Assessing the Utilization Level of Metaverse:
Teaching Mathematics at the Primary Level

Rommel Alali
https://orcid.org/0000-0001-7375-4856
King Faisal University, Saudi Arabia

Yousef Wardat
https://orcid.org/0000-0003-2370-9808
Higher Colleges of Technology, UAE

ABSTRACT

The integration of metaverse technology within the educational domain is progressing swiftly, owing to its advanced technological features. This technology has the ability to captivate learners and empower teachers by offering unique learning opportunities and capabilities. Hence, the present study sought to identify the extent of Metaverse technology utilization in primary-level mathematics instruction, as perceived by both supervisors and teachers of Gifted Students. The study employed a descriptive survey method and utilized a questionnaire as the primary research tool. The study's results indicated that teachers of gifted students acknowledged and utilized Metaverse technology to a significant extent in the context of teaching mathematics at the primary level Perspectives of Supervisors and Teachers themselves. This suggests that Metaverse technology has been effectively integrated into their instructional practices, enabling them to provide enhanced learning experiences for their students.

KEYWORDS

Metaverse Technology, Primary Level, Teachers of Gifted Students, Teaching Mathematics

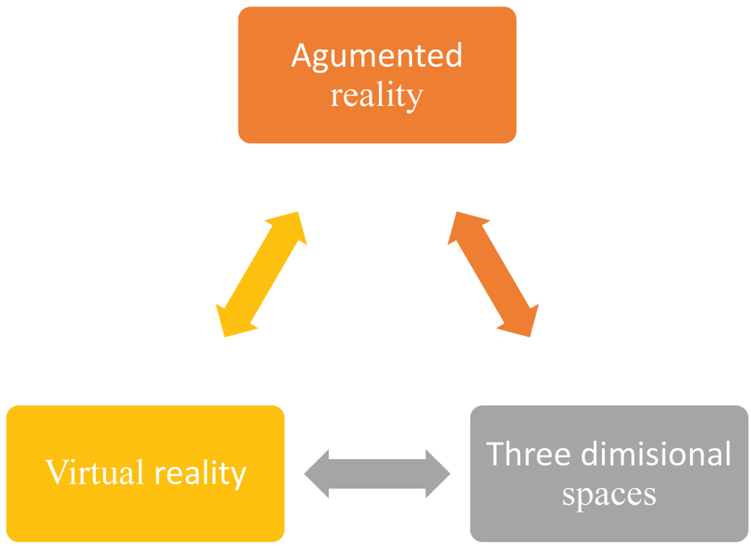
In recent times, technology has become increasingly prevalent, solidifying its role in various domains (Azizi & Mujari, 2022). The field of education, in particular, has undergone significant changes with the integration of information technology, which has had an impact on classroom settings and beyond. Furthermore, unexpected events such as COVID-19, natural disasters, and extreme weather conditions have compelled educators, parents, and students to embrace technological solutions (AlAli, 2023; Hussain & Ibrahim, 2022).

The advent of the metaverse can be seen as an organic evolution stemming from the remarkable strides made in digitization and communication in recent years. Initially limited to media domains, the metaverse has progressively expanded its reach to encompass multiple facets of everyday existence. Furthermore, its integration into social-media platforms has developed significantly, shifting from a conceptual notion to a palpable phenomenon (Al-Zuhairi, 2022).

Metaverse technology merges elements such as virtual reality (VR), augmented reality (AR), mixed reality (MR), and 3D settings. It also includes real-time interaction features and smooth integration with intelligence technologies (Lee et al., 2021; Kiong, 2022). This innovation allows

DOI: 10.4018/IJDET.346988

Figure 1. Representation of Metaverse Technology



millions of people globally to participate in shared experiences in virtual environments, creating a sense of being present. Users can actively engage in interactions within settings that closely resemble life scenarios (Al-Sawy, 2022).

The metaverse signifies state-of-the-art progress that enables individuals to seamlessly interact and cooperate by merging elements of AR and 3D spaces. This platform fosters and supports interactions. Moreover, it provides users with an enriching and immersive communication experience in environments that closely mimic real-world situations, eliciting feelings such as happiness, amazement, and contentment (Zhang et al., 2022).

Several metaverse systems, including Second Life, OpenSimulator, Minecraft, Fortnite, Roblox, Sandbox, and Decentraland, have emerged and gained in popularity, attracting an increasing number of users. As VR platforms become increasingly accessible and interconnected, significant opportunities for metaverse progress across various domains arise. Additionally, the development of comfortable and durable VR headsets and accessories further enables the incorporation of these technologies into educational settings (Rospigliosi, 2022).

In the realm of the metaverse, it is crucial to create education-specific hardware and software, highlighting the significance of collaboration among educators, researchers, designers, and developers to offer unified guidance. Sarıtaş (2015) suggests that educational institutions should implement a comprehensive plan that includes curriculum creation, teacher training, educational philosophy, data security, legal and political elements, and resource and infrastructure change. This holistic approach is vital for effectively tackling the numerous challenges linked with metaverse-driven education.

The researchers give a brief review of metaverse technology in the context of schooling, characterizing it as an internet-based communication platform that enables interaction between teachers and students (Sarıtaş, 2015; Rospigliosi, 2022). Three-dimensional representations of both educators and students are used to increase immersion and create a sense of presence in this virtual-classroom setting. Within this immersive space, teachers utilize various tools and techniques to deliver explanations and engage in discussions, thereby promoting student involvement and a tangible sense of being physically present.

In the field of education, metaverse technology encompasses a diverse array of functionalities and viewpoints, enhanced by the integration of artificial intelligence (AI) technologies. The use of augmented virtual reality glasses contributes to an immersive educational experience by enabling three-dimensional visuals and enhancing the feeling of being fully immersed in the virtual learning environment. Through the integration of advanced features such as 3D avatars, virtual spaces, and AI integration, metaverse technology provides an innovative platform that promotes dynamic and interactive educational experiences.

Metaverse Technology's Incorporation into Education

First, in terms of classroom setup and customization, metaverse technology empowers teachers to create tailored learning environments suited to specific subjects. Additionally, educators can choose from a variety of existing educational settings that align with students' interests. Metaverse technology offers seamless accessibility and communication, overcoming geographical constraints through virtual interactions, which is particularly advantageous for remote-learning situations. This capability facilitates direct engagement with students, mirroring the dynamics of traditional educational settings. Furthermore, metaverse technology is critical in resolving issues caused by crises such as the COVID-19 pandemic, ensuring continuous distance teaching while increasing student participation and connectivity (Contreras et al., 2022; Tashtoush et al., 2022).

In terms of conveying scientific knowledge, metaverse technology offers an intriguing possibility to fascinate pupils and improve their cognitive abilities. It facilitates the presentation of complex scientific objects and samples while creating a safe environment for students to avoid any hazards. Additionally, this technology allows students to engage in virtual worlds that intently resemble reality, including natural landscapes such as mountains and oceans. This immersive experience allows for authentic study and examination of content, which improves students' comprehension (Hwang & Chien, 2022; Wardat et al., 2021).

Metaverse technology serves a critical function in promoting motivation and fostering the attractiveness of learning to students. Through the utilization of augmented-reality features, educators can adeptly seize students' attention and stimulate their active engagement in the learning journey. This augmentation of reality not only bolsters students' comprehension but also fosters their acceptance of the scientific content being presented. Moreover, metaverse technology facilitates in-depth exploration of complex topics, employing top-notch graphics, images, and videos to eloquently convey intricate concepts (Tashtoush et al., 2023).

Metaverse technology leverages students' keen interest in modern technology, drawing them toward educational content and cultivating an immersive virtual-classroom atmosphere that amplifies overall student involvement. By furnishing a learning experience that is both immersive and technologically sophisticated, metaverse platforms capitalize on students' inherent attraction to digital media, thereby heightening their motivation and interest in educational content. This amalgamation of augmented reality, dynamic multimedia elements, and alignment with student preferences renders metaverse technology a potent instrument for nurturing engagement and perpetuating motivation throughout the learning journey (Lin et al., 2022).

