Jurnal Ilmiah Sekolah Dasar
Volume 8, Number 3, 2024 pp. 536-546
P-ISSN: 2579-3276 E-ISSN: 2549-6174
Open Access: https://doi.org/10.23887/jisd.v8i3.70808

Revolutionizing Elementary Math Learning: Exploring the Potential of Metaverse Technology Integration

Loso Judijanto[1*], Guntur Arie Wibowo[2], Syamsul Ghufron[3], Nunung Suryana Jamin[4], Abdul Rozak[5]

[1] Indonesia Palm Oil Strategic Studies, Jakarta, Indonesia
[2] Universitas Samudra, Langsa, Indonesia
[3] Universitas Nahdlatul Ulama Surabaya, Surabaya, Indonesia
[4] Universitas Negeri Gorontalo, Gorontalo, Indonesia
[5] Universitas Islam Negeri Syarif Hidayatullah Jakarta, Jakarta, Indonesia

ARTICLE INFO

Article history:
Received November 28, 2023
Accepted July 10, 2024
Available online August 25, 2024

Kata Kunci:
Teknologi Metaverse*, Sekolah Dasar, Pengajaran Matematika*

Keywords:
Metaverse Technology, Elementary School, Mathematics Teaching

ABSTRAK

Integrasi teknologi metaverse dalam pendidikan terus berkembang untuk menciptakan pengalaman belajar imersif. Namun, implementasinya dalam pembelajaran matematika di tingkat sekolah dasar masih minim, sehingga kurang mampu menarik minat siswa. Penelitian ini bertujuan untuk menganalisis pemanfaatan teknologi metaverse oleh guru dalam proses pembelajaran matematika di sekolah dasar. Penelitian menggunakan pendekatan kuantitatif dengan kuesioner sebagai instrumen pengumpulan data, melibatkan guru dan pengawas siswa berbakat sebagai subjek penelitian. Hasil penelitian menunjukkan bahwa guru mengenali dan memanfaatkan teknologi metaverse secara signifikan dalam pengajaran matematika, yang berdampak positif pada keterlibatan siswa dan menciptakan pengalaman belajar yang lebih bermakna. Perspektif guru dan pengawas memperlihatkan bahwa teknologi ini mampu mendukung praktik pembelajaran yang lebih efektif. Analisis data menunjukkan adanya perbedaan signifikan antara perspektif guru dan pengawas terkait pemanfaatan teknologi metaverse, terutama pada individu yang telah mengikuti lebih dari dua pelatihan terkait teknologi ini. Namun, tidak ditemukan perbedaan signifikan berdasarkan pengalaman mengajar siswa berbakat. Penelitian ini menyimpulkan bahwa teknologi metaverse memiliki potensi besar untuk diintegrasikan dalam pembelajaran matematika di sekolah dasar, mendorong inovasi pendidikan berkelanjutan yang mampu meningkatkan minat dan pemahaman siswa dalam konsep-konsep matematika.

ABSTRACT

The integration of metaverse technology in education continues to evolve, providing immersive learning experiences. However, its implementation in elementary mathematics education remains limited, resulting in low student engagement. This study aims to analyze the extent to which teachers utilize metaverse technology in teaching mathematics at the elementary level. Employing a quantitative approach, data were collected using questionnaires administered to teachers and gifted student supervisors. The findings reveal that teachers significantly recognize and utilize metaverse technology in mathematics instruction, positively influencing student engagement and creating more meaningful learning experiences. The perspectives of teachers and supervisors indicate that integrating metaverse technology supports more effective teaching practices. The data analysis shows a statistically significant difference between teachers' and supervisors' perspectives regarding the use of metaverse technology, particularly among individuals who have attended more than two related training sessions. However, no significant differences were found based on teaching experience with gifted students. This study concludes that metaverse technology holds great potential for integration into elementary mathematics education, promoting sustainable educational innovation. It can enhance students' interest and understanding of mathematical concepts through interactive and engaging learning environments.

Corresponding author
*E-mail addresses: losojudijantobumn@gmail.com (Loso Judijanto)

1. INTRODUCTION

In the 21st century, the use of technology is increasingly expanding into various fields and making it a very basic need for daily communication (Srivastava et al., 2020; Fedorov & Mikhaleva, 2020). Specifically in the field of education, technology greatly influences users in obtaining information and methods of conveying information both inside and outside the classroom. In addition, unexpected circumstances such as the COVID-19 outbreak, conflicts in foreign countries, natural disasters, and extreme weather require teachers, parents, and students to take advantage of the advantages offered by technology (Bell et al., 2024; Atlam et al., 2022). In this case, the emergence of the metaverse can be considered a logical consequence of the extraordinary progress in the world of digitalization and communication in the modern era. The influence of the media used extends to cover various fields and aspects of human daily life (Alizadehsalehi et al., 2020; Haltas et al., 2021). In addition, the widespread use of metaverses on social media platforms has grown significantly, moving from a concept that was initially considered commonplace and is now a reality that cannot be denied (Pellegrino et al., 2023; Golf-Papez et al., 2022). In overcoming emergencies such as the COVID-19 pandemic and the need to support the distance learning process, the education sector has carried out a transformation, that is widely integrated (Mishra et al., 2020; Mustapha et al., 2021). Metaverse technology includes many immersive elements such as virtual reality (VR), augmented reality (AR), mixed reality (MR), and 3D environments, as well as real-time interactions and seamless integration with artificial intelligence (AI). This technology facilitates the sharing of experiences between an unlimited number of users around the world, providing a truly immersive environment that reflects the real-world environment. This allows users to engage in virtual communication of facts in an environment that closely resembles reality (Barreda-Ángeles & Hartmann, 2022; Scurati et al., 2021). Metaverse is a contemporary technology in which users interact and collaborate in a virtual environment, seamlessly integrating virtual reality, augmented reality, and 3D space. These immersive platforms not only facilitate direct engagement, but also provide a fun and enjoyable communication experience in a real environment, providing users with feelings of joy, fascination, and satisfaction (Reer et al., 2022; Scorolli et al., 2023).

