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Systematic Literature Review on the Use of Metaverse in Education

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Abstract

Metaverse is a concept that has existed in our lives for years. However, it has become widely known by gaining new meanings thanks to the developments in blockchain and virtual reality technologies and the marketing techniques of social media companies. The aim of this study is to examine the studies on the use of Metaverse technology in education. In the study, it is also aimed to analyze the changing understanding of technology use in education over the years and to investigate the reflections of the concept of Metaverse on education. This systematic literature review is based on the reporting criteria of PRISMA 2020 (Page et al., 2021) and the scope of the study consists of 22 academic studies including the keyword "metaverse" and the keywords "education" or "teaching" or "learning" in academic studies scanned in Scopus, WoS, Eric and Proquest indexes. In this study, the distribution of the studies used in the metaverse in education by year, country, field, type of research, and the context of the technology used is included. In order to contribute to the research on the Metaverse in the field of education, it has been tried to determine the opportunities and risks that teaching in the Metaverse environment can offer to the field of education. In addition, it is thought that this study will shed a light on future studies.

Introduction

Computer and Internet technologies have an important role in daily life because they affect interpersonal interaction, communication and social behavior (Duman, 2008). Considering the fact that the developments in computer technology take place in our lives in stages, the first stage is the development of personal computers, second stage is introduction of the Internet, and the third stage is the development of mobile devices (Kamenov, 2021). Today, we are in the fourth stage where immersive environments created by digital reality technologies take place in our lives.

It can be clearly observed that the digital reality technologies have a potential to transform the field of education, remote working, marketing and economy fields and the entertainment industry, and have started to create a new information communication paradigm. It can be said that the new paradigm has emerged, which is shaped around the concept of Metaverse (Mystakidis, 2022). The word “metaverse” is formed by the combination of the words “meta” which means beyond or after, and the word “universe” (Cheng et al., 2022). Since metaverse consists of the combination of the words meaning beyond and universe, it also means beyond the universe. Metaverse can have different meanings for different disciplines or environments, but mainly it is a multi-user platform and

technological innovation, which is a digital reality environment beyond physical reality when it comes to computer technology or teaching technology.

Metaverse technology has a potential to attract interest of many in distance education by having the power to overcome the basic limitations of web-based, two-dimensional e-learning tools regarding reality and motivation (Collins, 2008). The use of information and communication technologies as fostering tools for learning processes based on emergent paradigms has become important in the transformation of students' learning (Demirer, 2013). Due to the fact that end users now could access technology more easily, technology integration along with changes in educational policies has become inevitable (Yang & Wu, 2012). With the influence of the constructivist approaches, the importance of using computer and Internet technologies in teaching environments is increasing (Çakır & Yıldırım, 2009). However, despite innovative practices and change in teaching paradigms based on advances in educational technologies, instructional methods remain unchanged and teaching process is revolving mainly around content transfer from textbooks (Friesen, 2017).

It is observed that major technology companies are in a competition to create the infrastructure and standards of Metaverse, continue to develop hardware and software for it, and deal with its privacy and security issues (Gadekallu et al., 2022). As a result of this competition, it is naturally expected such issues as the privacy rights of users must be protected, Metaverse will be inclusive for the education sector, and digital reality-based, ergonomic, comfortable and lighter hardware should be produced (Han et al., 2022). As Metaverse gains importance and interest especially in the field of distance learning, there is a need for research studies on examining the effects and practices of this subject area. Therefore, the aim of this study is to examine the studies on the use of Metaverse in the field of education, to determine the distribution of Metaverse studies regarding the year, country, field, type of research and the context of the technology used, and to shed on light for future studies accordingly.

Metaverse was first brought to the world scene in 1992 by Neal Stephenson 's science fiction novel named Snow Crash (Duan et al., 2021). Many efforts and research have been made to transform Metaverse technology from which does not actually exist but only based on a fiction book into a technology that can be used in real life (Kye et al., 2021). A research organization named as “The Acceleration Studies Foundation” (ASF) announced its Metaverse roadmap in 2006 including augmented reality, virtual worlds, mirror worlds, and lifelogging.

Ball (2022) describes Metaverse as a massively scaled and interoperable network of real-time rendered three-dimensional virtual worlds that can be simultaneously and permanently experienced by an unlimited number of users. Bosworth and Clegg (2021) states that metaverse is a series of sandboxes that you can create and explore with other people who are not in the same physical space. They defined the Metaverse within a frame where the perception of reality is created, the real-world merges with the virtual space and the reality is expanded into the virtual space.

Metaverse means a world in which virtual and reality interact and develop together throughout social, economic and cultural activities being carried out to create entities and values (Lee, 2021). Metaverse technology has started

to enter our lives quickly and some of its applications have begun to be used in education (Lee et al., 2022). For this reason, it is important to be able to determine the limits of the concept of Metaverse and the meanings of the concept of Metaverse from the very beginning to establish a solid foundation for the use of Metaverse in education.

In Metaverse applications, people will be able to use the Non Fungible Token (NFT) they produce, and share their virtual products, for instance, digital lands. Users will be able to create spaces for surfing, entertaining and learning on an interoperable platform and be a part of a global community (Hirsh-Pasek et al., 2022). The current and future usage of Internet services at 5G speed has created a great opportunity for the realization of experiences and applications on Metaverse platforms (Lee et al., 2021).

There are several Mertaverse platforms that were created up till now (e.g., Second Life, Open Simulator, Minecraft, Fortnite, Roblox, Sandbox, and Decentraland). These platforms are attracting many user day by day and the number of members is increasing accordingly. For example, Roblox has reached up to over 42 million active users, an increase of 19% since 2019 (Rospigliosi, 2022). As virtual reality platforms become easier to use and more interconnected, Metaverse platforms will promise further improvements in all areas. When virtual reality glasses and accessories acquire a more comfortable design appropriate for long-term use, it may become much more feasible to expand their usage areas and adapt them to educational environments.

It is quite significant to produce metaverse-based hardware and software products adaptable to teaching environments. Thus, it is important for educators, researchers, designers and developers to work together and guide each other on this issue. More specifically in terms of the adoption of new technological paradigms in education, Sarıtaş (2015) suggests that “educational institutions should develop a comprehensive strategy including curricula, professional development of teachers, educational philosophy, data security, legal and political issues, and transformation of resources and infrastructure to be able to address the many unique challenges that lie ahead” (p. 176).