Mathematics, renowned for its abstract nature, often presents challenges to students due to its plethora of symbols and the absence of tangible experiences associated with its concepts. To solve this, virtual mathematics laboratories have developed as critical instructional tools, increasing learner motivation, aiding in mathematical-idea memory, and developing problem-solving skills. Recognizing the significance of this approach, the National Council of Teachers of Mathematics (2000) promotes the use of more-effective teaching techniques to instill meaning in mathematics education and provide students with a firm foundation. This paradigm change strives to make mathematics more approachable, fun, and relevant to students' daily experiences. Numerous studies highlight the importance of the metaverse and virtual math labs in the realm of mathematics education, particularly through simulations, manual sensors, and instructional strategies. Metaverse technology connects tangible experiences with abstract concepts, providing insights into real-world events.

The rise of the metaverse has introduced a fresh era of simulated learning environments, granting learners access to tools and the capability to revisit experiences conveniently. Functioning as a virtual learning environment, the metaverse mirrors real-life settings, enriching students' laboratory skills. The digital platform known as the mathematics metaverse is web-based and offers a range of activities, sensors, and virtual tools accessible through links and icons. It utilizes multimedia software applications aimed at enhancing students' scientific reasoning abilities and higher-order cognitive skills such as analysis, synthesis, and evaluation. Through engaging students in interactive learning environments, the mathematics metaverse plays a significant role in fostering critical-thinking skills and deepening knowledge. Therefore, incorporating the mathematics metaverse is essential for achieving the objectives of mathematics education, especially in elementary-school curricula that emphasize inquiry-based learning. Integrating the mathematics metaverse improves the quality and length of learning experiences, creating a lasting imprint on learners—an important goal of mathematics education.

Various researchers have underscored numerous benefits linked to incorporating the mathematics metaverse:

- The mathematics metaverse improves conceptual understanding and promotes various thinking skills (Al-Saeed, 2018).
- Flexible learning opportunities: students can engage in mathematics-metaverse activities at their own pace and convenience, fostering personalized and flexible learning experiences (Hassan, 2019).
- Professional development for educators: mathematics-metaverse tools and methodologies offer mathematics educators effective teaching strategies, facilitating the seamless integration of theoretical concepts with practical applications (Bujaily, 2019).
- The mathematics metaverse promotes a new instructional method through immersive and interactive technologies.
- Making real-world connections: the mathematics metaverse helps students connect mathematical principles to real-life circumstances and applications in diverse scientific disciplines.
- Overcoming resource constraints: the mathematics metaverse provides virtual tools and simulations to overcome limited physical equipment.

Through this approach, the mathematics metaverse presents a potentially beneficial avenue for improving mathematics education and encouraging fruitful learning outcomes. Its usage furnishes a sturdy platform for hands-on learning encounters, closing the disparity between theoretical understanding and its practical application, all the while nurturing cognitive and innovative growth among students.Top of Form

Metaverse technology plays a vital role in achieving various educational objectives, particularly within the orbit of mathematics, by:

- Promoting autonomy in thinking: metaverse platforms empower students to engage in critical and creative thinking, nurturing their ability to think independently and solve problems autonomously.
- Offering cutting-edge resources: metaverse technology presents a diverse array of interactive tools, activities, and resources that are innovative and captivating, capturing students' attention and enriching their educational journey.
- Cultivating creativity and innovation: metaverse environments create a conducive space for creativity and innovation, encouraging students to explore and express themselves freely while building self-confidence in their abilities.
- Facilitating experiential learning: metaverse platforms enable students to engage in hands-on, experiential learning experiences where they can explore mathematical concepts, discover relationships, and experiment with mathematical principles in a dynamic virtual environment.

- Fostering core mathematical competencies: metaverse technology leads students through a continuum from hands-on encounters to semi-physical engagements and eventually to conceptual comprehension, aiding in the cultivation of crucial mathematical skills and principles.
- Instilling favorable perceptions of mathematics: through its accessibility, enjoyment, and practical relevance, metaverse technology fosters constructive attitudes toward mathematics, inspiring students to embrace mathematical learning with optimism and self-assurance.

Moreover, incorporating metaverse technology into education offers students practical experiences that connect theoretical knowledge with real-world application. This integration also nurtures cognitive abilities and fosters innovative thinking processes among learners, equipping them for success in an ever-evolving digital and interconnected world (Al-Ghanmi, 2022).

In primary education, a variety of metaverse programs play a significant role in teaching mathematics concepts. Virtual hands, for instance, are three-dimensional electronic models that offer tactile learning experiences, engaging multiple senses and enhancing students' comprehension of mathematical concepts. They offer benefits such as adaptable accessibility and ease of use across diverse learning settings, ultimately empowering students to independently navigate their mathematical learning paths (Abdel Hussein et al., 2020).

Furthermore, specialized applications such as GeoGebra, commonly employed in engineering fields, are specifically designed for teaching mathematical concepts. Designed for use on computers or tablets, these applications provide extensive assistance in teaching diverse mathematical concepts and skills. GeoGebra, for instance, presents a plethora of tools and functionalities that enrich the delivery of mathematics instruction in virtual settings, furnishing educators and students with invaluable aids for mathematical discovery and education.

To effectively integrate metaverse technology into mathematical instruction, mathematics instructors must possess several critical competencies:

- Proficiency in software evaluation: educators should be able to analyze educational software's suitability for teaching and learning, ensuring alignment with educational goals and instructional methodologies.
- Commitment to professional growth: teachers should actively pursue continuous professional-development opportunities to enhance their ability to integrate virtual labs and other metaverse technologies into mathematics instruction.
- Engagement in educational training: educators should actively participate in educational courses and training sessions focused on innovative teaching methods that incorporate modern educational technologies, including metaverse platforms.
- Focus on practical-skills acquisition: teachers should prioritize acquiring practical experience with metaverse technology, seeking hands-on learning opportunities through workshops, collaborative projects, and professional-development activities.
- Proficiency in technology usage: educators must demonstrate proficiency in using computers, internet resources, and educational technology tools to facilitate effective teaching and assessment, leveraging digital resources to enrich student learning experiences.

Methodological Innovation

This research contributes to the field by proposing a novel approach to integrating metaverse technology into mathematics education. Unlike previous studies that have primarily focused on theoretical frameworks or small-scale applications, our methodology aims to systematically evaluate the effectiveness of metaverse technology in enhancing mathematics learning outcomes on a larger scale. Through the utilization of a blend of quantitative and qualitative approaches, encompassing methods like surveys, interviews, and classroom observations, the researchers seek to deliver thorough insights into the practical integration and influence of metaverse technology in elementary mathematics instruction.

Significance of Methodological Development

This innovative methodology addresses the gap in existing literature by offering a rigorous and comprehensive assessment of the utilization of metaverse technology in mathematics education. By combining quantitative data on student performance and engagement with qualitative insights from teachers and students, our objective is to offer a nuanced understanding of the opportunities and challenges linked to incorporating metaverse technology into the classroom. This approach not only bolsters the credibility and applicability of our findings but also offers practical guidance for educators, policymakers, and technology developers looking to maximize the effectiveness of metaverse technology in educational environments.

In summary, our research methodology represents a significant advancement in the field of mathematics education by offering a systematic and evidence-based approach to evaluating the impact of metaverse technology on student learning outcomes. By providing insights into the effectiveness of metaverse-based instruction, we hope to contribute to the ongoing efforts to harness technology to improve educational experiences and outcomes for all students.

Problem Study

Given the significant advancements in metaverse technology, which includes VR, AR, MR, 3D environments, and AI, and the recognition of its potential benefits in mathematics education, this study seeks to close the gap between the availability of this technology and its adoption by educators. The primary purpose of this study is to assess the current level of integration of metaverse technology in mathematics instruction by building on previous research that has shown the favorable influence of virtual laboratories on students' conceptual understanding. By examining educators' adoption rates and usage patterns, this research seeks to uncover obstacles, difficulties, and opportunities related to the integration of metaverse technology into mathematics teaching practices.