Several Metaverse platforms have been developed to date, such as Second Life, Open Simulator, Minecraft, Fortnite, Roblox, Sandbox, and Decentral (Tirachini et al., 2020; Yu, 2019). The application of Metaverse technology in education is growing rapidly thanks to features that attract students and enable teachers to provide open learning opportunities and attract interest in learning. This provides distance education while maintaining a sense of comfort and feeling free from pressure (Selvaraj et al., 2021; Bruggeman et al., 2022). Second, in the realm of scientific content, Metaverse technology interestingly presents scientific material and attracts students' interest. Metaverse technology also simplifies the presentation of complex scientific materials and specimens, creating a safe environment that protects students from potential harm. Additionally, Metaverse technology allows students to immerse themselves in a virtual world that closely resembles the real world. This immersive experience provides a technical environment in which students can realistically observe and explore course material (Álvarez et al., 2020; Kuhail et al., 2022; Scurati et al., 2021).. The virtual classroom environment promotes a fun atmosphere, which increases the level of student engagement, especially in the area of mathematics (J. H. Lumbantoruan & Manalu, 2024; J. H. Lumbantoruan & Ditasona, 2024). As a result, mathematics conducted virtually has emerged as a necessary tool in increasing students' motivation in mathematics, helping them retain facts and concepts, and improving problem-solving skills. The American Council of Teachers of Mathematics recommends the above approach. Therefore, it is very important to use more effective teaching tools to understand mathematics education and provide students with a solid foundation, thereby enabling them to understand its importance and value. In this way, mathematics can be transformed from an abstract subject into an accessible and enjoyable field, in tune with students' realities. Several studies reinforce the importance of Metaverse technology and virtual mathematics laboratories in mathematics education, especially through the application of hand sensors, simulations, and educational technologies. Metaverse technology is a microcosm of real life, bridging the gap between real experiences and abstract concepts (Bibri & Jagatheesaperumal, 2023; Pizzolante et al., 2023; De Felice et al., 2023). By integrating mathematics, the quality and durability of learning are improved, providing a long-term impact on students. This is one of the main goals of mathematics education. Many researchers have highlighted the many benefits associated with the use of the Mathematical Metaverse, including Improved conceptual understanding (Pahmi et al., 2023; Fütterer et al., 2022). The Mathematical Metaverse helps students develop a deep conceptual understanding of mathematical concepts and encourages various thinking skills.

Utilization of the Metaverse provides an enriching platform for gaining practical experience and bridging the gap between knowledge, implementation in the field, and facilitation in the development of student's cognitive and innovative processes (AlGerafi et al., 2023; Beck et al., 2023). However, the fact in the field is that the lack of interest from educators and students in using Metaverse in learning makes the

expected learning process less effective. The help of Metaverse, helps educators facilitate the development of student independence in the mathematics learning process (Tlili et al., 2022; AlGerafi et al., 2023). In addition to simulating software for metaverse components, a variety of tools can be used, including virtual hundred boards, virtual shard templates, Deniz chunks, virtual computing chunks, Geoboard, and more. These tools provide an interactive platform in the metaverse that facilitates mathematical learning and exploration. However, the facts on the ground are that there are still many educators and students who doubt the use of Metaverse. Another fact is that in one educational institution, the use of Metaverse is still minimal and has not been utilized optimally. So, this research provides important innovation in exploring the potential of Metaverse technology in increasing students' interest in learning at the elementary school level (Anthwal et al., 2024; Logayah et al., 2023). This research highlights the importance of integrating Metaverse technology into the learning process to create a more engaging and effective learning experience for students. Research findings show that teachers and gifted students can recognize and make significant use of Metaverse technology in the context of mathematics teaching, thereby providing a better learning experience.

Considering the importance of Metaverse technology which includes virtual reality (VR), augmented reality (AR), mixed reality (MR), 3D environments, and artificial intelligence (AI) in the development of education and use by researchers in the field of mathematics education as well as the shortcomings of the implementation and use of Metaverse by teachers, creates a gap between theory and expectations. The theory says that using the Metaverse increases interest and motivates students in the learning process, while educators use the Metaverse minimally. Therefore, it is necessary to research to analyze the extent to which Metaverse technology is utilized in the classroom learning process, especially in the elementary school-level mathematics learning process. The novelty of this study investigates how immersive, virtual environments in the Metaverse can shape foundational cognitive skills such as spatial awareness, memory retention, and focus in young children. Unlike previous studies focusing on higher education, this research could explore how these immersive interactions specifically enhance or hinder cognitive development in elementary-age children.

2. METHOD

The method in this research uses a quantitative descriptive approach, namely studying phenomena in a natural context and describing them comprehensively (Fàbregues et al., 2023; Baas et al., 2020). This approach is used to develop research instruments, analyze and interpret them with the help of existing literature, and then propose appropriate solutions. The population and sample in this research include all teacher educators and supervisors of gifted students in Jakarta, during the second semester of the 2022/2023 academic year. The research sample included all elementary school mathematics teachers and supervisors responsible for gifted students, both in public and private schools in East Jakarta. This research sample consisted of 64 teachers and 8 supervisors. Data collection techniques use questionnaires. Questionnaires are used to obtain reliable information and have data that is reliable, valid, and trustworthy. Construction tools are created and built through relevant references. The questionnaire was created using research indicators. The questionnaire was developed using sub-tools and ensured that reality was achieved through state-of-the-art technology in Primary schools. The questionnaire in this study had 25 items. Questionnaires were given to experts to be validated and questionnaires that were valid and reliable were distributed to respondents to be assessed and given responses with a rating scale of points 1 to 5. Questionnaires were distributed via Google from the link that had been prepared in this research. Table 1 shows the research indicators that were the basis for preparing the questionnaire

Table 1. Research Indicators and Distribution of Research Samples based on Mathematics Teaching

Number	Training courses	Frequency
1	Not attending any course	14
2	Attend one training course	9
3	Attending two training courses	12
4	Attending more than two training courses	37
	Total	**72**