Method

This study is a systematic literature review investigating the use of Metaverse in the field of education. Systematic literature review can be defined as a systematic, open and reproducible method for defining, evaluating and synthesizing the structure of the studies conducted (Fink, 2014). The research process was applied in accordance with the PRISMA 2020 checklist (Page et al., 2021). The PRISMA checklist is a guide sheet to prepare an organized reporting of systematic compilation, review and analysis studies in the international literature (Hür, 2021).

Data Sources

Databases were examined in the field of education for Metaverse. The existing literature was also taken into consideration in order to set up a basis for determining the keywords. The keyword "Metaverse" and the combination of the keywords such as "education" or "teaching" or "learning" were used to conduct this study.

Web of Science, Scopus, Eric and Proquest databases, which have high impact factors, were examined in accordance with the specified keywords. Due to the widespread use of the Metaverse environment in education in recent years, the study did not restrict the literature in years. Full text of the studies found in databases were evaluated and included in the systematic review based on inclusion and exclusion criteria as well as on their quality and relevance.

Quality and Conformity Assessment

Inclusion and exclusion criteria were established to assess the quality and relevance of studies in the literature (see Table 1).

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
• Academic articles, Book chapters and books • Studies with the keyword "Metaverse" • Studies with the word "education" or "teaching" or "learning" • Full text studies • Public works • Studies published in English	• Whitepapers, online presentations, abstracts, and news • Studies not published in English • Non-full text works • Studies whose subject scope is not relevant enough to be examined

The literature review included full-text conference proceedings, journal articles published in high-impact indexes, books and book chapters. Technical reports, online presentations, news, and conference abstracts were not found suitable for review due to the lack of peer-review process. Although some studies (e.g., articles, books, conference papers) were found to have a keyword Metaverse, there was no relevant work within the scope of the notion of Metaverse. Hence, those studies not specifically addressing the Metaverse concept were not included in the review.

Results

Search Results

Studies containing the keyword "Metaverse" as well as at least one of the keywords "education", "learning" or "teaching" and those published in Scopus, Web of Science, Eric and Proquest databases were examined. 13 studies whose full texts could not be reached and four studies that were not in English were excluded from the scope of the review. Nine of the remaining 34 studies were also excluded because they were the same studies in different databases. Only one study was included in the evaluation from the repetitive recordings. After the conformity and quality evaluation on the remaining 30 studies, eight studies were excluded from the review, and a total of 22 studies were included in the systematic review.

Figure 1 shows the flowchart for the selection of studies included in the review.

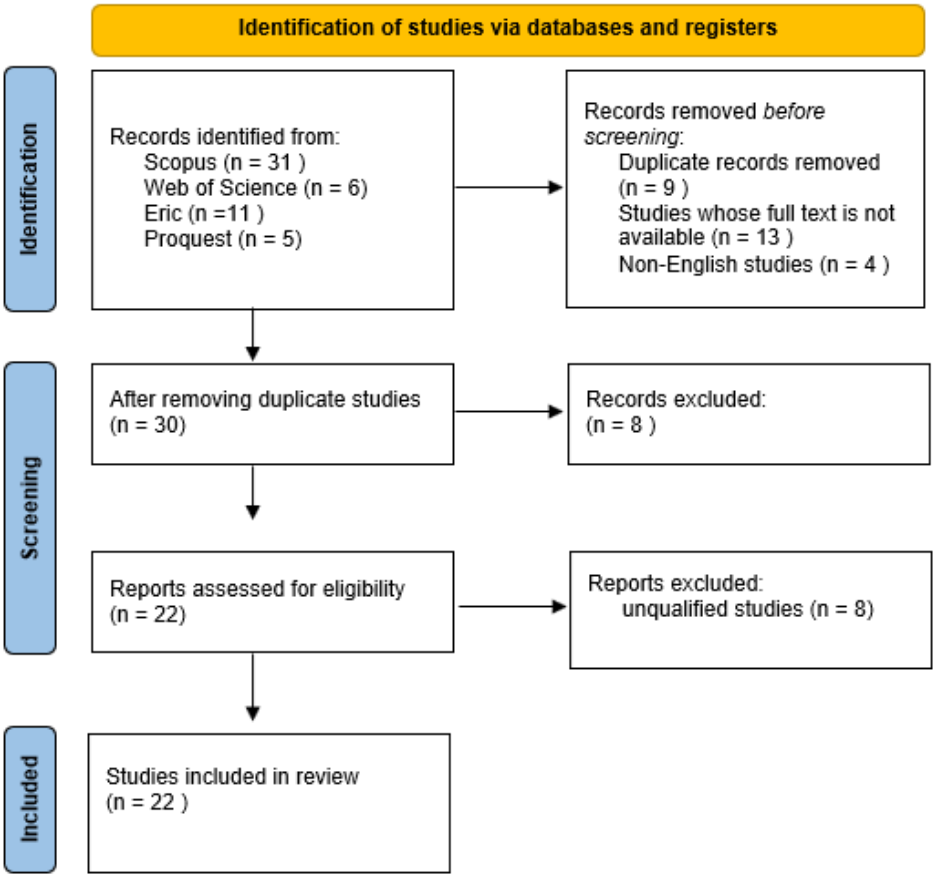

Figure 1. PRISMA 2020 Flow Chart

Features of the Studies

The year in which and *the country where the studies were conducted* were included in the review. Additional features such as *type of studies, the sample size (if any), the sample type (if any), the type of Metaverse technology used (if any), the objectives of the studies, the results of the studies,* and *the definition and technological context of Metaverse* were included in the review. First, title and abstract of all studies were examined and then the full text of those were evaluated in detail according to the inclusion and exclusion criteria. The characteristics of the reviewed studies (see Table 2), their goals (see Table 3), their findings (see Table 4), and the studies containing the definition and technological context of Metaverse (see Table 5) are given in the following sections.

Among the studies (n=22) included in this systematic literature review, there were 9 studies with students, academicians or adults in terms of sample diversity. The sample sizes in these studies ranged from 3 to 108. There was a total of 283 participants in 9 studies. Except for these 9 studies, 13 studies did not have any sample of individuals as they were only descriptive review studies. The largest number of studies (n=5) within the scope of the review that met the inclusion criteria were conducted in Japan. The most studies on Metaverse in the field of education (n=3) were done in the years of 2012 and 2022.

In addition, the number of studies in this field decreased after 2012 and increased again after 2020. By examining the types of studies according to their purposes, the largest number of studies (n=9) were found to be descriptive

studies. Considering the types of studies regarding the research methods, the largest number of studies (n=9) were found to conduct design-based research. It was found that the most studies were carried out at higher education level (n=10). The largest number of studies (n=6) was conducted with the participation of undergraduate students. On the other hand, there were seven studies which Metaverse platforms and tools were not used. The most common Metaverse technology (n=7) used in studies was 3D computer software (SecondLife). Table 2 below shows the characteristics of studies (i.e., country, year, research type, research method, education level of samples, and the technology used). The distributions of the features in the table are examined under the headings in the following section.