Study Questions

The primary objective of this study was to explore two main research questions:

- How do supervisors and teachers perceive the efficacy of metaverse technology in enhancing basic mathematics teaching for gifted students?
- Are there statistically significant differences in the attitudes of supervisors and teachers toward the integration of metaverse technology in basic mathematics instruction for gifted students, considering variations in their levels of expertise and training?

The Importance of the Study

The emergence of novel educational models (Kuş, 2021). The metaverse provides chances for immersive and blended learning encounters within the realm of online distance education and virtual campuses. In this shifting landscape, conventional physical classrooms lose relevance as avatars adeptly communicate body language and facial cues, facilitating genuine virtual engagement. By integrating social dynamics into the metaverse, opportunities arise for employing blended active-teaching methods, promoting deep and enduring learning. Additionally, it promotes inclusivity in global education by transcending geographical limitations, fostering a democratic educational atmosphere. Nevertheless, with the education sector increasingly adopting the metaverse and its elements, tackling concerns related to race, gender, and physical disability within this virtual space becomes imperative. Specifically, challenges encountered during the COVID-19 pandemic, such as diminished engagement, challenges in maintaining focus, communication barriers, limited classroom involvement, and valuation difficulties, could possibly be mitigated through the integration of the metaverse. Thus, there is an urgent need to examine teachers' and educators' knowledge, attitudes, and awareness regarding the metaverse concept (Hendriyanto et al., 2024 ; Mystakidis, 2022).

Implementing the metaverse emerges as a notably efficient and impactful educational tactic for attaining mathematics teaching goals, particularly in primary schooling. Its efficacy lies in its congruence with Piaget's theory (Ondog & Kilag, 2023). This underscores the progression of students through the sensory operations phase in cognitive development. As a result, the metaverse meets the sensory needs of primary-level students, providing a flexible approach that seamlessly aligns with instructional methods such as discovery learning. By integrating these approaches, teachers can leverage their unique advantages to foster favorable results in mathematics education, given the establishment of suitable learning environments. Moreover, comprehensive preparation and proficiency in utilizing metaverse elements are essential for achieving the intended educational objectives. Additionally, offering assistance to educators in overcoming difficulties and fostering their skills in utilizing this technology, while assisting policymakers in formulating strategies for its seamless integration into all public educational initiatives, are critical advancements (Al-Mutairi & Rizk, 2022).

LITERATURE REVIEW

Advancements in metaverse technology have spurred numerous studies offering insightful recommendations for enhancing teaching environments across various educational domains. Here, we synthesize these recommendations to illuminate key strategies and their implications for pedagogy and content delivery:

- Creating active learning environments: Park & Kim (2022) advocate for integrating experiential learning and gamification methods to encourage active student participation. Through immersive and interactive learning activities, educators can cultivate deeper understanding and retention of concepts.
- Emphasizing storytelling: Camilleri (2024) underscores the power of storytelling in educational content. By weaving narratives into lessons, educators can captivate students' imaginations and enhance their overall learning experiences, thereby fostering greater comprehension and retention.
- Integrating real-life elements: Suzuki et al. (2020) stress the importance of embedding real-life elements into virtual environments to enhance relevance and authenticity. By contextualizing learning within familiar settings, educators can facilitate deeper connections and understanding among students (Kanematsu et al., 2014).
- Utilizing scalable metaverse technology: Piumsomboon et al. (2017) advocate for the adoption of scalable metaverse technology and speech detection to enrich educational experiences and support pedagogical approaches. Such tools offer flexibility and adaptability, catering to diverse learning needs and preferences.
- Creating participatory learning environments: Sarıtaş and Topraklıkoğlu (2022) emphasize the importance of fostering participatory and sustainable learning environments through metaverse technology. By empowering students to actively engage with content and collaborate with peers, educators can cultivate deeper levels of understanding and critical-thinking skills.
- Leveraging AR for engagement: Durak & Karaoğlan Yılmaz (2019) explore students' perspectives on AR in education, highlighting its role in providing engaging and effective learning experiences. By overlaying digital content onto the physical world, AR offers unique opportunities for immersive and interactive learning experiences.
- Enhancing mathematics education with AR and virtual manipulatives: Özdemir and Özçakır (2019), Altıok (2020), and Mutluoğlu and Erdoğan (2021) demonstrate the positive impact of AR-

supported mathematics education and virtual manipulative teams on academic achievement and attitudes toward mathematics. These resources enable students to engage in hands-on exploration and visualization, promoting a more profound understanding of concepts and enhancing problem-solving abilities.

- Exploring teachers' perspectives on technology integration: Al-Ghanmi (2020) and Abu Sarah (2019) explore teachers' perspectives on technology integration in mathematics education, highlighting its benefits in visualization, providing equal opportunities, capturing attention, and enhancing motivation among students. Additionally, Eşin and Özdemir (2022) stress the significance of choosing and employing technological tools that meet particular instructional requirements, ensuring effective integration into teaching practices.

In the realm of mathematics education, virtual laboratories have risen as impactful resources for bolstering teaching proficiency, academic performance, cognitive abilities, learning outcomes, and attitudes toward mathematics among elementary-school pupils. These dynamic platforms provide students with avenues for interactive experimentation and investigation, fostering enhanced comprehension and practical application of mathematical principles (Boz & Özerbaş, 2020; Hassan, 2019; Al-Saeed, 2018).

In summary, the integration of metaverse technology offers diverse opportunities to enhance teaching environments, catering to the individual needs and preferences of students while fostering deeper engagement and understanding across various educational domains.

METHODOLOGY

This research adopted a descriptive methodology, aiming to delve into the phenomenon within its natural context and provide a comprehensive description. The descriptive approach facilitated the development of the study instrument, thorough analysis of existing literature, and the formulation of appropriate solutions based on the findings.

Population and Sample

Performed during the second semester of the 2022/2023 academic year, this survey included all mathematics teachers and supervisors working with gifted students in Saudi public schools. These schools were located in five different regions of Saudi Arabia: north, south, east, west, and central. From this cohort, a random sample of primary-level mathematics teachers and supervisors overseeing gifted kids was drawn.

The sample comprised 120 teachers, representing 91% of the total sample, and 12 supervisors, making up the remaining 9% of the total sample.

Courses Focused on Innovative Instructional Methodologies in Mathematics Teaching

There are four categories of training-course attendance in this study:

- No attendance: participants who did not attend any training course.
- Single-course attendance: participants who attended one training course.
- Double-course attendance: participants who attended two training courses.
- Multiple-course attendance: participants who attended more than two training courses.

Table 1 depicts the distribution of participants based on the amount of training courses taken in mathematics-teaching approaches.

Table 1. Distribution of Participants Categorized by Number of Training Courses Completed

Training Courses	Frequency	Percentage
No attendance	10	7.5%
Single-course attendance	21	15.9%
Double-course attendance	39	29.5%
Multiple-course attendance	62	46.9%
Total	132	100%

The Survey Instrument

The instrument served as the cornerstone of data collection, chosen for its established validity and reliability. Its construction involved a thorough review of pertinent literature, spanning books, articles, and prior research, to identify the underlying subdimensions and complexities of metaverse-technology adoption among elementary-school kids.

At the outset, the instrument was formulated by creating items that corresponded to the study's aims, centering on two principal dimensions: the incorporation of metaverse technology in mathematics instruction and its application by educators. Subsequently, a thorough refinement process was undertaken to generate an initial version, carefully selecting suitable items for each dimension.

During this refinement step, great care was taken to ensure that the questionnaire accurately measured the desired constructs and reflected the intricacies of using metaverse technology in mathematics education. After careful consideration, the final version of the instrument comprised 21 items, meticulously designed to encompass key aspects of the dimensions and provide a reliable and valid measure for assessing metaverse-technology utilization among primary-school students in mathematics instruction.