Data analysis technique. The collected data was analyzed using SPSS Version 25.0 by evaluating the items, testing validity, and testing reliability using the Rasch Model (Campos et al., 2020). The reliability criteria for accepting an item exceed 0.50, indicating the reliability of the item is acceptable. The acceptable separation value is set at a minimum of 2, indicating adequate discrimination between individuals (Goode et al., 2020; Feng et al., 2020). A five-category scale was used for the 'use of Metaverse in mathematics

teaching' instrument, with the following categories: 1 = Never use, 2 = Rarely, 3 = Sometimes, 4 = Almost all the time, and 5 = Use often. The structure of the observation section displays respondents' answers based on a ranking scale. The observed averages describe the response pattern, which is expected to follow a fairly normal pattern with a systematic progression from negative to positive, as shown. To ensure reliability using the Rasch model, it is important to assess person reliability and item reliability. Reliability criteria must exceed 50% to be considered satisfactory. In addition, item and person separation values must exceed 2 to be considered acceptable, as previous research has shown (Herrera-Franco et al., 2020; Mousa & Othman, 2020). In this study, the reliability of the scale was evaluated by measuring person reliability and item reliability. The results indicate that the scale exhibits an appropriate level of reliability for its items.

3. RESULT AND DISCUSSION

Result

To assess the extent to which teachers utilized Metaverse technology in teaching mathematics, the study sample's responses to the scale items were analyzed. Frequencies, percentages, standard deviations, and ranks were computed based on these responses. The outcomes are presented in Table 2.

Table 2. Research sample responses regarding the extent of use of Metaverse technology

Item	Mean	Std. Deviation	Rank
First Dimension: The degree to which teachers employ Metaverse technology in teaching mathematics			
The teacher is actively involved in the creation of metaverse content for the mathematics course that he/she is teaching or supervising.	3.39	1.523	6
The teacher employs metaverse technology to track and assess students' progress in the mathematics course.	3.35	1.551	7
The teacher consistently utilizes metaverse technology throughout the instruction of the mathematics course.	3.31	1.426	8
The teacher's utilization of metaverse technology facilitates the exchange of experiences among colleagues.	3.59	1.589	3
The mathematics teacher collaborates with colleagues in constructing the content of the metaverse reality, thereby fostering a shared knowledge base.	3.42	1.464	5
The utilization of metaverse technology enables the teacher to save time and effort in effectively communicating knowledge.	3.56	1.666	4
While utilizing metaverse reality technology, students actively engage in interactive sessions with the teacher.	3.61	1.694	2
The incorporation of metaverse technology contributes to the professional development of mathematics teachers.	3.68	1.704	1
Overall Average	**3.49**	**1.509**	**-**
Second Dimension: The degree to which teachers use Metaverse technology in teaching mathematics			
I use virtual Dienes pieces for teaching mathematical concepts (specifically, numbers and operations) to students.	4	1.049	3
I use virtual Linking Cubes to teach students mathematical concepts (addition, subtraction, and classification).	3.9	1.118	7
I use Domino's Virtual Subtraction Facts as a teaching tool to help students understand the concept of subtraction.	3.63	1.237	9
I utilize the virtual number line as an instructional tool to teach students the concept of numbers.	3.97	1.166	5
I use virtual fraction slides to teach students the concept of fractions, as well as operations are performed on them.	3.97	1.172	6
I utilize the virtual arithmetic scale as an instructional tool to teach students the concept of mathematical operations.	3.45	1.349	10
I utilize virtual clock models to teach students the skill of telling time.	4.02	1.133	2
I utilize virtual engineering tools to teach students the art of drawing engineering designs.	4.08	1.055	1
I use virtual drawing applications such as GeoGebra and Desmos as instructional tools to teach students the skill of drawing geometric shapes.	3.37	1.448	12

Item	Mean	Std. Deviation	Rank
I utilize virtual geometric pieces to instruct students in the Geometric Shapes and Spatial Reasoning unit.	3.88	1.168	8
I utilize virtual geometric anthropomorphic to teach students in the Geometric Shapes unit.	3.98	1.135	4
I utilize virtual calculators to enhance students' learning experience when calculating the area of a circle.	3.35	1.390	13
I utilize the virtual Geoboard as an instructional tool to teach students how to draw geometric shapes.	3.41	1.399	11
Overall Average	**3.77**	**0.3839**	**-**

The analysis of Table 2 reveals that the employment of Metaverse technology by teachers in teaching mathematics, as perceived by both supervisors and teachers themselves, was relatively high. The overall average score was 3.49 out of 5, indicating a mean falling within the fourth category (3.41-4.22) on the five-point scale. This average corresponds to the fourth category on the five-point scale, which represents "Almost every time use" according to the study tool. The standard deviation of 1.509 suggests a degree of consensus among teachers and supervisors regarding the extent of teachers' adoption of Metaverse technology in mathematics instruction. Most of the items received high scores, except for items 1, 2, and 3, which obtained moderate scores. This simple disparity in opinions reflects the varying perspectives of the sample on those particular items. Table 3 indicates that the degree of teachers' utilization of Metaverse technology in teaching mathematics, as perceived by both supervisors and teachers themselves, was remarkably high. The overall average score of 3.77 out of 5 corresponds to the fourth category on the five-point scale, signifying "Almost every time used" according to the study tool. According to the sample's feedback, the most notable items about the extent of teachers' utilization of Metaverse technology in teaching mathematics were ranked as follows: item 8, item 7, and item 1, in descending order of approval. Regarding the items with the lowest scores in terms of teachers' utilization of the Metaverse technique in teaching mathematics, they corresponded to items 12, 9, and 13 in descending order. To address the second inquiry, which examines whether there are statistically significant disparities between the perspectives of supervisors and teachers regarding the utilization of Metaverse technology in teaching mathematics at the primary level based on academic qualification, experience, and training, statistical analyses including t-tests and one-way analysis of variance (ANOVA) were conducted. Table 3 presents the outcomes of the t-test, showcasing the extent to which teachers use Metaverse technology in teaching mathematics at the primary level as perceived by both supervisors and teachers themselves, categorized according to academic qualification, experience, and training.

