, 20%), “Improving the quality of learning” (f=49, 61%), “Increasing the eagerness to learn” (f=9, 11%) and “Decreasing teaching costs” (f=3, 4%). On the theme of “Improving the quality of learning", the prominent codes were: "Enabling the concretization of abstract concepts" (f=16), "Allowing permanent learning" (f=9) and "Allowing meaningful learning". Here are some examples of preservice teachers' views under this theme:

PT5: "If the students use one of these [methods] while learning about three-dimensional objects, they will have the chance to see the objects, without the need for abstract reconstruction. This way, the student will have learned the objects, without any questions or doubts in mind."

PT17: "[These methods] can be used for increasing meaningful learning in topics that are hard to learn."

On the theme of "Supporting methods of teaching", frequently repeated codes were: "Enabling the display of cases/experiments hard to conduct" (f=5), "Allowing extramural activities (trips, fieldwork, etc.)" (f=4) and "Enriching learning methods and materials" (f=4). Here are some examples of preservice teachers' views under this theme:

PT9: "We can do pedagogically useful activities like modelling and school trips, from where we are."

PT19: "In biology, which is my field, the metaverse could provide the teaching and education for fieldwork activities or when the weather is bad."

On the theme of "Increasing the eagerness to learn", the code "Increasing the students' attention and motivation" (f=8) was frequently repeated. Here are some example sentences from preservice teachers' views on this theme:

PT7: "[These methods] would increase the students' interest in the class, as it is already rather hard to draw their attention to the lesson. They would allow the class to be more fun."

PT23: "To motivate the students who learn differently"

2) The Preservice Biology And Mathematics Teachers Views On Which Subjects/Modules Can Be Best Associated With The Use Of VR, AR, And The Metaverse In Education

The preservice biology and mathematics teachers' views on which subjects/modules can be best associated with the use of VR, AR, and the metaverse were grouped under two themes. Table 2 contains the codes under each theme and their frequency and percentage values:

Table 2
Distribution of Views Regarding the Association of Subject Matters with the Use of VR, AR, and the Metaverse in Education.

Theme	Code	f	f_t	%
Field of Biology	Environmental issues	1	20	54
	Kingdoms of living things	1		
	Organ systems	4		
	Population Biology	1		
	Physiology	2		
	Biogeography	1		
	Cell division	1		
	Environment and ecosystem	3		
	Cell and its components	3		
	Reproduction	1		
	Genetics	1		
	Anatomy	1		
Field of Mathematics	Geometry	5	17	46
	Geometry of space	3		
	Analytical Geometry	1		
	Solid bodies	6		
	Derivation	1		
	Integration	1		
	Total		37	100

According to Table 2, preservice teachers' have evaluated their views on the association of subject matters with the use of VR, AR and the metaverse in education, under the following themes: "Field of biology" (f=20, 54%) and "Field of mathematics" (f=17, 46%). For the "Field of biology", these examples reflecting the teachers' views can be given:

PT2: "I believe that [these methods] can be used for the teaching of the systems in our body and on the topics of population and ecosystem."

PT4: "Virtual trips can be organized regarding the environment, while for physiology, augmented reality could be used."

PT20: "Through these methods, cell and human physiology and systems, topics otherwise too theoretical, could be made more comprehensible."

For the "Field of mathematics", these examples reflecting the teachers' views can be given:

PT3: "In math, [these methods] can be used for teaching solid bodies to show the shapes in three dimensions. Instead of making the students memorize the formulas, virtual representation would allow for them to see how these formulas are derived."

PT15: "[They] could be used for geometric shapes and the applications of derivation and integration. They may make these topics feel more real."

3) The Preservice Biology and Mathematics Teachers Views on What Would be Needed to Enable the Effective Use of VR, AR, and the Metaverse in Education

The preservice biology and mathematics teachers' views on what would be needed to enable the effective use of VR, AR, and the metaverse were grouped under four themes. Table 3 contains the codes under each theme and their frequency and percentage values:

Table 3

Distribution of Views Regarding the Effectiveness of the Use of VR, AR and the Metaverse in Education.