Validity and Reliability

The instrument used in this study underwent extensive validation to verify its reliability and validity. Nine specialists in educational technology, curriculum development, and teaching methodologies were invited to provide feedback. Their insights resulted in changes, reformulations, and the removal of specific items to improve the instrument's clarity and usefulness.

Subsequently, the instrument underwent piloting with 19 teachers and 4 supervisors, whose responses and feedback were instrumental in refining the final version. To ascertain construct validity, Rasch model analysis was employed, known for its robustness in evaluating measurement properties and ensuring objectivity in psychological and educational measurement (Saleh & AlAli, 2024).

To understand the findings of Rasch model analysis, several crucial factors must be considered. First, the degree of fit for objects or humans, known as infit, is important. Infit calculates the square transformation of residuals, which indicates the difference between anticipated and observed values. Typically, infit values between 0.4 and 1.5 are regarded as appropriate, while standardized fit statistic (ZSTD) values between -2 and 2 are considered acceptable.

Another crucial aspect to consider is item-polarity analysis, which is measured by point-measure correlation (PTMEA). This analysis assesses the consistency of items in measuring the intended constructs. Negative indicators suggest discrepancies in how certain items or individuals respond compared to expectations, warranting further investigation or potential removal. PTMEA values falling between 0.2 and 1 are generally deemed suitable.

Furthermore, evaluating dimensionality is essential to confirm the instrument's content and construct validity. Dimensionality refers to whether the instrument measures a single dimension in one direction. Rasch model analysis necessitates meeting the dimensionality criterion, with over 40% of raw variance explained by measures and unexplained variance in the first contrast being less than 15.

Table 2. The Item Dimensionality Analysis of the Instrument

	Empirical Modeled
Total raw variance in observationsRaw variance explained by measuresRaw variance explained by personsRaw variance explained by itemsRaw unexplained variance (total) Unexplained variance in 1st contrastUnexplained variance in 2nd contrastUnexplained variance in 3rd contrastUnexplained variance in 4th contrastUnexplained variance in 5th contrast	31.4 100.0% 100.0%11.2 46.3% 41.6% 4.3 9.8% 17.5%6.1 22.4% 26.3% 18.1 66.1% 100.0% 71.3%2.6 11.2% 13.9% 2.2 6.9% 13.6%2.1 6.6% 13.3%1.7 5.6% 9.7%1.6 5.2% 7.5%

Moreover, item separation is crucial for determining the instrument's ability to differentiate among individuals based on varying difficulty levels of items. Higher separation values indicate greater diversity along the trait continuum, while lower values suggest item redundancy and less variation among individuals. Moreover, items should meet a reliability criterion exceeding 0.50, indicating satisfactory item reliability (AlAli & Saleh, 2022). A minimum separation value of 2 is deemed suitable, indicating ample discrimination among individuals. These standards were set based on research conducted by AlAli and Al-Barakat (2022).

Table 2 shows the findings of the dimensionality analysis, which are consistent with the calibration measurements. These findings support the dimensionality assessment, with the measures accounting for more than 40% of the raw variation and less than 15% of the unexplained variance in the first contrast. Thus, the multidimensional data results show a strong fit with the Rasch model.

The validity of the instrument was assessed by examining mean square (MNSQ) infit values. The MNSQ data indicated that the instrument demonstrated sufficient validity, with scores falling within the recommended range of 0.4 to 1.5. The item-polarity analysis corroborated this finding by revealing PTMEA values in the permitted range of 0.2 to 1. Furthermore, the instrument had an appropriate ZSTD value that ranged from -2 to 2, as shown in Table 3. The precise values reported in Table 3 confirm that the instrument had strong validity and fit, as indicated by the MNSQ infit, PTMEA, and ZSTD values all being within acceptable ranges.

This comprehensive assessment of the MNSQ infit values, PTMEA values for item polarity, and ZSTD values confirms the instrument's good validity and fit to the measurement model.

In order to gauge how often participants utilized the metaverse in teaching mathematics, a five-point rating scale was employed by the instrument titled “Utilization of the Metaverse in Teaching Mathematics.” This scale has five categories: 1 (*never use*), 2 (*almost never*), 3 (*occasionally sometimes*), 4 (*almost every time*), and 5 (*frequently use*). Table 4 and Fig. 1 show an overview of the category structure, as well as the distribution and percentage of replies on the use of the metaverse in mathematics instruction. The observation part of the table displays respondents' ratings on the scale.

As depicted in Table 4, the most commonly selected response category by respondents was 4 (*almost every time*), with 48 responses (36%). Following closely was Response 3 (*occasionally sometimes*), with 40 responses (30%). Response 2 (*almost never*) received 21 responses (16%), while the least frequently chosen was response 5 (*frequently use*), with 18 responses (14%). Response 1 (*never use*) had the fewest responses at 5 (4%).

The observed average scores reflect the anticipated pattern of responses, demonstrating a relatively normal distribution. There is a systematic progression from negative (low frequency) to positive (high frequency) ratings, indicating that the scale categories effectively captured the range of respondents' reported metaverse-utilization frequencies.

When reliability is measured using the Rasch model framework, it is critical to include both human and item reliability. Generally, reliability more than 50% is considered adequate. Previous research has shown that item and person separation values must exceed 2 to be considered appropriate.

Table 3. Analysis of Item Fit for the Instructional Illustrations Instrument

Items	InfitMNSQ ZSTD		OutfitMNSQ ZSTD		PTMEACORR EXP	
UMT19	1.73	1.8	1.87	1.9	0.73	0.64
EMT5	1.72	1.7	1.84	1.8	0.72	0.62
UMT12	1.71	1.8	1.81	1.7	0.71	0.59
EMT8	1.51	1.6	1.79	1.6	0.69	0.57
UMT21	1.50	1.6	1.77	1.5	0.66	0.56
EMT3	1.48	1.6	1.75	1.4	0.64	0.55
EMT4	1.35	1.4	1.66	1.5	0.61	0.53
EMT1	1.31	1.7	1.61	1.3	0.60	0.51
UMT15	0.99	1.5	1.43	1.5	0.59	0.50
EMT2	0.98	1.4	1.37	1.6	0.59	0.50
EMT7	0.96	1.5	1.31	1.1	0.63	0.56
UMT17	0.93	1.3	1.11	1.5	0.63	0.56
EMT6	0.89	1.4	1.03	1.3	0.64	0.53
UMT11	0.88	1.1	0.90	1.1	0.64	0.54
UMT9	0.83	-1.1	0.88	1.2	0.66	0.54
UMT14	0.94	-0.9	0.97	-1.1	0.66	0.60
UMT16	0.83	-1.3	0.79	-0.8	0.66	0.61
UMT10	0.85	-1.4	0.77	-1.3	0.67	0.51
EMT3	0.83	-1.2	0.77	-1.5	0.68	0.54
UMT18	0.82	-1.1	0.76	-1.4	0.66	0.55
EMT7	0.81	-1.0	0.77	-1.4	0.65	0.56

In this study, the scale's reliability was determined by assessing both person and item dependability. The findings, as shown in Table 5, suggested that the scale's items had a sufficient level of dependability.