Table 3. Mean, Standard Deviation, and t-value

Dimensions		N	Mean	Std. Deviation	t_{value}	Sig.
Employing Metaverse technology in teaching mathematics	Bachelor's	51	2.55	1.528	2.049	0.056
	Postgraduate	21	1.88	1.140		
Using Metaverse technology in teaching mathematics	Bachelor's	51	2.58	1.515	2.423	0.101
	Postgraduate	21	1.81	1.308		
Overall average	Bachelor's	51	2.57	1.525	2.317	0.068
	Postgraduate	21	1.87	1.331		

According to the findings presented in Table 3, there are no statistically significant differences observed in the mean scores of respondents regarding the utilization of Metaverse technology in teaching mathematics at the primary level based on their academic qualifications. Table 4 shows the results of a one-way analysis of variance for the degree of availability of actively open-minded thinking indicators on the results of gifted programs in the dimensions of the scale due to the number of programs acquired by the gifted students.

Table 4. Results of Variance Analysis of Differences in Response Means

Aspect	Dimensions	Statistical Parameters	Sum of Squares	df	Mean Square	F	Sig
Training	Employing Metaverse	Between Groups	57.893	2	28.946	14.656	0
		Within Groups	347.59	176			

Aspect	Dimensions	Statistical Parameters	Sum of Squares	df	Mean Square	F	Sig
	technology in teaching mathematics	Total	405.49	178	1.975		
	Using Metaverse	Between Groups	7.877	3	2.626	3.852	0.01
		Within Groups	175.88	258			
	technology in teaching mathematics	Total	183.76	261	0.682		
	Whole Dimensions	Between Groups	15.439	3	2.173	3.192	0.01
		Within Groups	235.514	193			
		Total	139.086	199	0.871		
Experience	Employing Metaverse technology in teaching mathematics	Between Groups	7.093	2	3.546	1.567	0.212
		Within Groups	298.39	176			
		Total	305.49	178	2.264		
	Using Metaverse technology in teaching mathematics	Between Groups	3.601	2	1.8	4.661	0.11
		Within Groups	222.89	277			
		Total	226.49	279	0.386		
	Whole Dimensions	Between Groups	3.419	3	1.481	3.126	0.13
		Within Groups	135.52	96			
		Total	139.34	99	0.377		

According to the findings presented in Table 4, there are no statistically significant differences observed in the mean scores of respondents regarding the employment of Metaverse technology in teaching mathematics at the primary level based on their experiences. While statistically significant differences are observed in the perspectives of teachers and supervisors regarding the extent of utilizing the Metaverse technique in teaching mathematics at the primary stage. These differences are observed when considering the training variable. To determine the direction of differences in favor of either category, a post-comparison Scheffe test was used to determine the four-course periods obtained in Table 5.

Table 5. Results of Scheffe Test for Differences between the Number of Courses Acquired by the Teachers

(I) Course	(J) Course	Mean Difference (I-J)	Sig.
0 course	1 course	0.23726	0.659
	2 courses	0.25884	0.511
	more than 2 course	-0.15524	0.722
1 course	0 course	-0.23726	0.659
	2 courses	0.02158	0.914
	more than 2 program	-0.39250	0.130
2 courses	0 course	-0.25884	0.511
	1 course	-0.02158	0.914
	more than 2 program	-0.41408	0.044
more than 2 course	0 course	0.15524	0.722
	1 course	0.39250	0.130
	2 courses	0.41408	0.044

Based on the findings presented in Table 5 significant statistical differences are evident in the perspectives of teachers and supervisors regarding the utilization of Metaverse technology in teaching mathematics at the primary level. These differences are observed when considering the training variable, specifically between individuals who received one course and those who received more than two courses. Notably, the viewpoints of those who received more than two courses favor a greater extent of utilizing Metaverse technology compared to those who received only one course. The analysis revealed that there were no statistically significant differences in the perspectives of teachers and supervisors regarding the

extent of utilizing Metaverse technology in teaching mathematics at the primary stage. This finding applies to each pair of the remaining training variable categories.

Discussion

The findings show that for supervisors and teachers, there is a relatively high level of utilization of Metaverse technology in teaching mathematics at the elementary level. This observation can be attributed to teachers' recognition of the inherent value of Metaverse technology in educational contexts, as well as their receptivity to the application of new and useful tools in the educational technology domain to enhance and simplify the teaching process. Metaverse technology provides an interactive and immersive learning experience that captures students' attention. Through the use of simulations, virtual environments, and augmented reality, students can actively participate in their learning, thereby increasing engagement and motivation (Pellegrino et al., 2023; Polas et al., 2022). This high level of engagement was recognized by supervisors and teachers as a positive aspect of utilizing Metaverse technology in mathematics classes. Metaverse technology offers visual representations, interactive models, and simulations that support students' conceptual understanding of mathematical concepts. These visual and interactive tools make abstract concepts more tangible and accessible, allowing students to explore and manipulate mathematical ideas in ways that promote deeper understanding. Supervisors and teachers appreciate the potential of Metaverse technology to improve students' conceptual understanding of mathematics (Rachmadtullah et al., 2023; Wijayanto et al., 2023). Metaverse technology enables learning experiences that are personalized and tailored to each student's needs. Teachers can create customized activities, adaptive assessments, and targeted feedback to meet different learning styles and proficiency levels. This personalized approach ensures that students receive the support and challenge needed to optimize their learning outcomes. Metaverse technology's ability to facilitate personalized learning is appreciated by supervisors and teachers. Metaverse technology aligns with today's students' digital fluency. This reflects their use of technology in their daily lives and capitalizes on their familiarity with digital tools (Muthmainnah et al., 2023; Onu et al., 2023). Supervisors and teachers recognize the importance of integrating technology into education to meet the needs and expectations of modern learners. Supervisors can provide professional development opportunities and support to teachers in effectively integrating Metaverse technology into their mathematics teaching. This training and mentorship allow teachers to develop the skills and confidence necessary to effectively implement Metaverse technology in the classroom. Supervisors and teachers appreciate the value of ongoing professional development in utilizing technology for mathematics instruction (Guggemos & Seufert, 2021; Seufert et al., 2021; Huang et al., 2022).