Table 2. Characteristics of Studies

Study Label	Country	Year	Research type	Research method	Education Level	Technology
S1	South Korea	2022	Exploratory	Literature review	Unspecified level	-
S2	Serbia	2022	Descriptive	Design-based research	Higher education	3D software
S3	South Korea	2022	Exploratory	Literature review	Unspecified level	-
S4	South Korea	2021	Descriptive	Design-based research	Unspecified level	Hololens
S5	South Korea	2021	Descriptive	Design-based research	Unspecified level	Hololens
S6	Japan	2020	Exploratory	Literature review	Unspecified level	-
S7	Colombia	2020	Explanatory	Mixed research	Higher education	3D software
S8	Singapore	2017	Exploratory	Literature review	Unspecified level	-
S9	Japan-United States (USA)	2015	Explanatory	Qualitative research	Higher education	3D software and Blink system
S10	Spain	2015	Descriptive	Design-based research	Higher education	3D software
S11	Japan	2014	Explanatory	Qualitative research	Primary education	3D software
S12	Colombia	2013	Explanatory	Qualitative research	Higher education	3D software
S13	Panama	2012	Descriptive	design-based research	Higher education	3D software
S14	China-USA	2012	Exploratory	Literature review	Unspecified level	-
S15	USA	2012	Explanatory	Mixed research	Adult learning	3D software
S16	Japan	2011	Descriptive	Design-based research	Higher education	3D software
S17	England	2010	Descriptive	Design-based research	Unspecified level	3D software
S18	Japan	2010	Descriptive	Design-based research	Higher education	3D software
S19	Japan	2009	Explanatory	Qualitative research	Higher education	3D software
S20	USA	2008	Exploratory	Literature review	Unspecified level	-
S21	US-UK	2006	Descriptive	Literature review	Unspecified level	-
S22	USA	2004	Exploratory	Design-based research	Higher education	projector, head tracking device

Distribution of Studies by Country

In terms of the distribution of studies by country, the findings showed that the country with the highest number of studies was Japan (see figure 2). Japan was followed by South Korea with four studies, the United States of America (USA) with three studies, and Colombia with two studies. One study was conducted in partnership with the USA and Japan, one study by the USA and the People's Republic of China together, and one study by the USA and the United Kingdom (UK) together. Only one study was found to be conducted in other countries mentioned above. Based on findings, two studies were carried out in South Korea, one in 2021 and the other in 2022. Moreover, studies in the USA and the People's Republic of China were carried out until 2012, no study after 2012 was found to be about Metaverse in education.

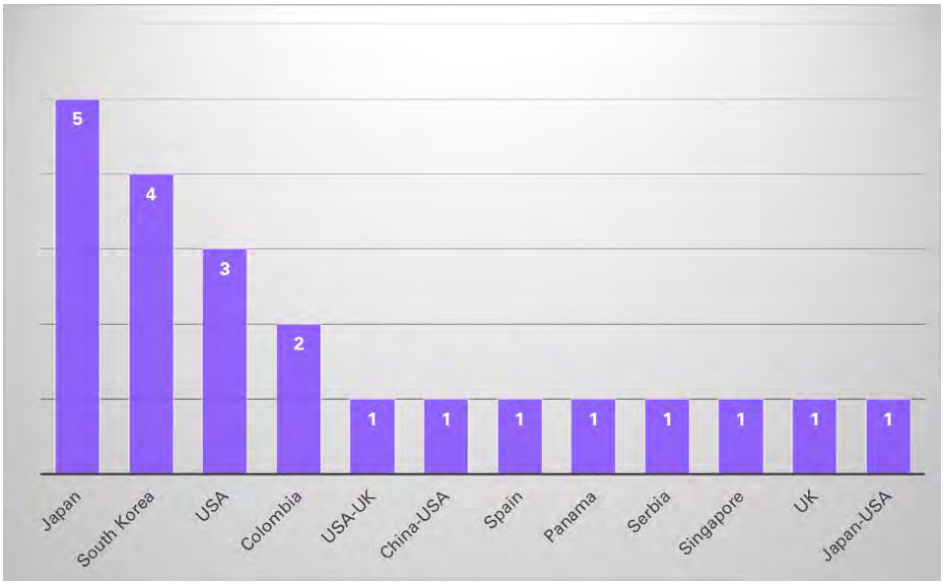

Figure 2. Distribution of Studies by Country

Distribution of Studies by Years

It is observed that the concept of Metaverse in the studies (from 2004 to 2022) has changed over the years from the perspectives of 3D computer software or digital reality. On the other hand, no studies were found in 2005, 2007, 2018 and 2019. It is seen that the largest number of studies (n=3) were done in both 2012 and 2022. It is also seen that the studies on Metaverse in education showed an increasing trend after the first years, then there was a decrease in the number of studies and an increase again in the recent years (see Figure 3). Among the studies examined, the concept of Metaverse in recent studies has tended to be perceived as based on either augmented reality or virtual reality technology. In previous years, the concept of Metaverse was handled in the form of places such as three-dimensional games and simulations. Moreover, it is observed that there has been an increase in the number of studies on Metaverse in recent years (Narin, 2021). The reason behind this is that big social media and technology companies such as Meta (formerly Facebook), Microsoft, Epic, Nvidia and Unity announced that they are investing in Metaverse and its components, which is seriously considered to be one of the technologies of the future along with the developments in virtual reality technologies (Dick, 2021).