RESULTS

To investigate the central subject of the level of metaverse technology integration in primary-level mathematics teaching by teachers, both supervisors' and teachers' perspectives were examined. The

Table 4. Calibration Scaling Analysis of Utilization of the Metaverse in the Teaching Mathematics' Instrument

CategoryLabel	ObservedCount	Observed%	ObservedAverage	SampleExpect	InfitMNSQ	OutfitMNSQ	StructureCalibration	CategoryMeasure
1	5	4	1.13	-1.76	1.9	1.77	Non	(-2.39)
2	21	16	.296	-.02	1.20	1.40	-1.86	-1.73
3	40	30	.80	.53	1.31	1.70	-.89	-.73
4	48	36	1.07	1.25	1.10	.71	.04	1.01
5	18	14	2.81	2.78	1.21	1.87	2.53	(3.24)

Figure 2. Overview of the Category Structure of the Instrument

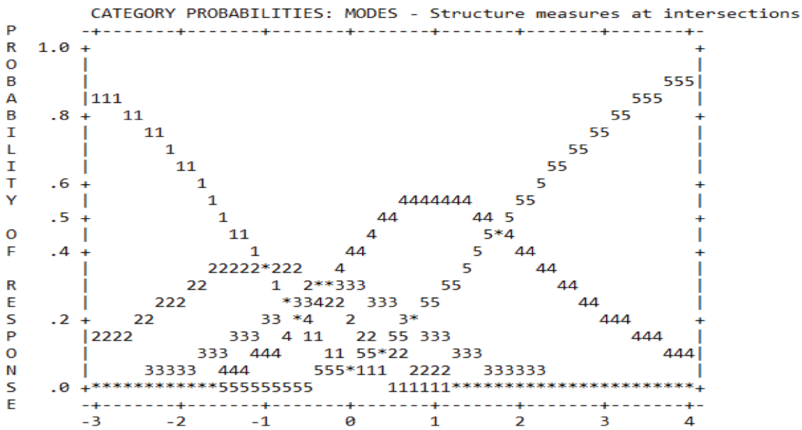


Table 5. Person and Item Separation and Reliability for the Instrument

	Score	Count	Measure	Error	Infit MNSQ	Infit ZSTD	Outfit MNSQ	Outfit ZSTD
Mean	136.1	36.0	1.62	.29	1.09	-.4	1.09	- .4
SD	24.5	.0	1.51	.14	.92	3.0	.94	3.0
Real *RMSE*	.83							
Adj. *SD*	2.12							
Separation	4.45							
Person reliability	.93							
Mean	118.7	272.0	.00	.09	1.00	-.1	1.09	.5
SD	37.6	.0	.34	.01	.15	1.5	.29	1.9
Real *RMSE*	.12							
Adj. *SD*	.35							
Separation	3.41							
Item reliability	.94							

investigation of the study sample's responses entailed computing frequencies, percentages, standard deviations, and ranks. The condensed results are outlined in Table 6.

Table 6 shows a strong integration of metaverse technology into mathematics instruction among educators, as reported by both supervisors and teachers. With an average score of 3.49 out of 5, it falls into the fourth category (3.41–4.22) on a five-point scale, indicating consistent use of metaverse technology in mathematics teaching. This average falls within the *almost every time* group, according to the study instrument. The standard deviation of 1.509 implies that instructors and supervisors agree on the level of metaverse technology use in mathematics instruction. While most questions earned high ratings, Items 1, 2, and 3 received middling scores, indicating that the sample had different viewpoints on those specific features.

Table 6 illustrates a substantial incorporation of metaverse technology into mathematics instruction by teachers, as evaluated by both supervisors and educators. With an average score of 3.77 out of 5 overall, it falls within the fourth category on a five-point scale, demonstrating widespread utilization of metaverse technology in mathematical teaching. Noteworthy aspects of teachers' adoption of metaverse technology in mathematics instruction were ranked in descending order of endorsement: Item 8, Item 7, and Item 1. In descending order, Items 12, 9, and 13 received the lowest ratings for instructors' implementation of the metaverse technique in teaching mathematics.

Table 6. Teachers' Metaverse Technology Use in Primary-Level Mathematics: Supervisor and Teacher Perspectives

No.	Item	Mean	Std. Deviation	Rank
Dimension 1: The extent to which educators utilize metaverse technology in the instruction of mathematics (EMT)				
1	The instructor actively contributes to the development of metaverse content for the mathematics course that they teach or administer.	3.39	1.523	6
2	The instructor uses metaverse technology to track and evaluate students' progress in the math course.	3.35	1.551	7
3	The teacher consistently integrates metaverse technology into the mathematics course's training.	3.31	1.426	8
4	The teacher's usage of metaverse technology promotes the sharing of experiences among colleagues.	3.59	1.589	3
5	Mathematics teachers collaborate to create metaverse reality content, which fosters a shared knowledge base.	3.42	1.464	5
6	The use of metaverse technology allows the teacher to save time and effort while efficiently communicating knowledge.	3.56	1.666	4
7	During metaverse-technology use, students actively participate in interactive sessions with their teacher.	3.61	1.694	2
8	The use of metaverse technology helps mathematics teachers flourish professionally.	3.68	1.704	1
Overall Average		**3.49**	**1.509**	
Dimension 2: The extent to which educators employ metaverse technology in teaching mathematics (UMT)				
1	I use virtual Dienes pieces for teaching mathematical concepts (specifically numbers and operations) to students	4	1.049	3
2	I use virtual Dienes pieces to teach mathematical concepts to pupils, with a focus on numbers and operations.	3.9	1.118	7
3	I use virtual linking cubes as teaching tools to help students understand mathematical topics like addition, subtraction, and categorization.	3.63	1.237	9
4	I use virtual dominoes as a teaching tool to help pupils learn the concept of subtraction.	3.97	1.166	5
5	I use the virtual number line in class to teach pupils about numbers.	3.97	1.172	6
6	I use virtual fraction slides to teach students about fractions and how to do operations on them.	3.45	1.349	10
7	I use the virtual arithmetic scale as a teaching tool to demonstrate mathematical operations to students.	4.02	1.133	2
8	I use virtual clock models to teach pupils how to tell the time.	4.08	1.055	1
9	I use virtual engineering tools to teach students how to create engineering ideas.	3.37	1.448	12
10	I use virtual drawing software such as GeoGebra and Desmos to teach pupils how to create geometric forms.	3.88	1.168	8
11	I use virtual geometric components to teach pupils about geometric shapes and spatial reasoning.	3.98	1.135	4
12	I use virtual geometric manipulatives to instruct students in geometric shapes.	3.35	1.390	13
13	I use virtual calculators to help pupils understand how to calculate the area of a circle.	3.41	1.399	11
Overall Average		**3.77**	**0.3839**	

Table 7. Metaverse Technology Usage in Primary Mathematics by Academic Qualification

Dimensions		*N*	Mean	Standard Deviation	*t*-value	Significance
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		

Various statistical examinations, encompassing *t*-tests and one-way analysis of variance (ANOVA), were conducted to explore potential noteworthy distinctions between supervisors and teachers regarding the utilization of metaverse technology in teaching primary-level mathematics. Factors such as academic credentials, experience, and training were considered in this analysis. Table 7 presents the outcomes of the *t*-tests concerning teachers' integration of metaverse technology in primary-level mathematics instruction, as perceived by both supervisors and educators. These results are categorized based on academic qualifications, experience, and training.

As indicated by the results presented in Table 7, there are no statistically notable variances in the average ratings of metaverse-technology utilization in primary-level mathematics instruction among participants when stratified by academic qualifications. Table 8 exhibits the outcomes of ANOVA concerning the levels of actively open-minded thinking indicators identified in the results of gifted programs across various facets of the scale, organized by the quantity of programs completed by gifted students.

Table 8 indicates that there are no statistically significant variations in the average ratings of metaverse-technology usage in primary-level mathematics teaching based on participants' experiences. Nonetheless, significant differences exist in how instructors and supervisors perceive the integration of metaverse technology in primary mathematics instruction. These differences become more pronounced when considering the training variable. To ascertain the preferred category, the Scheffé test of post-comparisons was employed to assess the influence of the four completed course periods.

Table 9 shows significant statistical disparities in teachers' and supervisors' attitudes toward incorporating metaverse technology into primary-level mathematics instruction. These discrepancies are most obvious when it comes to training, specifically between people who completed one course and those who completed more than two. Interestingly, individuals who finished numerous courses reported higher levels of metaverse-technology adoption than those who completed only one course. However, there were no statistically significant differences in the opinions of instructors and supervisors across other training categories, indicating that changes are mostly due to the amount of training rather than criteria such as experience or academic qualifications.