Theme	Code	f	f_t	%
Setting up technological equipment	Need for technological infrastructure	17	19	38
	Need for financial sources	2		
Generating knowledge of technology	Need for technology-savvy teachers	10	23	46
	Need for technology-savvy preservice teachers	1		
	Need for technology-savvy students	7		
	Need for education on technology	5		
Producing the environment of technological education	Need for technology-related in-service training programs	2	6	12
	Need for a technology-related curriculum	1		
	Need for digital material/content	2		
	Need for an equality of opportunity for education	1		
Creating interest in technology	Need for technologically-motived students	2	2	4
	Total		50	100

According to Table 3, preservice teachers' have evaluated their views on what would be necessary to enable the effective use of VR, AR and the metaverse in education, under the following themes: "Setting up technological equipment" (f=19, 38%), "Generating knowledge of technology" (f=23, 46%), "Producing the environment of technological education" (f=6, 12%) and "Creating interest in technology" (f=2, 4%). On the theme of "Setting up technological equipment", the code of the "Need for technological infrastructure" (f=17) was the most prominent one. Here are some examples of preservice teachers' views under this theme:

PT2: "A solid infrastructure is the first thing for schools to have in order to enable the use of these methods."

PT13: "Systemic and infrastructural inadequacies should be solved."

On the theme of "Generating knowledge of technology", frequently repeated codes were: "Need for technology-savvy teachers" (f=10), "Need for technology-savvy students" (f=7) and "Need for education on technology" (f=5). Here are some examples of preservice teachers' views under this theme:

Pt7: "Teachers need to be informed on this topic and the school needs to have the necessary set-up."

PT9: "Teachers and students need to receive training on virtual reality."

PT17: Sufficiently developed technological tools should be provided and the students should have enough knowledge on how to use them."

On the theme of "Producing the environment of technological education", here are some examples of preservice teachers' views:

PT14: "The class content should be enriched with real physical media and digital media such as audio, images or video."

PT15: "İnservice training and student training is a must for the technological infrastructure and this system to progress well."

PT23: "Teachers need to know more about it. İnservice training is necessary."

Discussion

The preservice biology and mathematics teachers have given views confirming that the application of VR, AR, and the metaverse in education would be beneficial. These views are in parallel with the field literature. There are parallels between Radu (2012) and Sırakaya and Alsancak Sırakaya (2018) who argue that AR's integration into the teaching process would make the classes more visual, concrete, and comprehensible, and the preservice teachers who state that the use of VR, AR, and the metaverse would concretize abstract notions and allow a long-lasting and meaningful learning process. Similarly, Başaran, Nacar, Nacar, Tüfekçi, and Vural (2022), Lin and Wang (2012), and Wojciechowski and Cellary (2013) argue that AR technologies would help concretize abstract subjects. Başaran et al. (2022) and

Ivanova and Ivanov (2011) also share the view that AR would encourage a long-lasting learning process, giving support to the results of our research. Aziz, Aziz, Paul, Yusof, and Noor (2012) also argue that VR, AR, and the metaverse increase the motivation of students, showing parallels with our research.

Preservice biology and mathematics teachers believe that VR, AR, and the metaverse technologies are significant tools to teach and learn both mathematics and biology more effectively. They emphasize the aspects of visualization and concretization in the subjects of biology and mathematics, with which they associate the use of VR, AR, and the metaverse. Accordingly, they argue that through these technologies, learning would be meaningful and of good quality. Moreover, according to the preservice teachers, these technologies could be effective in increasing the eagerness to learn and thus indirectly facilitate the learning process. Such views of the preservice teachers are also supported by the literature, such as the findings of Mystakidis, Fragkaki, and Filippousis (2021) that AR and VR technologies are able to ameliorate the students' learning process and quality of learning, through developing their episodic memory, and views of Jeon and Jung (2021) that metaverse technology could strengthen students' educational skills like learning, communication and empathy.