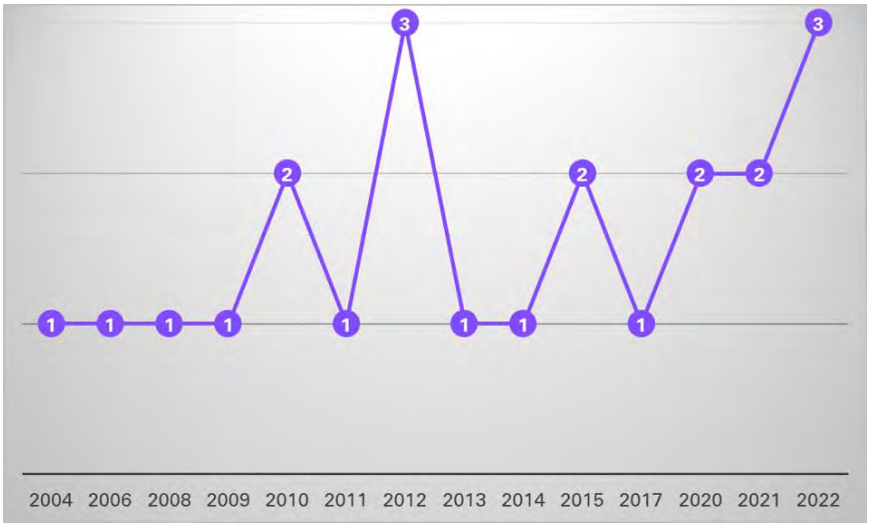

Figure 3. Distribution of Studies by Years

Distribution of Research Types According to the Purpose of the Studies

Research types of 22 studies were analyzed according to their purpose. Studies were categorized as exploratory, descriptive, and explanatory research studies according to their purpose. Exploratory research is a research that is conducted when the research topic is newly introduced to the field, provides preliminary information to the researcher, and is conducted to gather information at the most general level about a research problem (Saunders et al., 2012). This type of investigation is usually carried out when the problem is still in its infancy. It is often referred to as the theory-building approach or interpretive research, as it is used to answer questions such as what, why, and how (Saunders et al., 2012). Descriptive research is a type of research used to describe the characteristics of the sample. Descriptive research is a research that aims to obtain a description of the subject or activities of interest. Cause and effect relationship is not sought in descriptive studies, but some basic statistics can be used (Aggarwal & Ranganathan, 2019). Explanatory research is a method that deals with the identification of causes and effects through hypothesis testing and is developed to investigate a phenomenon that has not been studied or properly explained before. Explanatory research aims to find the cause of events by establishing cause-effect relationships (Swedberg, 2020).

Figure 4 below shows that approximately half (n=9) of the studies consisted of descriptive studies. Studies on Metaverse in education are those using basic statistics such as determining frequency and percentages, aiming to define the characteristics of the Metaverse environment rather than find a cause-effect relationship. Metaverse platforms are not easy to develop nor readily available for use in education. In a Metaverse platform, the environment should be designed in accordance with the purpose of the course as well as the needs of learners. However, instead of examining the effects of Metaverse environments on learners, teachers, and learning processs, it was preferred to examine the Metaverse environment itself. According to the Figure 4, the number of exploratory and explanatory studies were less than that of descriptive studies. The reason for this might be explanatory studies requiring a long process and a better planning, and more effort to test various dependent variables within the Metaverse platforms. When the distribution of exploratory studies by years was examined, it was observed that the number of these kind of studies increased in recent years. The reason for this would be the development of

digital reality technologies in recent years and the concept of Metaverse being perceived as a virtual reality-based platform rather than 3D computer programs. Therefore, definitions and explanations of Metaverse should be reconsidered and revised in the field.

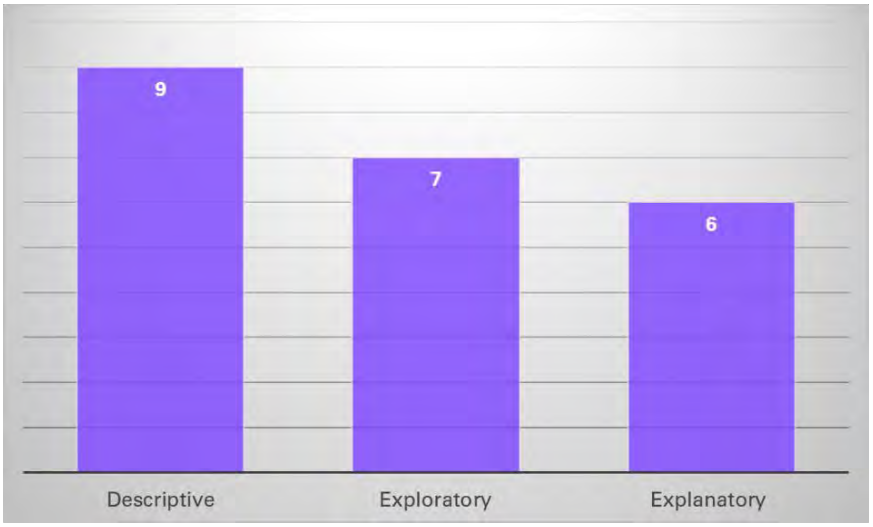

Figure 4. Distribution of Research Types According to the Purpose of the Studies

Distribution of Studies According to Research Methods

22 studies included in the study were examined according to their research methods. Studies were categorized as quantitative research, mixed research, design-based research and literature review. Among the studies examined, there was no study carried out using qualitative methods. It can be clearly seen that nearly half (n=9) of the studies included in the analysis were design-based research (see figure 5). Seven studies conducted literature review, four studies quantitative research, and two studies mixed research method.

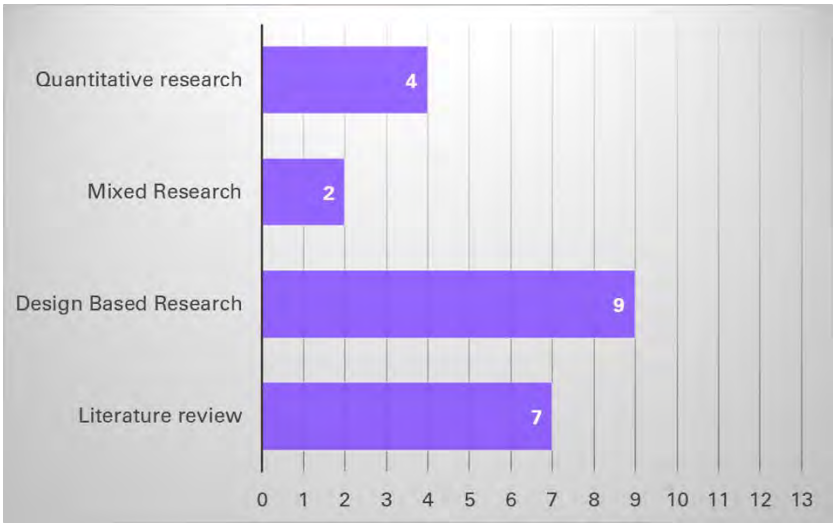

Figure 5. Distribution of Studies According to Research Methods

In design-based research studies, subject-specific teaching materials or environments were developed using 3D

computer software platforms such as Secondlife (see Figure 6). Descriptive studies in which the quality and effectiveness of the teaching environments were tried to be determined by collecting opinions of the participants.