DISCUSSION

The initial data show that metaverse technology is widely used in basic mathematics instruction, according to both supervisors and teachers. This inclination toward integrating metaverse tools in education may arise from educators' recognition of the inherent advantages of leveraging such innovative technologies to enrich and optimize teaching practices. One notable benefit highlighted by both supervisors and teachers is the enhanced student engagement facilitated by metaverse technology. Students actively participate in the learning process by using immersive and interactive learning experiences such as simulations, virtual environments, and augmented reality, which leads to

Table 8. ANOVA Analysis: Metaverse Technology Use in Primary Math Instruction by Training and Experience

Variance Source			Sum of Squares	*df*	Mean Square	*F*	Significance
Training	Employing metaverse technology in teaching mathematics	Between groups	57.893	2	28.946	14.656	.000
		Within groups	347.59	176	1.975		
		Total	405.49	178			
	Using metaverse technology in teaching mathematics	Between groups	7.877	3	2.626	3.852	.010
		Within groups	175.88	258	.682		
		Total	183.76	261			
	Whole dimensions	Between groups	15.439	3	2.173	3.192	.010
		Within groups	235.514	193	.871		
		Total	139.086	199			
Experience	Employing metaverse technology in teaching mathematics	Between groups	7.093	2	3.546	1.567	.212
		Within groups	298.39	176	2.264		
		Total	305.49	178			
	Using metaverse technology in teaching mathematics	Between groups	3.601	2	1.800	4.661	.110
		Within groups	222.89	277	.386		
		Total	226.49	279			
	Whole dimensions	Between groups	3.419	3	1.481	3.126	.130
		Within groups	135.52	96	.377		
		Total	139.34	99			

improved motivation and involvement. Educators value the increased degree of involvement produced by metaverse technology because it improves the effectiveness of mathematics-education delivery.

Metaverse technology provides visual representations, interactive models, and simulations that help students understand mathematical topics more effectively. These tools make abstract mathematical ideas tangible and accessible, allowing students to explore and manipulate topics in a hands-on manner, enhancing their comprehension. Both supervisors and teachers appreciate metaverse technology's ability to improve pupils' conceptual understanding of mathematical concepts through concrete and interactive content.

Metaverse technology enables the creation of customized learning experiences for each student. Educators can provide specialized exercises, adaptive assessments, and specific feedback to accommodate different learning styles and skill levels. This personalized approach guarantees that students receive individualized support and opportunities, which improves their learning outcomes.

Table 9. Scheffé Test Results for Discrepancies Among the Number of Courses Completed by Teachers

I Course	*J* Course	Mean Difference (*I-J*)	Significance
0 courses	1 course	.23726	.659
	2 courses	.25884	.511
	More than 2 courses	-.15524	.722
1 course	0 courses	-.23726	.659
	2 courses	.02158	.914
	More than 2 courses	-.39250	.130
2 courses	0 courses	-.25884	.511
	1 course	-.02158	.914
	More than 2 courses	-.41408	.044
More than 2 courses	0 courses	.15524	.722
	1 course	.39250	.130
	2 courses	.41408	.044

Both supervisors and teachers accept metaverse technology's ability to support tailored learning experiences, such as:

- Promoting collaborative learning: metaverse technology fosters collaboration and communication among students, facilitating teamwork, group projects, and peer interaction in virtual environments. This cultivates vital skills that are essential in mathematics education. Supervisors and teachers acknowledge the significance of collaborative learning enabled by metaverse technology.
- Adapting to digital fluency: metaverse technology aligns with the digital proficiency of contemporary students, leveraging their familiarity with digital tools and technology. This ensures that mathematics education remains relevant and captivating in today's digital era. Both supervisors and teachers value the integration of technology into education to meet the needs of modern learners.
- Facilitating professional advancement: supervisors play a pivotal role in nurturing teachers' development regarding the incorporation of metaverse technology into mathematics teaching. By offering tailored training and guidance, educators can enhance their proficiency and confidence in effectively utilizing metaverse technology. Both supervisors and teachers value continuous professional-development opportunities focused on harnessing technology for teaching mathematics.

This demonstrates how educators are aware of the potential advantages and importance of incorporating metaverse technology into the classroom, especially when it comes to mathematics teaching. Through dynamic and visually immersive experiences made possible by metaverse technology, students can interact captivatingly with mathematical topics. The technology encourages interactive exercises, group problem-solving, and hands-on investigation—all of which help students comprehend and remember mathematical concepts better. Educators can design interactive virtual worlds, simulations, and assignments that cater to a variety of learning preferences by integrating metaverse technology into their teaching strategies. This approach encourages students to actively participate in the learning process. This integration therefore has the potential to improve student motivation, engagement, and eventually academic success in mathematics.

Furthermore, instructors' and supervisors' enthusiastic adoption of metaverse technology demonstrates their willingness and preparedness to implement cutting-edge instructional strategies. This openness to investigating and incorporating new technology into classroom environments is indicative of a commitment to modify teaching strategies in response to students' changing needs and preferences in the modern digital environment. This finding is consistent with earlier studies by Hassan (2019), Al-Saeed (2018), Boz and Özerbaş (2020), Özdemir and Özçakır (2019), Abu Sarah (2019), Şeyma and Özdemir (2022), Al-Ghanmi (2020), and Rojas et al. (2023), which highlight the benefits and adoption of cutting-edge technologies, such as the metaverse, in educational environments.

When the second study question was investigated, significant differences were found between the perspectives of supervisors and instructors on the use of metaverse technology in primary-level mathematics instruction, particularly with regard to training. Notably, there was a higher propensity to employ metaverse technology among those who completed more than two courses. Several factors contribute to this finding. First, the increased focus on metaverse technology in the curriculum and its relatively simple implementation may have led to higher adoption rates among teachers. Additionally, this technology's ability to engage students and enhance their focus promotes experiential learning, thus fostering self-learning abilities.

The observed disparities in viewpoints can be attributed to various reasons. First, teachers who underwent extensive training likely developed a higher level of familiarity and comfort with the technology, influencing their positive perception of its effectiveness. Second, multiple training courses may have equipped teachers with deeper pedagogical insights specific to metaverse technology, enhancing their ability to leverage it effectively. This, coupled with increased confidence in implementation, further reinforces their positive outlook toward its utility in mathematics instruction.

Additionally, extensive training likely facilitated the acquisition of a broader skill set related to metaverse technology, including design proficiency, content-integration strategies, and troubleshooting skills. Peer interactions and collaborations among trained teachers may have also contributed to fostering positive attitudes toward technology integration. Furthermore, heightened technological competence and continued engagement in professional-development activities enable teachers to stay abreast of advancements, enhancing their confidence and proficiency in utilizing metaverse technology for mathematics instruction.

These findings resonate with prior research conducted by Al-Mutairi and Rizk (2022), Al-Harithi and Al-Issa (2022), Al-Anazi and Massad (2018), and Al-Qahtani (2010), which similarly highlight the positive impact of training and professional development on teachers' perceptions and practices regarding technology integration in education.

It is important to interpret these statistically significant differences cautiously, keeping in mind that teachers with fewer training courses do not always have less favorable opinions or possess inferior skills. Rather, they represent differing degrees of exposure to, familiarity with, and expertise with metaverse technology, which shapes an individual's viewpoint on its use in math education. Each person's experience and chances for professional growth influence how they perceive the possible advantages and difficulties of integrating metaverse technology into the classroom.

Furthermore, it appears that teaching circumstances in mathematics instruction are the same for all teachers, regardless of experience level, as there are no statistically significant changes depending on teachers' experience with gifted students. Due to teaching mathematics' inherent complexity, teachers of various backgrounds and specializations face the same difficulties. As a result, educators typically use similar instructional strategies and methods to help pupils understand the material, regardless of their degree of experience. These results are consistent with earlier research by Al-Harithi and Al-Issa (2022), Al-Mutairi and Rizk (2022), Al-Anazi and Massad (2018), and Al-Masaad and Al-Afeisan (2017), which also discovered no appreciable variations in teachers' answers according to the number of years of experience they had utilizing contemporary technologies.

