Exploring the Use of Metaverse as an Immersive Supplementary Tool in Mathematics Teachers' Training: Insights from Facilitators

Lara Ruth Mavil A. Ching-Dailo[1], Gily M. Aguilos[1,2], Ben Paul B. Dela Cruz[1], Edd Francis O. Felix[1]
laching1@up.edu.ph gvmagalona@up.edu.ph bbdelacruz2@up.edu.ph eofelix@up.edu.ph
[1]Institute of Mathematical Sciences, College of Arts and Sciences,
University of the Philippines Los Baños, Laguna, Philippines
[2]Department of Mathematics, School of Science and Engineering,
Ateneo de Manila University, Quezon City, Philippines

Abstract

A metaverse enables its users to experience navigating through simulated environments with its wide array of features. This research seeks to explore the use of the metaverse as an immersive supplementary tool for training mathematics teachers. Specifically, guided by the Metaverse-enabled Immersive Learning Environment (MeILE) framework, the study aims to assess the developed metaverse-based tool (MATHVerse PH) based on facilitators' perceptions of its social, cognitive, and teaching presence, as reflected in their personal stories of its usage. The developed metaverse-based tool was applied during breakout sessions on one of the topic areas in the Mathematics Teachers' Training at the University of the Philippines Los Baños. This narrative research utilized the Story Circle method for collecting and analyzing data. Narratives from the three faculty members who facilitated the training were collected through focus group interviews. Three overarching themes were identified: valuable features of the metaverse, barriers to participants' successful use of the metaverse, and approaches for facilitators' effective utilization of the metaverse. The enabling functionalities of MATHVerse PH, coupled with the facilitators' beneficial strategies, helped attain the training session's objective of aiding the participants to apply content knowledge and pedagogy on the fundamental concepts of "Counting Techniques". Revisions to the tool were also implemented based on the study's findings. This study offered notable insights into the use of the MATHVerse PH as an immersive supplementary tool for training mathematics teachers. The extension of its usability to other types of training may also be examined for future applications.

1. Introduction

Metaverse in Education

The COVID-19 pandemic brought radical changes in the educational sector on a worldwide scale [3]. Numerous institutions continued to deliver instruction despite class interruptions through access to the internet. Even after the pandemic has ended, access to the internet and other computer-based resources remains an important tool for educational institutions. The metaverse is an example of these resources. The use of the metaverse, which utilizes augmented and virtual reality, offers a means to expand the physical world, enabling users to maintain uninterrupted connections within real and simulated environments [2]. The metaverse has reshaped education by providing environments with "immersive and interactive" properties, which are said to capture the interest of learners in ways that the conventional teaching method cannot offer [1]. Previous works [1], [2], [3], [6], and [9] have provided valuable insights into the attributes of the metaverse in a formal education setting. However, these studies are mostly from the students' perspective. Inputs from the viewpoint of instructional facilitators who have experienced handling sessions where the metaverse was utilized in a teachers' training setting have yet to be explored at the time of writing. This serves as the impetus for the study, making it designed to address this unexplored aspect.

MATHVerse PH in Mathematics Teachers' Training

In this paper, we delve further into the application of the metaverse-based tool, MATHVerse PH, in breakout sessions on one of the topic areas of the Mathematics Teachers' Training from the perspective of facilitators who had first-hand experience using it and observed how participants navigated through this platform.

The Mathematics Teachers' Training is part of the annual public service initiatives of the Institute of Mathematical Sciences (IMS) of the University of the Philippines Los Baños (UPLB). The three-day online training program was attended by eighty-five (85) mathematics high school teachers and secondary education students from different parts of the country. The training aims to strengthen participants' knowledge and teaching strategies on the following topic areas of Basic Probability: (1) counting techniques, (2) basic probability, and (3) random variables and probability distributions. These topics are commonly perceived as complex, making them difficult for students to learn and equally challenging for teachers to explain more effectively. Distinguished mathematics professors from the IMS of UPLB delivered the lectures for each topic area. After each lecture, breakout sessions were conducted. In the breakout sessions, participants were given ample time to practice what they had learned from the lectures through exercises guided by equally competent and knowledgeable facilitators.