Other findings revealed statistically significant differences in teachers' and supervisors' perspectives regarding the extent of utilization of Metaverse technology in elementary mathematics instruction (Gupta et al., 2023). These differences were observed based on the training variable, which prioritizes individuals who received more than two courses. The researchers attributed these results to several factors. First, they argue that the higher level of use of Metaverse technology among teachers in teaching mathematics can be attributed to the increased curriculum emphasis on this technology and its ease of application compared to conventional methods of conveying information and exploring mathematical concepts (Al Shareef et al., 2022; Özdemir, 2022). In addition, the statistically significant differences in the views of teachers and supervisors regarding the extent of use of Metaverse technology in mathematics teaching at the elementary level, based on training variables, can be attributed to several reasons: first, increased familiarity and comfort: Teachers who received more than two courses on Metaverse technologies likely have a higher level of familiarity and comfort in using such technologies in their teaching practices (Braun-Lewensohn et al., 2019; Hassan et al., 2019). This increased familiarity may lead to more positive perceptions regarding its effectiveness and potential benefits in teaching mathematics. Peer interactions can influence perceptions and encourage positive attitudes toward the use of Metaverse technology in mathematics teaching. Sixth, technological competence: Teachers who have undergone several training courses have likely developed higher levels of technological competence in using Metaverse technology. Seventh, knowledge transfer: teachers who have received more training courses on Metaverse technologies may have more opportunities to engage in professional development activities, attend workshops, or collaborate with experts in the field. These results are consistent with the research (Kasneci et al., 2023; Onu et al., 2023; Polas et al., 2022).

It is crucial to acknowledge that these statistically significant differences do not imply that teachers with fewer training courses hold negative views or possess lesser capabilities. Rather, these differences reflect varying levels of exposure, knowledge, and experience with Metaverse technology, which can influence one's perspective on its application in mathematics instruction (Lemay et al., 2021; Støle et al., 2020). Each individual's unique background and opportunities for professional development contribute to their outlook and understanding of the potential benefits and challenges associated with utilizing Metaverse

technology in the classroom. The findings also revealed that no statistically significant differences were observed based on the teachers' experiences with Gifted Students (Purwanto et al., 2020). This is attributed to the fact that teachers encounter similar teaching conditions when instructing mathematics, without any consideration given to their experience levels. Due to the inherent complexity of mathematics, it serves as a common denominator among all mathematics educators. Consequently, they encounter comparable challenges and tend to employ comparable teaching methods and educational techniques to facilitate students' comprehension of the subject. These findings align with multiple studies conducted (Al-Azawei & Alowayr, 2020; Chen et al., 2020).

This research implies that teachers and students utilize Metaverse technology effectively in the mathematics learning process at the elementary level. In addition, this research also shows the need for continuous training and education for teachers to be able to optimally integrate Metaverse in their teaching practices. The weakness of this research is that it does not analyze the barriers to implementing metaverse technology in elementary school education. This is because the aim of the research is not to show the teacher training program implemented by the Education Department regarding the use of metaverse technology in the learning process in elementary schools.

This research also has weaknesses, namely that it does not conduct an analytical study of the curriculum at the elementary stage with a focus on alignment with the developmental needs of elementary school students, and at this stage, the researcher has not yet achieved metaverse integration. technology in the learning process. Recommendations have been put forward by researchers to increase the use of Metaverse technology in mathematics teaching at the elementary level, as perceived by supervisors and teachers. The can improve their skills, expand their knowledge, and stay up to date on the latest developments in leveraging Metaverse technology for effective mathematics teaching. To encourage the effective integration of Metaverse technology in teaching practices, it is recommended to foster a collaborative learning community between teachers and supervisors.

4. CONCLUSION

To increase the use of Metaverse technology in the teaching process at the elementary school level, teachers and supervisors of gifted children must have ongoing professional development initiatives that specifically target and utilize Metaverse technology to help students understand the material. Programs such as these are designed to encourage teachers to actively participate in training sessions and ongoing professional development programs at the school. This research is already doing this and teachers can improve their skills, expand their knowledge, and stay up to date with the latest technological developments in utilizing Metaverse technology in effective teaching. To encourage the effective integration of Metaverse technology in teaching practices, it is recommended to foster collaborative learning communities among teachers and supervisors. This research can be achieved by creating platforms and opportunities that facilitate knowledge sharing and exchange of best practices regarding Metaverse technologies. The research encourages regular communication and collaboration within the community to enable teachers to learn from each other, gather insights, and collectively develop innovative approaches for the integration of Metaverse technologies into their teaching practices.

5. REFERENCES

Al-Azawei, A., & Alowayr, A. (2020). Predicting the intention to use and hedonic motivation for mobile learning: A comparative study in two Middle Eastern countries. *Technology in Society*, *62*(August 2020), 101325.1-25. https://doi.org/10.1016/j.techsoc.2020.101325.

Al Shareef, H. J., Al Harbi, A., Alatawi, Y., Aljabri, A., Al-Ghanmi, M. A., Alzahrani, M. S., Algarni, M. A., Khobrani, A., Haseeb, A., Alsenani, F., & Elrggal, M. E. (2022). Evaluate the Effectiveness of Outpatient Parenteral Antimicrobial Therapy (OPAT) Program in Saudi Arabia: A Retrospective Study. *Antibiotics*, *11*(4), 1–8. https://doi.org/10.3390/antibiotics11040441.

AlGerafi, M. A. M., Zhou, Y., Oubibi, M., & Wijaya, T. T. (2023). Unlocking the Potential: A Comprehensive Evaluation of Augmented Reality and Virtual Reality in Education. *Electronics (Switzerland)*, *12*(18), 1-22. https://doi.org/10.3390/electronics12183953.