RECOMMENDATIONS AND FUTURE DIRECTIONS

According to this study's results, the researchers make various suggestions to enhance the incorporation of metaverse technology in elementary-level math education, as seen by supervisors and educators.

- Establish and execute customized continuing professional development programs focused on metaverse technology. Motivate educators to engage in continuous training sessions and professional-development programs that specifically target metaverse technology, helping them improve their abilities and understanding in utilizing this technology for teaching mathematics.
- Promote collaborative learning communities. Encourage teachers and supervisors to work together to enhance the successful incorporation of metaverse technology. Create forums for sharing information and swapping successful methods regarding metaverse technology, promoting frequent communication and teamwork to create new strategies for using it in teaching.
- Conduct comparative analysis on the use of metaverse technology by gifted and typical students in middle and high school. These investigations can shed light on potential disparities in technology uptake and efficacy among different student groups.
- Identify and address potential implementation barriers for metaverse technology in primary-school instruction through research. Understanding these barriers can help you devise strategies to overcome obstacles and ensure successful incorporation into your teaching practices.
- Evaluate the success of educational departments' metaverse technology–based training programs. Evaluate how these programs affect instructors' abilities, knowledge, and confidence in using metaverse technology for mathematics instruction.
- Analyze primary-stage curricula to ensure alignment with students' developmental needs, particularly regarding the integration of metaverse technology in mathematics teaching. Ensure that curriculum content and instructional strategies effectively leverage metaverse technology to support students' learning and development.

Implementing these guidelines can help to improve the use of metaverse technology in primary-level mathematics education, thereby increasing students' learning results and experiences.

CONFLICTS OF INTEREST

The authors declare there are no competing interests.

FUNDING

The authors thank the Deanship of Scientific Research at King Faisal University, Saudi Arabia for the financial support under annual research grant A192.

PROCESS DATES

Received: October 4, 2023, Revision: May 9, 2024, Accepted: May 3, 2024

CORRESPONDING AUTHOR

Correspondence should be addressed to Yousef Wardat (United Arab Emirates, yousef_alwardat@yahoo.com)

REFERENCES

Abdel Hussein, W., George, A., & Kate, A. (2020). *Learning and teaching in the age of information technology*. Dar Al-Sadiq Cultural Center.

Abu Sarah, A. M. (2019). Developing the components of mathematical prowess for basic sixth-grade students in Palestine using mathematical modeling based on "interactive computer-augmented reality" applications. *International Journal of Internet Education*, *18*(1), 65–128. 10.21608/jaee.2019.68794

Al-Anazi, A., & Massad, A. (2018). The reality of the use of technology in the teaching of mathematics for primary school in the city of Arar from the point of view of teachers. *Arab Journal of Science and Research Publishing*, *23*(2), 1–22. 10.26389/AJSRP.A290418

Al-Ghanmi. (2020). The effectiveness of an educational program using virtual hands on tablet devices to develop arithmetic skills among students with learning difficulties in mathematics in Jeddah Governorate. *Uluslararas Insan Bilimleri Dergisi*, *4*, 8–24.

Al-Harithi, M., & Al-Issa, H. (2022). The reality of using augmented reality technology and the obstacles that might face it in teaching preparatory school science from the point of view of female teachers and supervisors in the city of Makkah. *Scientific Journal of the College of Education*, *38*(6), 210–248.

Al-Khathami, Z., & Al-Osaimi, S. (2022). The reality of using virtual laboratories in the practical application of chemistry experiments in distance education during the coronavirus pandemic from the teachers' perspective in Bisha Governorate. *Journal of Educational and Psychological Sciences*, *6*(19), 157–182. 10.26389/AJSRP.Z150921

Al-Masaad, A., & Al-Afeisan, N. (2017). The use of modern techniques in the teaching of science curriculum developed in general education from the viewpoint of teachers of science in Al-Kharj. Education and Psychology Letter, Saudi Arabia, 58, 133-156. http://search.shamaa.org/FullRecord?ID=123079

Al-Mutairi, A., & Rizk, H. (2022). The degree of use of virtual labs in teaching mathematics at the primary stage from the point of view of teachers and supervisors. *Arab Journal of Specific Education*, *6*(22), 225–256. 10.21608/ejev.2022.233125

Al-Qahtani, I. (2010). The reality of using virtual classrooms in the distance education program from the point of view of faculty members at King Abdulaziz University in Jeddah [Unpublished master's thesis, Umm Al-Qura University, Saudi Arabia].

Al-Saeed, R. (2018). Tablet: A virtual math lab for teaching practical skills and life applications of math. *Journal of Mathematics Education*, *21*(4), 6–39. 10.21608/armin.2018.81235

Al-Sawy, M. (2022). The metaverse world between reality and hope and its effectiveness in the field of graphics. *Journal of Applied Arts and Sciences*, *9*(4), 135–151. 10.21608/maut.2022.265993

Al-Zuhairi, T. (2022). Social networks and their role in the growing phenomenon of counterfeit marketing: The Iraqi market on metaverse as a model. *Journal of Governance. Social Responsibility and Sustainable Development*, *4*(2), 1–15.

AlAli, R. (2023). Prospects of metaverse technology in home economics education: Examining the future in the context of digital learning. *International Journal of eBusiness and eGovernment Studies, 15*(2), 89–112.

AlAli, R., & Al-Barakat, A. (2022). Using structural equation modeling to assess a model for measuring creative teaching perceptions and practices in higher education. *Education Sciences*, *12*(10), 690. 10.3390/educsci12100690

AlAli, R., Alsoud, K., & Athamneh, F. (2023). Towards a sustainable future: Evaluating the ability of STEM-based teaching in achieving sustainable development goals in learning. *Sustainability (Basel)*, *15*(16), 12542. 10.3390/su151612542

AlAli, R., & Saleh, S. (2022). Towards Constructing and Developing a Self-Efficacy Scale for Distance Learning and Verifying the Psychometric Properties. *Sustainability (Basel)*, *14*(20), 13212. 10.3390/su142013212

Altıok, S. (2020). The effects of augmented reality supported symmetry teaching on the academic achievement of primary school students and student opinions. *Educational Technology Theory and Practice*, *10*(1), 177–200. 10.17943/etku.622871

Azizi, E., & Mujari, K. (2022). Using modern communication technology to improve administrative communication [Master's thesis, Larbi Ben M'hidi University of Oum El Bouaghi, Algeria].

Boz, İ., & Özerbaş, M. A. (2020). Opinions of primary school teachers on the use of technology in mathematics lessons. *Science Education Art and Technology Journal*, *4*(2), 56–66.