Figure 6. Use of Second Life in Education (Kemp & Livindstone, 2006)

Distribution of Studies by Participants' Education Level

In 10 of the 22 studies included in the review, the education levels of the participants in the studies were not specified (see Figure 7). Most of these 10 studies (n=8) were literature review studies which did not focus on education level. On the other hand, most of the studies with education level (n=10) were studies conducted at higher education level. There was only one study at adult education level and one at primary education level.

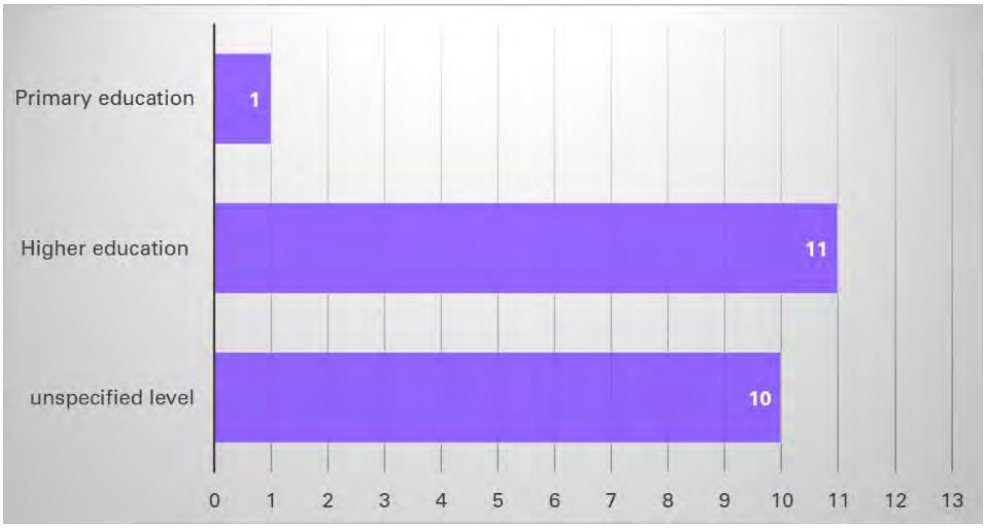

Figure 7. Distribution of Studies by Participants' Education Levels

Distribution of Studies by Sample Types

Different sample types were found to be in 22 studies included in this systematic review (see Figure 8). It is found

that six studies recruited undergraduate students, one study consisted of adults, one study included both undergraduate students and assistants, and one study consisted of primary school students. Participants were not included in design-based research and literature review studies (n=13). Accordingly, the studies in which the participants took part were the studies carried out at the higher education level with the highest number of undergraduate students.

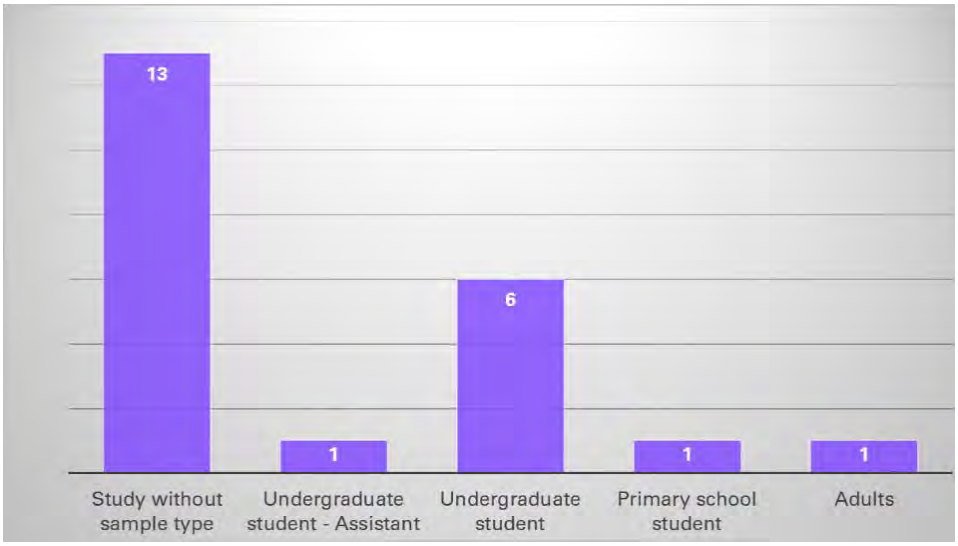

Figure 8. Distribution of Studies by Sample Types

Distribution of Studies by Technology Used

It is found that the most used Metaverse platform was a 3D computer software, that is, SecondLife (n=7). SecondLife was followed by the OpenSim platform, which is also a 3D computer software. It is seen that these software were included in studies conducted between 2009 and 2016. In addition, an unknown named 3D computer software was used in two studies.

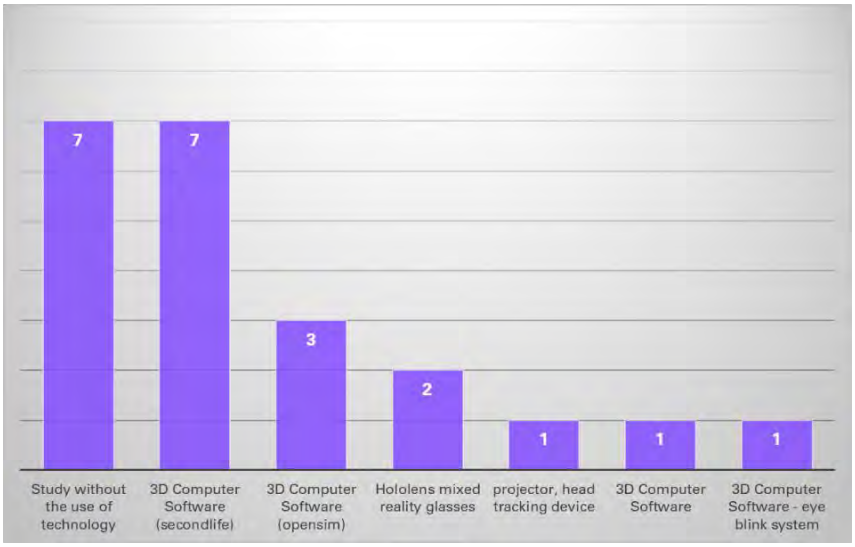

Figure 9. Distribution of Studies by Technology Used

Apart from these technologies, it is observed that there were two studies using mixed reality glasses, which we can consider them compatible with today's Metaverse understanding. These studies were different studies of the same authors using Microsoft Hololens (see Figure 10). Apart from this, there was a study using a projector and a head-tracker, which may be difficult to consider it as a Metaverse technology. Yet, since the technology, which was used in a study in 2015, was named as Metaverse by the authors, it was decided to include it among the studies examined.