Alizadehsalehi, S., Hadavi, A., & Huang, J. C. (2020). From BIM to extended reality in AEC industry. *Automation in Construction*, *116*(March), 1-13. https://doi.org/10.1016/j.autcon.2020.103254.

Álvarez, J. A. M., Arnold, E. G., Burroughs, E. A., Fulton, E. W., & Kercher, A. (2020). The design of tasks that address applications to teaching secondary mathematics for use in undergraduate mathematics courses. *Journal of Mathematical Behavior*, *60*(August 2020), 1-18. https://doi.org/10.1016/j.jmathb.2020.100814.

Anthwal, A., Uniyal, A., Gairolla, J., Singh, R., Gehlot, A., Abbas, M., & Akram, S. V. (2024). Industry 4.0 technologies adoption for digital transition in drug discovery and development: A review. *Journal of Industrial Information Integration*, *38*(January), 100562. https://doi.org/10.1016/j.jii.2024.100562.

Atlam, E. S., Ewis, A., El-Raouf, M. M. A., Ghoneim, O., & Gad, I. (2022). A new approach in identifying the psychological impact of COVID-19 on university student's academic performance. *Alexandria Engineering Journal*, *61*(7), 5223–5233. https://doi.org/10.1016/j.aej.2021.10.046.

Baas, J., Schotten, M., Plume, A., Côté, G., & Karimi, R. (2020). Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies. *Quantitative Science Studies*, *1*(1), 377–386. https://doi.org/10.1162/qss_a_00019.

Barreda-Ángeles, M., & Hartmann, T. (2022). Psychological benefits of using social virtual reality platforms during the covid-19 pandemic: The role of social and spatial presence. *Computers in Human Behavior*, *127*(December 2020), 1-13. https://doi.org/10.1016/j.chb.2021.107047.

Beck, D., Morgado, L., & O'Shea, P. (2023). Educational Practices and Strategies with Immersive Learning Environments: Mapping of Reviews for using the Metaverse. *IEEE Transactions on Learning Technologies*, *1*(January), 1-23. https://doi.org/10.1109/TLT.2023.3243946.

Bell, I., Laurie, N., Calle, O., Carmen, M., & Valdez, A. (2024). Education for disaster resilience: Lessons from El Niño. *Geoforum*, *148*(November 2023), 103919.1-11. https://doi.org/10.1016/j.geoforum.2023.103919.

Bibri, S. E., & Jagatheesaperumal, S. K. (2023). Harnessing the Potential of the Metaverse and Artificial Intelligence for the Internet of City Things: Cost-Effective XReality and Synergistic AIoT Technologies. *Smart Cities*, *6*(5), 2397–2429. https://doi.org/10.3390/smartcities6050109.

Braun-Lewensohn, O., Abu-Kaf, S., & Al-Said, K. (2019). Women in refugee camps: Which coping resources help them to adapt? *International Journal of Environmental Research and Public Health*, *16*(20), 1-11. https://doi.org/10.3390/ijerph16203990.

Bruggeman, B., Garone, A., Struyven, K., Pynoo, B., & Tondeur, J. (2022). Exploring university teachers' online education during COVID-19: Tensions between enthusiasm and stress. *Computers and Education Open*, *3*(June), 100095. 1-13. https://doi.org/10.1016/j.caeo.2022.100095.

Campos, C. I. de, Pitombo, C. S., Delhomme, P., & Quintanilha, J. A. (2020). Comparative analysis of data reduction techniques for questionnaire validation using self-reported driver behaviors. *Journal of Safety Research*, *73*(June 2020), 133–142. https://doi.org/10.1016/j.jsr.2020.02.004.

Chen, X., Zou, D., Cheng, G., & Xie, H. (2020). Detecting latent topics and trends in educational technologies over four decades using structural topic modeling: A retrospective of all volumes of Computers & Education. *Computers and Education*, *151*(September 2019), 103855.1-21. https://doi.org/10.1016/j.compedu.2020.103855.

De Felice, F., Petrillo, A., Iovine, G., Salzano, C., & Baffo, I. (2023). How Does the Metaverse Shape Education? A Systematic Literature Review. *Applied Sciences (Switzerland)*, *13*(9), 1-24. https://doi.org/10.3390/app13095682.

Fàbregues, S., Sáinz, M., Romano, M. J., Escalante-Barrios, E. L., Younas, A., & López-Pérez, B. S. (2023). Use of mixed methods research in intervention studies to increase young people's interest in STEM: A systematic methodological review. *Frontiers in Psychology*, *13*(January), 1–14. https://doi.org/10.3389/fpsyg.2022.956300.

Fedorov, A., & Mikhaleva, G. (2020). Current trends in media and information literacy in research and scientific publications of the early 21st century. *International Journal of Media and Information Literacy*, *5*(2), 153–163. https://doi.org/10.13187/IJMIL.2020.2.153.

Feng, D. C., Liu, Z. T., Wang, X. D., Chen, Y., Chang, J. Q., Wei, D. F., & Jiang, Z. M. (2020). Machine learning-based compressive strength prediction for concrete: An adaptive boosting approach. *Construction and Building Materials*, *230*(January), 1-20. https://doi.org/10.1016/j.conbuildmat.2019.117000.

Fütterer, T., Scheiter, K., Cheng, X., & Stürmer, K. (2022). Quality beats frequency? Investigating students' effort in learning when introducing technology in classrooms. *Contemporary Educational Psychology*, *69*(January), 102042.1-20. https://doi.org/10.1016/j.cedpsych.2022.102042.

Golf-Papez, M., Heller, J., Hilken, T., Chylinski, M., de Ruyter, K., Keeling, D. I., & Mahr, D. (2022). Embracing falsity through the metaverse: The case of synthetic customer experiences. *Business Horizons*, *65*(6), 739–749. https://doi.org/10.1016/j.bushor.2022.07.007.