Bujaily, F.Fatima Abdullah Bujaily. (2019). The reality of benefiting from virtual laboratories in teaching science at the secondary stage in Jeddah Governorate. *Journal of Educational and Psychological Sciences*, *3*(20), 121–140. 10.26389/AJSRP.F050119

Camilleri, M. A. (2024). Metaverse applications in education: A systematic review and a cost-benefit analysis. *Interactive Technology and Smart Education*, *21*(2), 245–269. 10.1108/ITSE-01-2023-0017

Contreras, G. S., González, A. H., Fernández, M. I. S., Cepa, C. B. M., & Escobar, J. C. Z. (2022). The importance of the application of the metaverse in education. *Modern Applied Science*, *16*(3), 1–34. 10.5539/mas.v16n3p34

Durak, A., & Karaoğlan Yılmaz, F. G. (2019). Opinions of secondary school students on educational applications of augmented reality. *Bolu Abant İzzet Baysal University Faculty of Education Journal, 19*(2), 468–481. 10.17240/aibuefd.2019.19.46660-425148

Eşin, Ş., & Özdemir, E. (2022). The metaverse in mathematics education: The opinions of secondary school mathematics teachers. *Journal of Educational Technology & Online Learning*, *5*(4), 1041–1060. 10.31681/jetol.1149802

Hassan, S. M. A. (2019). Designing a virtual laboratory using patterns of feedback to develop the skills of measuring objects and the aesthetic sense of mathematics among primary school students. *Journal of Mathematics Education*, *22*(12), 6–66. 10.21608/armin.2019.81273

Hendriyanto, A., Suryadi, D., Juandi, D., Dahlan, J. A., Hidayat, R., Wardat, Y., Sahara, S., & Muhaimin, L. H. (2024). The didactic phenomenon: Deciphering students' learning obstacles in set theory. *Journal on Mathematics Education*, *15*(2), 517–544. 10.22342/jme.v15i2.pp517-544

Hussain, A., & Ibrahim, A. (2022). The degree of using assistive technology in developing the communication and academic skills of deaf and hard-of-hearing students, and the challenges of its use from the point of view of the students themselves and their teachers. *Journal of the College of Education*, *38*(9), 68–107. 10.21608/mfes.2022.271530

Hwang, G. J., & Chien, S. Y. (2022). Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective. *Computers and Education: Artificial Intelligence*, *3*, 100082. 10.1016/j.caeai.2022.100082

Jarrah, A. M., Khasawneh, O. M., & Wardat, Y. (2020). Implementing pragmatism and John Dewey's educational philosophy in Emirati elementary schools: Case of mathematics and science teachers. *International Journal of Education Economics and Development*, *11*(1), 58–75. 10.1504/IJEED.2020.104287

Kanematsu, H., Kobayashi, T., Barry, D. M., Fukumura, Y., Dharmawansa, A., & Ogawa, N. (2014). Virtual STEM class for nuclear safety education in metaverse. *Procedia Computer Science*, *35*, 1255–1261. 10.1016/j.procs.2014.08.224

Kiong, L. V. (2022). *Metaverse made easy: A beginner's guide to the metaverse: Everything you need to know about Metaverse*. NFT and GameFi.

Kuş, O. (2021). Metaverse: Perceptions regarding opportunities and concerns in the "digital big bang.". *Intermedia International E-journal*, *8*(15), 245–266. 10.21645/intermedia.2021.109

Lin, H., Wan, S., Gan, W., Chen, J., & Chao, H. C. (2022). Metaverse in education: Vision, opportunities, and challenges. In *2022 IEEE International Conference on Big Data (Big Data)* (pp. 2857–2866). IEEE. 10.1109/BigData55660.2022.10021004

Mutluoğlu, A., & Erdoğan, A. (2021). The effect of virtual manipulatives developed for 6th grade mathematics lesson on students' achievement and attitudes toward geometry. *International Journal of Educational Studies in Mathematics*, *8*(3), 195–218. 10.17278/ijesim.942382

Mystakidis, S. (2022). Metaverse. *Encyclopedia*, *2*(1), 486–497. 10.3390/encyclopedia2010031

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Retrieved from https://www.nctm.org/Standards-and-Positions/Principles-and-Standards/

Ondog, J., & Kilag, O. K. (2023). A Constructivist Framework for Early Grade Numeracy: Drawing on Jean Piaget's Cognitive Development Theory. *Excellencia: International Multi-disciplinary Journal of Education (2994-9521), 1*(4), 308-320.

Özdemir, D., & Özçakır, B. (2019). An analysis of the effects of augmented-reality activities in teaching fractions on 5th-grade students' math achievement and attitudes. *Adıyaman University Journal of Educational Sciences*, *9*(1), 21–41. 10.17984/adyuebd.495731

Park, S., & Kim, S. (2022). Identifying world types to deliver gameful experiences for sustainable learning in the metaverse. *Sustainability (Basel)*, *14*(3), 1361. 10.3390/su14031361

Piumsomboon, T., Lee, Y., Lee, G., & Billinghurst, M. (2017). CoVAR: A collaborative virtual and augmented reality system for remote collaboration. In *SIGGRAPH Asia 2017 Emerging Technologies* (pp. 1–2). ACM., 10.1145/3132818.3132822

Rojas, E., Hülsmann, X., Estriegana, R., Rückert, F., & Garcia-Esteban, S. (2023). Students' perception of metaverses for online learning in higher education: Hype or hope? *Electronics (Basel)*, *12*(8), 1867. 10.3390/electronics12081867

Rospigliosi, P. A. (2022). Metaverse or simulacra? Roblox, Minecraft, Meta and the turn to virtual reality for education, socialisation and work. *Interactive Learning Environments*, *30*(1), 1–3. 10.1080/10494820.2022.2022899

Şahin, G. (2016). Using the game of Second Life as a model for experiential learning in social studies teaching [Master's thesis, Muğla Sıtkı Koçman University]. Türkiye Council of Higher Education Thesis Center Database (428406).

Saleh, S., & AlAli, R. (2024). Constructing and development of the psycho-computing traits scale: a psychometric analysis of computer users and students in the field of computer science. *Cogent Social Sciences, 10*(1), 2344231. 10.1080/23311886.2024.2344231

Saleh, S., AlAli, R., Wardat, Y., Al-Qahtani, M., Soliman, Y., & Helali, M. (2023). Structural relationships between learning emotion and knowledge organization and management processes in distance learning environments: An applied study. *European Journal of Investigation in Health, Psychology and Education*, *13*(9), 1569–1589. 10.3390/ejihpe1309011437754453

Sarıtaş, M. T. (2015). The emergent technological and theoretical paradigms in education: The interrelations of cloud computing (CC), connectivism and internet of things (IoT). *Acta Polytechnica Hungarica*, *12*(6), 161–179. 10.12700/APH.12.6.2015.6.10

Sarıtaş, M. T., & Topraklıkoğlu, K. (2022). Systematic literature review on the use of metaverse in education. *International Journal of Technology in Education*, *5*(4), 586–607. 10.46328/ijte.319

Şimşek, İ., Erbay, H. N., & Kirişçi, M. (2019). Teaching fractions at the 5th grade level in a three-dimensional virtual learning environment: Second life example. *Journal of Ahi Evran University Kırşehir Education Faculty*, *20*(1), 139–154. 10.29299/kefad.2018.20.01.005

Suzuki, S., Kanematsu, H., Barry, D. M., Ogawa, N., Yajima, K., Nakahira, K. T., Shirai, T., Kawaguchi, M., Kobayashi, T., & Yoshitake, M. (2020). Virtual experiments in metaverse and their applications to collaborative projects: The framework and its significance. *Procedia Computer Science*, *176*, 2125–2132. 10.1016/j.procs.2020.09.249

Tashtoush, M., Wardat, Y., Aloufi, F., & Taani, O. (2022). The Effectiveness of Teaching Method Based on the Components of Concept-Rich Teaching in Achievement for Students of Linear Algebra Course and Their Attitudes Towards. *Journal of Higher Education Theory and Practice*, *22*(7), 41–57.

Tashtoush, M. A., Wardat, Y., AlAli, R., & Al-Saud, K. (2023). The impact of cyberbullying on student motivation to learn: Insights from Abu Dhabi Emirate schools. *Humanities and Social Sciences Letters*, *11*(4), 461–474. 10.18488/73.v11i4.3566

Zahrani, A. A. (2022). The degree of employing virtual laboratories in teaching scientific concepts to middle-school students from the point of view of teachers and supervisors in the city of Mecca. *The Arab Journal of Qualitative Education*, *6*(22), 23–64. 10.21608/ejev.2022.233119

Zhang, X., Chen, Y., Hu, L., & Wang, Y. (2022). The metaverse in education: Definition, framework, features, potential applications, challenges, and future research topics. *Frontiers in Psychology*, *13*, 6063. 10.3389/fpsyg.2022.101630036304866