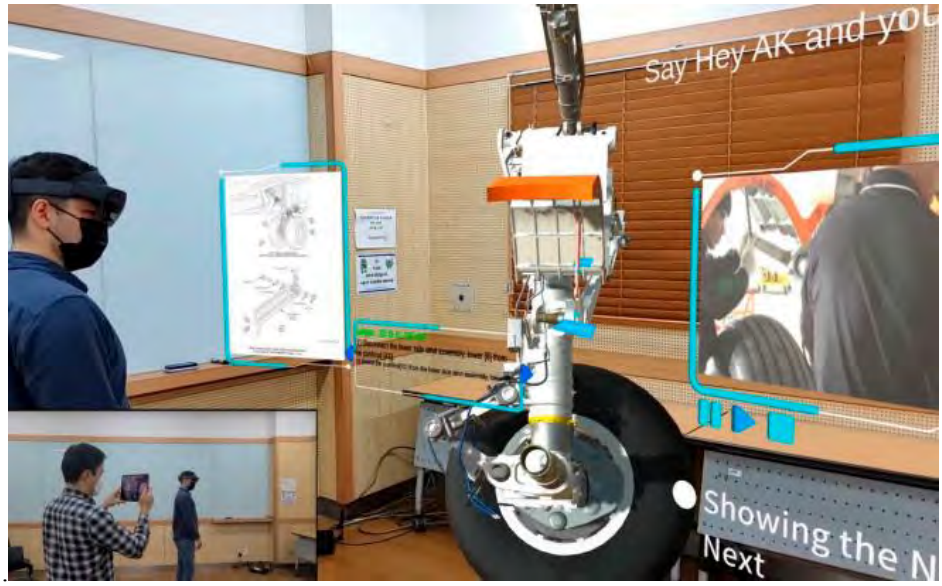

Figure 10. Use of Hololens in Education (Siyaev & Jo, 2021)

Objectives of the Studies Examined

The purpose of each study is different from each other based on different cases and situations. It was tried to determine how the concept of Metaverse was used in the field of education considering the technological context. In order to better understand the structures of the studies included in the systematic review, the objectives of the studies are presented in Table 3.

Table 3. Objectives of the Studies

Label of Study	Aim of the Study
S1	Develop a Metaverse world in which gamification can be maximized by providing a customized gaming experience.
S2	Create an educational experience in virtual worlds and overcome the limitations of pandemic situations.
S3	Explain the concepts, basic techniques, limitations, and guidelines for implementation needed to realize the Metaverse.
S4	Performing mixed reality training of aircraft maintenance for Boeing 737 on smart glasses developed with deep learning speech interaction module.

Label of Study	Aim of the Study
S5	Developing an aircraft maintenance training environment with speech recognition technology in Metaverse in addition to legacy manuals, 3D models and simulators.
S6	Analyze devices in virtual world, introduce current learning system, examine virtual learning systems, and propose concept for learning system in Metaverse.
S7	Metaverse acceptance level of students and teachers.
S8	Collaborative virtual and augmented reality environments.
S9	Virtual problem-based learning environment (Metaverse) on blink behavior.
S10	Facilitate the acquisition of French for tourism purposes through a virtual environment.
S11	Realizing the subject of radioactivity and nuclear safety with experiments and in the Metaverse environment and examining the effect of using Metaverse in STEM education.
S12	Explain the findings of implementing an English as a Second Language-based educational interaction through the use of Second Life.
S13	Metaverse as virtual learning environments and their applications in Electronics education.
S14	Examine the application of meta databases to support effective collaboration and knowledge sharing in virtual teams.
S15	Understand the relationship of trust development between meta database technology and its virtual members by examining how technology capabilities are used and modified to shape trust.
S16	To provide learning content for Japanese language and culture studies to international students in Japan and to understand the advantages and disadvantages of the Metaverse platform for foreign language and culture learning.
S17	Examining an excavation training simulation from an educational and technical point of view.
S18	determine the effectiveness of the use of problem-supported learning activities in the Metaverse.
S19	Examining how an anatomical eyeball as a three-dimensional learning material in Second Life can bring satisfaction and enjoyment to participants.
S20	To demonstrate that the educational uses of virtual worlds are already being explored and documented, and that academic research into virtual worlds is indeed of serious nature.
S21	To summarize the advantages and weaknesses of multi-user virtual environments for teaching and explore the possible benefits of integrating them closely with traditional Learning Management Systems.
S22	Provide visualization of the turbulent flow behavior of the flame and various combustion zones.

The aims of studies (S1, S3, S6, S8, S14, S20, S21) could be summarized as they aimed to explain the concepts, techniques and limitations of the Metaverse; to propose a concept for learning in Metaverse; to make comparisons with traditional teaching systems; to discuss the future of the Metaverse. The aims of the studies (S4, S5) in which metaverse technology was used based on digital reality are to perform aircraft maintenance training with mixed reality glasses, and to perform training in Metaverse environment with deep learning and speech recognition

technologies. The aims of design-based research studies (S2, S4, S5, S10, S13, S16, S17, S18, S22) were to create an educational experience in virtual worlds; to facilitate French and Japanese learning; and to provide mathematics education, electronics education, and excavation training on the Metaverse platform. The aims of quantitative research studies (S9, S11, S12, S19) were found to be examining the effect of teaching in the metaverse environment on blinking behavior, STEM education, English education and participants' satisfaction levels.

Results of Studies

The results of the studies included in the review vary according to the aims and problem situations of the studies. By examining the results of the studies, it is aimed to have an idea about the effectiveness of Metaverse, whether the use of Metaverse technology has the desired effect on the scrutinized variables. In addition, this study tried to determine the results of Metaverse technology and its contributions to the field of education (see Table 4).