Goode, K. L., Dunphy, B. J., & Parsons, D. M. (2020). Environmental metabolomics as an ecological indicator: Metabolite profiles in juvenile fish discriminate sites with different nursery habitat qualities. *Ecological Indicators*, *115*(November 2019), 1-13. https://doi.org/10.1016/j.ecolind.2020.106361.

Guggemos, J., & Seufert, S. (2021). Computers in Human Behavior Teaching with and teaching about technology – Evidence for professional development of in-service teachers. *Computers in Human*

Behavior, *115*(November 2020), 106613.1-11. https://doi.org/10.1016/j.chb.2020.106613.

Gupta, S., Montenovo, L., Nguyen, T., Lozano-Rojas, F., Schmutte, I., Simon, K., Weinberg, B. A., & Wing, C. (2023). Effects of social distancing policy on labor market outcomes. *Contemporary Economic Policy*, *41*(1), 166–193. https://doi.org/10.1111/coep.12582.

Haltas, I., Yildirim, E., Oztas, F., & Demir, I. (2021). A comprehensive flood event specification and inventory: 1930–2020 Turkey case study. *International Journal of Disaster Risk Reduction*, *56*(1), 1–13. https://doi.org/10.1016/j.ijdrr.2021.102086.

Hassan, C., East, J., Radaelli, F., Spada, C., Benamouzig, R., Bisschops, R., Bretthauer, M., Dekker, E., Dinis-Ribeiro, M., Ferlitsch, M., Fuccio, L., Awadie, H., Gralnek, I., Jover, R., Kaminski, M. F., Pellisé, M., Triantafyllou, K., Vanella, G., Mangas-Sanjuan, C., … Dumonceau, J. M. (2019). Bowel preparation for colonoscopy: European society of gastrointestinal endoscopy (esge) guideline-update 2019. *Endoscopy*, *51*(8), 775–794. https://doi.org/10.1055/a-0959-0505.

Herrera-Franco, G., Montalván-Burbano, N., Carrión-Mero, P., Apolo-Masache, B., & Jaya-Montalvo, M. (2020). Research trends in geotourism: A bibliometric analysis using the scopus database. *Geosciences (Switzerland)*, *10*(10), 1–29. https://doi.org/10.3390/geosciences10100379.

Huang, B., Siu-Yung Jong, M., Tu, Y. F., Hwang, G. J., Chai, C. S., & Yi-Chao Jiang, M. (2022). Trends and exemplary practices of STEM teacher professional development programs in K-12 contexts: A systematic review of empirical studies. *Computers and Education*, *189*(January), 104577. https://doi.org/10.1016/j.compedu.2022.104577.

Kasneci, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G., Günnemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeffer, J., Poquet, O., Sailer, M., Schmidt, A., Seidel, T., … Kasneci, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. *Learning and Individual Differences*, *103*(February). https://doi.org/10.1016/j.lindif.2023.102274.

Kuhail, M. A., Elsayary, A., Farooq, S., & Alghamdi, A. (2022). Exploring Immersive Learning Experiences: A Survey. *Informatics*, *9*(4), 1-22. https://doi.org/10.3390/informatics9040075.

Lemay, D. J., Baek, C., & Doleck, T. (2021). Comparison of learning analytics and educational data mining: A topic modeling approach. *Computers and Education: Artificial Intelligence*, *2*(December 2020), 100016.1-14. https://doi.org/10.1016/j.caeai.2021.100016.

Logayah, D. S., Salira, A. B., Kirani, K., Tianti, T., & Darmawan, R. A. (2023). Pengembangan Augmented Reality Melalui Metode Flash Card Sebagai Media Pembelajaran IPS. *Jurnal Basicedu*, *7*(1), 326–338. https://doi.org/10.31004/basicedu.v7i1.4419.

Lumbantoruan, J. H., & Ditasona, C. (2024). Development of a mathematics module on circle material based on the small group discussion model. *Journal of Education and Learning (EduLearn)*, *18*(1), 18–25. https://doi.org/10.11591/edulearn.v18i1.20920.

Lumbantoruan, J. H., & Manalu, R. U. (2024). Effectiveness of learning mathematics derivative materials using modules equipped with cooperative models in high schools. *International Journal of Evaluation and Research in Education* , *13*(1), 523–533. https://doi.org/10.11591/ijere.v13i1.25354.

Mishra, L., Gupta, T., & Shree, A. (2020). Online teaching-learning in higher education during lockdown period of COVID-19 pandemic. *International Journal of Educational Research Open*, *1*(1). https://doi.org/10.1016/j.ijedro.2020.100012.

Mousa, S. K., & Othman, M. (2020). The impact of green human resource management practices on sustainable performance in healthcare organisations: A conceptual framework. *Journal of Cleaner Production*, *243*(1), 1–63. https://doi.org/10.1016/j.jclepro.2019.118595.

Mustapha, I., Van, N. T., Shahverdi, M., Qureshi, M. I., & Khan, N. (2021). Effectiveness of Digital Technology in Education During COVID-19 Pandemic. A Bibliometric Analysis. *International Journal of Interactive Mobile Technologies*, *15*(8), 136–154. https://doi.org/10.3991/ijim.v15i08.20415.

Muthmainnah, Al Yakin, A., & Ibna Seraj, P. M. (2023). Impact of metaverse technology on student engagement and academic performance: the mediating role of learning motivation. *International Journal of Computations, Information and Manufacturing (IJCIM)*, *3*(1), 10–18. https://doi.org/10.54489/ijcim.v3i1.234.

Onu, P., Pradhan, A., & Mbohwa, C. (2023). Potential to use metaverse for future teaching and learning. In *Education and Information Technologies* (Issue August). https://doi.org/10.1007/s10639-023-12167-9.

Özdemir, Ş. (2022). Remote schooling during a pandemic: Visibly Muslim mothering and the entanglement of personal and political. *Gender, Work and Organization*, *29*(4), 1375–1385. https://doi.org/10.1111/gwao.12819.