According to the obtained results, when it comes to what would be needed to enable the effective use of VR, AR and the metaverse in teaching and learning processes, the preservice teachers mostly draw attention to the need for well-informed individuals (students, preservice teachers, teachers), as well as infrastructure and formation/training. Indeed, Fernandez (2017) emphasizes the crucial role of teachers who will raise the children and create an environment of teaching, in the use of virtual world implementations such as VR, AR and the metaverse in education. Moreover, the researchers argue that the competencies of teachers should be increased both for their career development, but also for the students to experience a learning environment integrated with technology (Michos & Hernández-Leo, 2020; Mysatikidis & Christopoulos, 2022).

CONCLUSIONS

In this research, the views of preservice biology and mathematics teachers regarding the use of VR, AR and the metaverse in education have been evaluated within three contexts: The benefits, which subjects to associate with and what is needed for the effectiveness of the use of VR, AR and the metaverse. The preservice biology and mathematics teachers' views on the benefits of the use of VR, AR, and the metaverse were grouped under five themes: Popularizing up-to-date teaching technologies, supporting methods of teaching, improving the quality of learning, increasing the eagerness to learn, decreasing teaching costs. From the view of the preservice teachers, it is seen that they focus on the themes of improving the quality of learning and supporting methods of teaching. Preservice teachers tend to agree that the use of VR, AR, and the metaverse in education will concretize abstract concepts, allow permanent and meaningful learning, make it easier to conduct or show experiments/cases that are otherwise difficult, and increase student attention/interest and motivation. Aside from that, preservice teachers state another benefit of the use of VR, AR, and the metaverse in education, by touching upon the saving of time, money, and effort.

In the research, the preservice biology and mathematics teachers' views on which subjects/modules can be best associated with the use of VR, AR, and the metaverse were grouped under two themes: The field of biology, and the field of mathematics, due to the participants of the research consisting of preservice biology and mathematics teachers. The preservice teachers have stated what subjects/modules can be best associated with the use of VR, AR, and the metaverse depending on their areas of interest. While preservice biology emphasized modules such as organ systems, environment and ecosystems, and cells and their components; preservice mathematics teachers focused on subjects or fields such as solid bodies, geometry, and geometry of space. Preservice teachers of both fields explained that they discussed the modules the most suitable for visualization and concretization in their respective fields.

According to the obtained results, the preservice teachers' views on what would be needed to enable the effective use of VR, AR, and the metaverse were grouped under four themes: Setting up technological equipment, generating knowledge of technology, producing the environment of technological education, and creating interest in technology. Preservice biology and mathematics teachers have emphasized the necessity of generating the knowledge of technology as a prerequisite for an effective use of VR, AR, and the metaverse. Within this theme, the need for technology-savvy teachers, technology-savvy preservice teachers, technology-savvy students, and an education on technology is mentioned. After mentioning the acquisition of technological knowledge, preservice teachers have drawn attention to the necessity of setting up technological equipment in the context of the need for technological infrastructure and financial sources. Preservice teachers have also mentioned “interest” as a significant driving force, not only for the benefits of using VR, AR, and the metaverse, but also as a prerequisite to enable their effective use. There are some preservice teachers who believe that with technologically motivated students, VR, AR, and the metaverse can effectively be utilized.

In light of these results, in order to enable the use in education of the new but rapidly advancing technologies of VR, AR, and the metaverse; not only should learning environments be suitably designed for such technological setups, but teachers and students should also be directed and informed to apply these technologies into the education, and new pedagogical material/content suitable for these technologies should be more extensively created.

RECOMMENDATIONS

Recommendations drawn from the results obtained through the research are listed below:

• The potentials of VR, AR and the metaverse can be presented to preservice biology and mathematics teachers and teachers through pre- and in-service training.

• Workshops in which experiences on the implementation of VR, AR, and the metaverse can be conducted for preservice teachers and teachers through pre- and in-service training.

• The preparation of VR, AR and metaverse materials for mathematics and biology topics requiring more visual images can be encouraged through support and know-how.

• The preservice biology and mathematics teachers could be advised to make the classes more attractive by informing students about the use of these technologies in classes.

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