Table 4. Results of Studies

Label of Study	Conclusion/results of the Study
S1	Gaming experience-based education should be actively considered in the Metaverse to avoid future problems with offline education. Providing a participatory educational experience focused on gaming, education using Metaverse can overcome the limitations of online education and create a sustainable learning environment.
S2	The use of metaverses in online learning can overcome limits during epidemics such as COVID-19.
S3	Important to interact as part of the story rather than seeing well- formed storytelling and immersive visual effects. Continued development of the brain-computer interface and Neuralink can translate into a form that gives an experience in the Metaverse that is difficult to distinguish from reality.
S4	Aircraft Maintenance Metaverse further enhanced aircraft maintenance training by providing intuitive and efficient control over the operation, and strengthened voice interaction in mixed reality smart glasses.
S5	The AI powered speech recognition system can be trained using synthesized data and can be used for industrial use with an average word error rate of 7.5% and overall accuracy of 94.7%.
S6	Metaverse integration should be provided to the education system in order to give the students a sense of vitality and reality necessary for maximizing the learning effect .
S7	It facilitates the use of pedagogies such as the flipped classroom and collaborative learning.It has been obtained that the level of acceptance of navigating and interacting in the virtual world is high. It facilitates the in-class and out-of-class education process synchronously and asynchronously. It should be scalable. Some technological and pedagogical challenges have been identified that need to be considered when implementing a virtual world.
S8	A mix of real and virtual teaching opportunities may be more effective. For those who are not comfortable using online 3D environments, training in shared sandboxes

Label of Study	Conclusion/results of the Study
	should be optional. The overhead of time required to implement VR-based Metaverse can become prohibitive for problems that require quick and efficient solutions. Modalities, such as the ability to touch scenes as if they were real 3D scenes, could increase the dimensions of electronic education in cyberspace.
S9	Students enjoyed the lesson. The difficulty of the problems is related to the number of blinks of the students. It has been determined that when teachers use the blink system, they can evaluate students' attitudes to achieve higher results in a virtual lesson.
S10	There are a few technical problems mostly related to bandwidth and servers, as well as limitations imposed by the platform that prevent their use. Virtual worlds support collaboration, fun, and learning as they are areas that require constant negotiation between avatars. Feeling that they actively participated in the activities motivated the participants.
S11	The students clearly enjoyed the virtual lesson.
S12	The students fully understood the subject taught in the virtual classroom.
S13	Experiments and the Metaverse environment can be effective in teaching.
S14	The Second Life platform has a very similar level of effectiveness to the traditional classroom teaching method for successful second language practice.
S15	On the Second Life platform, the attendance rate is higher than the traditional course.
S16	A virtual world application with interesting features such as being flexible, adaptable, accessible and based on free software for e-learning support allows to perform all kinds of simulations, signal analysis and other activities as in a complete ICT laboratory.
S17	Real-life hand movements are reflected on the platform late.
S18	Metaverse technologies provide capabilities for shared media and processing, the interaction and continued use of these capabilities impacts people.
S19	Metaverse technologies provide capabilities for communication, team process, and interaction, the interaction and continued use of these capabilities impacts people.
S20	Metaverse technologies provide capabilities for shared media, communication, team process, and interaction, the interaction and continued use of these capabilities impact people.
S21	The Secondlife platform positively affects the reliability of individuals and institutions.
S22	Individual reliability and trust; Awareness is positively impacted by the use of certain VWTCs such as communication, interaction, creation and team process.

The results of studies (S2, S3, S8) which make inferences about the future of Metaverse were as follows: Metaverse platforms are expected to be used in order to complement the deficiencies in online learning environments; it is expected that digital reality-based Metaverse technology will reach a level that cannot be distinguished from reality by the help of the development of brain-computer interfaces and the provision of

additional features such as the sense of touch. The results of such studies as S1, S3, S5, S6, S7, S8, S11, S21, S22 made suggestions for further development of Metaverse technology in teaching environments that can be listed as follows: active learning environments based on experimental learning and gamification should be created; storytelling should be given importance rather than visual effects; real life elements should not be ignored; features such as scalable Metaverse technology and speech detection should be used together with artificial intelligence technology; and students' learning should be supported with pedagogy and content knowledge. The studies labeled as S7, S8, S10, S13 reached conclusions about the disadvantages of using Metaverse in educational environments. They stated such disadvantages as technological difficulties related to bandwidth and servers during the use of Metaverse; extra time or work required to design and develop a Metaverse environment in which learning and teaching process will take place; limitations and restrictions of Metaverse platforms may prevent the desired teaching practice; and real-life movements may be reflected on the Metaverse platform too late.

This review study found that all studies reached conclusions about the beneficial aspects of using Metaverse in educational settings. According to these results:

- A participatory and sustainable learning environment could be created
- The efficiency of the learning process can be maximized with Metaverse.
- Metaverse can facilitate the use of synchronous and asynchronous learning, as well as methods such as flipped classroom and cooperative learning.
- Metaverse can be used for fun learning to provide motivation and cooperation.
- Metaverse can be used to ensure students' attendance.
- Metaverse contributes to the development of trust building, awareness raising, communication skills, interaction, product creation and team management processes.

Metaverse and its Technological Context in Studies

In the studies included in the systematic review, Metaverse technology appears in two different contexts, namely, three-dimensional computer software-based Metaverse platforms and digital reality-based Metaverse platforms (see Table 5). Some studies (S1, S2, S8) used the concept of Metaverse in a single way, even though they deal with it in both contexts above. Table 5 below summarizes the definition of the concept of Metaverse and the context of Metaverse technology (3D software-based or digital reality-based). The definition of Metaverse in the studies examined and how it is perceived based on these definitions was also examined. According to Table 5, it can be seen that many different definitions of the Metaverse were made. Within these definitions, Metaverse was mentioned as a virtual world, a virtual environment or a virtual space (S1, S3, S4, S5, S7, S8, S9, S10, S11, S14, S15, S16, S18, S19, S20) and a three-dimensional world (S4, S5, S16, S20, S21). It is seen that there are studies (S2, S4, S5, S6, S7, S9, S10, S16, S19) that refer to the metaverse as a mixed reality world or talk about the avatar feature of a human being with a digital twin. Definitions in many studies (S2, S4, S5, S7, S12, S13, S14, S15, S16, S19, S20) emphasized the interaction feature of the Metaverse. Additionally, definitions in some studies (S12, S14, S15, S19, S22) mentioned that Metaverse is scalable, a new type of Internet, a simulation software, and has no physical limitations, aims to simulate the real world. Based on these definitions, Metaverse perceived

today as they are virtual worlds in which people exist and interact through their avatars, created by computers connected by blockchain technology, and also powered by digital reality technologies.