Pahmi, S., Hendriyanto, A., Sahara, S., Muhaimin, L. H., Kuncoro, K. S., & Usodo, B. (2023). Assessing the

Influence of Augmented Reality in Mathematics Education: A Systematic Literature Review. *International Journal of Learning, Teaching and Educational Research*, *22*(5), 1–25. https://doi.org/10.26803/ijlter.22.5.1.

Pellegrino, A., Wang, R., & Stasi, A. (2023). Exploring the intersection of sustainable consumption and the Metaverse: A review of current literature and future research directions. *Heliyon*, *9*(9), e19190.1-17. https://doi.org/10.1016/j.heliyon.2023.e19190.

Pizzolante, M., Borghesi, F., Sarcinella, E., Bartolotta, S., Salvi, C., Cipresso, P., Gaggioli, A., & Chirico, A. (2023). Awe in the metaverse: Designing and validating a novel online virtual-reality awe-inspiring training. *Computers in Human Behavior*, *148*(February), 107876.1-14. https://doi.org/10.1016/j.chb.2023.107876.

Polas, M. R. H., Afshar Jahanshahi, A., Kabir, A. I., Sohel-Uz-Zaman, A. S. M., Osman, A. R., & Karim, R. (2022). Artificial Intelligence, Blockchain Technology, and Risk-Taking Behavior in the 4.0IR Metaverse Era: Evidence from Bangladesh-Based SMEs. *Journal of Open Innovation: Technology, Market, and Complexity*, *8*(3), 1-24. https://doi.org/10.3390/joitmc8030168.

Purwanto, B. E., Jatmiko, A., Pahrudin, A., Munifah, Wardhani, S., Purnama, S., & Joemsittiprasert, W. (2020). The implementation of cooperative learning to developed management of language learning system. *Journal for the Education of Gifted Young Scientists*, *8*(1), 379–392. https://doi.org/10.17478/jegys.675251.

Rachmadtullah, R., Setiawan, B., Wasesa, A. J. A., & Wicaksono, J. W. (2023). Elementary school teachers' perceptions of the potential of metaverse technology as a transformation of interactive learning media in Indonesia. *International Journal of Innovative Research and Scientific Studies*, *6*(1). https://doi.org/10.53894/ijirss.v6i1.1119.

Reer, F., Wehden, L. O., Janzik, R., Tang, W. Y., & Quandt, T. (2022). Virtual reality technology and game enjoyment: The contributions of natural mapping and need satisfaction. *Computers in Human Behavior*, *132*(1), 107242.10. https://doi.org/10.1016/j.chb.2022.107242.

Scorolli, C., Naddei Grasso, E., Stacchio, L., Armandi, V., Matteucci, G., & Marfia, G. (2023). Would you rather come to a tango concert in theater or in VR? Aesthetic emotions & social presence in musical experiences, either live, 2D or 3D. *Computers in Human Behavior*, *149*(August), 107910.1-20. https://doi.org/10.1016/j.chb.2023.107910.

Scurati, G. W., Bertoni, M., Graziosi, S., & Ferrise, F. (2021). Exploring the use of virtual reality to support environmentally sustainable behavior: A framework to design experiences. *Sustainability (Switzerland)*, *13*(2), 1–20. https://doi.org/10.3390/su13020943.

Selvaraj, A., Radhin, V., KA, N., Benson, N., & Mathew, A. J. (2021). Effect of pandemic based online education on teaching and learning system. *International Journal of Educational Development*, *85*(May), 102444. https://doi.org/10.1016/j.ijedudev.2021.102444.

Seufert, S., Guggemos, J., & Sailer, M. (2021). Technology-related knowledge, skills, and attitudes of pre- and in-service teachers: The current situation and emerging trends. *Computers in Human Behavior*, *115*(May 2020), 106552.1-7. https://doi.org/10.1016/j.chb.2020.106552.

Srivastava, A., Gupta, M. S., & Kaur, G. (2020). Energy efficient transmission trends towards future green cognitive radio networks (5G): Progress, taxonomy and open challenges. *Journal of Network and Computer Applications*, *168*(2), 1-39. https://doi.org/10.1016/j.jnca.2020.102760.

Støle, H., Mangen, A., & Schwippert, K. (2020). Assessing children's reading comprehension on paper and screen: A mode-effect study. *Computers and Education*, *151*(February), 1-13. https://doi.org/10.1016/j.compedu.2020.103861.

Tirachini, A., Chaniotakis, E., Abouelela, M., & Antoniou, C. (2020). The sustainability of shared mobility: Can a platform for shared rides reduce motorized traffic in cities? *Transportation Research Part C: Emerging Technologies*, *117*(1), 1-26. https://doi.org/10.1016/j.trc.2020.102707.

Tlili, A., Huang, R., Shehata, B., Liu, D., Zhao, J., Metwally, A. H. S., Wang, H., Denden, M., Bozkurt, A., Lee, L. H., Beyoglu, D., Altinay, F., Sharma, R. C., Altinay, Z., Li, Z., Liu, J., Ahmad, F., Hu, Y., Salha, S., … Burgos, D. (2022). Is Metaverse in education a blessing or a curse: a combined content and bibliometric analysis. *Smart Learning Environments*, *9*(1), 1-31. https://doi.org/10.1186/s40561-022-00205-x.

Wijayanto, P. W., Thamrin, H., Haetami, A., Mustoip, S., & Oktiawati, U. Y. (2023). The Potential of Metaverse Technology in Education as a Transformation of Learning Media in Indonesia. *Jurnal Kependidikan: Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran Dan Pembelajaran*, *9*(2), 396. https://doi.org/10.33394/jk.v9i2.7395.

Yu, C. (2019). *Yu CH , Tsai CC , Wang Y , Lai KK , Tajvidi M . Towards Building a Value Co-Creation Circle in Social Commerce . Computers in Human Behavior 2018 DOI : https://doi.org/10.1016/j.chb.2018.04.021 Towards Building a Value Co-Creation Circle in Social Commerc*. *2*(April), 1–26. https://doi.org/10.1016/j.chb.2018.04.021.