Table 5. Metaverse Definition and Technological Context in Examined Studies

Label of Study	**Metaverse Definition and Technological Context**
S1	"A gaming platform where users create their own virtual playgrounds by customizing the virtual world." (3D software based) (Digital reality based)"
S2	"Simulation space based on interaction with a computer, inhabited by several users, represented by iconic images called avatars, able to communicate with each other in a synchronized manner." (3D software based) (Digital reality based)
S3	"A virtual world based on everyday life where both real and unreal coexist." (Digital reality based)
S4	"The mixed reality world within the physical world, where users come together and interact in a 3D virtual environment." (Digital reality based)
S5	"The mixed reality world within the physical world, where users come together and interact in a 3D virtual environment." (Digital reality based)
S6	Three-dimensional computer environments where users exist with their avatars." (3D software based)
S7	Digital structures in which participants interact through avatars, with which they try to reproduce real life in a virtual metaphoric environment without space-time constraints." (3D software based)
S8	"Parallel worlds existing in virtual spaces powered by interconnected computers." (3D software based) (Digital reality based)
S9	"A virtual three-dimensional world where avatars do everything for us." (3D software based)
S10	" An interface program that allows the user to connect to the virtual world through an avatar and create the world he needs to achieve the goal." (3D software based)
S11	"Virtual 3D World." (3D software based)
S12	Simulated areas of social interaction on the web that aim to mimic the real world geographically, sociographically, economically and communicatively, but overcome the

Label of Study	Metaverse Definition and Technological Context
	limitations of the real physical world." (3D software based)
S13	"A computer-generated world where people can share and interact as if they were in the real world." (3D software based)
S14	"Three-dimensional virtual environments that allow people to interact with each other through software tools without physical limitations." (3D software based)
S15	"Three-dimensional virtual worlds where people interact with each other and their environment using the metaphor of the real world, but without physical limitations." (3D software based)
S16	"3D digital environment where one can navigate and interact with other avatars in a virtual space created by electronic objects with a user-agent avatar to create online campuses, virtual museums, academic conferences." (3D software based)
S17	"A relatively new type of Internet application, similar to 3D games, different from the Internet in that its demands on host systems and network traffic are more bandwidth intensive." (3D software based)
S18	"World-class three-dimensional virtual space services that can offer complementary activities between face-to-face learning and e-learning, with state-of-the-art technology that can be used for experiential education." (3D software based)
S19	"It is not only a cyberspace with a space simulator, but also a virtual world where there are social activities, where the computer user can interact with other users through their own representation of avatars." (3D software based)
S20	"Going beyond the vision of an immersive 3D virtual world, networks that create and interact with physical world objects, actors, interfaces, and virtual environments." (3D software based)
S21	"A permanent 3D world like SecondLife." (3D software based)
S22	"In addition to developing self-configuring, scalable visual displays, a digital technology that enables learning and teaching in an inclusive, non-restrictive environment powered by commodity hardware." (3D software based) (Digital reality based)

Conclusion and Discussion

The concept of Metaverse and the technology it expresses have been used in different formats and platforms for years. To observe the change in the concept of metaverse over the years, a need has arisen to conduct a systematic literature review. There are many studies on Metaverse when it is examined regardless of any discipline and field. There is a need for in-depth analysis to determine how each of these studies deal with the Metaverse. For this reason, in this study, the subject of Metaverse was examined by limiting it to the field of education. The first conclusion reached in this review is that research on the Metaverse continues not only in recent years, but also in the past ten years and even before. After an in-depth examination of the studies, it was observed that there were changes in the way the concept of Metaverse was handled. In the first studies on Metaverse in education, the concept was discussed in the context of three-dimensional software, while in later studies, the concept of Metaverse began to be discussed in the context of digital reality technologies. The reason why the concept has become popular in recent years is that it connects with already popular augmented reality and virtual reality technologies, which give a feeling of immersion. Major social media and technology companies continue to invest in digital reality technologies. With the development of blockchain technology, since it has the potential to provide the concept of metaverse with a completely different position, studies in this field have gained a vast interest and importance.

Looking at the findings in the distribution of the studies examined by countries, it is difficult to say that there is a certain pattern. There are more studies in technologically developed countries such as Japan, South Korea and the USA. The fact that Metaverse technology, which has a relatively high cost and requires users to have high technology literacy, is easier to access in developed countries can be interpreted as a reason for this situation.

The findings in the distribution of the studies examined by years showed a certain pattern. While the highest number of studies were found in 2012, the number of studies decreased later reached the same level again in 2022. The concept of Metaverse has changed in this 10-year period. Wheras the studies conducted in 2012 were three-dimensional software-based Metaverse studies, the studies in 2022 were digital reality-based Metaverse studies. Today, when Metaverse is mentioned, virtual reality glasses and digital reality-based games come to mind. This is important in terms of having an opinion on the speed of technology development and how it affects our lives in a 10-year period.

Considering the findings in the distribution of research types according to the purpose of the studies examined, the result shows that most of the studies were descriptive studies, and all of the descriptive studies were design-based research studies. Experimental methods were not preferred in design-based studies, or applications whose effects on a dependent variable were not carried out. In design-based research studies, mostly three-dimensional computer software-based software has been developed on Metaverse platforms. For the descriptive studies conducted in recent years, there are studies carried out using mixed reality glasses. This situation can be interpreted as the understanding the concept of Metaverse has evolved and the developments in technology have been kept up, and digital reality-based Metaverse technologies have begun to be used in education instead of three-dimensional software-based Metaverse. Additionally, since digital reality-based Metaverse technologies have just

begun to be developed in education, research is mostly carried out in the form of design-based research. When these designs take a certain shape, it can be expected that there will be an increase in the number of studies which the effects of various dependent variables are examined in.

Considering the findings in the distribution of the studies examined according to their research method, it was observed that most of the studies were conducted in the design-based research type. For some of the design-based studies, it was observed that data were collected from the participants through interviews and questionnaires, and numerical data such as frequency or percentage were used. However, these studies do not fully cover the statistical and methodological processes applied for quantitative research methods. For this reason, since the method used in the studies cannot be considered as a quantitative or a qualitative research method, studies involving designs developed on Metaverse platforms were examined under the design-based research type. In most of the studies carried out with the design-based research method, the design was developed on three-dimensional software-based Metaverse platforms. Platforms such as Second Life are open source and open to developing different Metaverse environments specific to each course, topic or participants.

When the distribution of the studies according to the education level of the participants was examined, it was observed that most of the studies were carried out at higher education level, except for the studies in the literature review type. This may be because of the fact that researchers prefer purposive sampling in their studies. Considering the findings in the distribution of the studies examined according to the sample type, mostly undergraduate students were included in the studies, since most of the studies were conducted at the higher education institutions.

Considering the findings in the distribution of the studies examined according to the type of technology used, the Second Life platform was used in the highest number of studies, except for the literature review type studies. Today, there are limited number of studies using digital reality-based Metaverse technology that comes to mind when Metaverse is mentioned. The reasons would be that the expected ergonomic developments in augmented and virtual reality technology are not at the desired level, and these devices are not yet affordable for a large number of end users, and the software development process suitable for devices is yet new and not widespread in order to conduct research on this subject. However, due to the recent entrepreneurship and attempts of technology companies in virtual/augmented reality devices and software marketing, the Metaverse technology is now more capable than ever before of changing our lives, which we believe it will be witnessed and observed in the following years.

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