MATHVerse PH was developed as a supplementary tool to conduct the breakout sessions of the topic area "Counting Techniques", more specifically on the principles and strategies guiding the "Art of Counting". The MATHVerse PH version used in the actual training (with the training identifiers redacted and activities accessible to guest accounts) can be navigated through this link: https://bit.ly/MATHVersePHBreakoutRoom3. MATHVerse PH is a digital twin of UPLB, the academic institution where the training's lead institute is based. It faithfully replicates the terrain, vegetation, landmarks, and key structures of the university. During the training, participants were split across three servers. In each server, a facilitator supervised the participants as they freely explored the featured locations and engaged in the embedded activities in this virtual world.

There were two embedded activities intended to gauge and elevate participants' knowledge of fundamental concepts on counting techniques. Activity 1 was a collaborative group task that involved twenty questions that all participants answered simultaneously. The questions were designed to determine the participants' preferred method (systematic listing, tabular method, or usage of a tree diagram) in obtaining the number of possible outcomes in a given problem. After each question, a real-time distribution of participants' answers was displayed, giving everyone an initial sense of how common or unique their responses were. Once all questions were completed, the five items with the most diverse set of answers were highlighted for group discussion, encouraging participants to reflect on differing perspectives and deepen their understanding through dialogue. The goal of the activity was to determine similarities and differences in the participants' responses. Allowing facilitators to understand how participants process their thoughts and weigh the pros and cons of using each method for the given problem. Activity 2, in contrast, was a more self-paced experience set across five themed booths, each with two subthemes containing five questions each. The first themed booth is about "The Game of Chance", containing rolling dice and drawing card problems. The next one is on "The Codebreaker's Vault", featuring problems on creating secure passwords and encoding secret messages. The third booth is related to "The Traveler's Dilemma". Under these are the itinerary and routing problems. Following it is the themed booth for "The Library of Possibilities". This includes arranging books on a shelf and selecting books for a reading list. The final themed booth is focused on "The Circle of Arrangements", where problems on seating at a round table and arranging circular objects can be found. All of these themed booths aim to assess and enhance participants' knowledge of

determining the number of possible outcomes involving two important concepts for counting arrangements and selections, namely permutations and combinations. Participants were free to move between booths and jump to any question they wished to answer. Immediate feedback was provided after each question, letting them know whether their answer was correct or not. While this activity could be done individually, participants were encouraged to collaborate or discuss items they found challenging. They can use the chat and microphone to communicate with both peers and the facilitator.

The use of MATHVerse PH in Mathematics Teachers' Training aims to leverage the metaverse's functionalities to provide a distinctive and engaging experience to participants. Veering away from the traditional method of conducting breakout sessions, the use of MATHVerse PH aspires to transport participants from various parts of the country to UPLB as they collaborate and learn in the virtual world.

Conceptual Framework

The exploration of MATHVerse PH as a metaverse-based tool for training mathematics teachers is anchored in the Metaverse-enabled Immersive Learning Environment (MeILE) framework introduced in [10]. The design of this framework merges Bloom's Digital Taxonomy and the cognitive enhancement principles of the Community of Inquiry (CoI) framework. The following are the three vital elements of the framework: social presence (SP), cognitive presence (CP), and teaching presence (TP). These elements are defined in the context of the CoI framework. Social presence pertains to creating a sense of belonging and personal connection among users. Cognitive presence refers to assisting participants through a systematic procedure of critical thinking and intellectual involvement to promote in-depth knowledge building and understanding in the virtual environment. Teaching presence highlights the establishment of a supportive learning environment, leading participants to attain learning objectives with its carefully crafted design and arrangement of educational information.

Research Aims and Questions

Guided by the MeILE framework, this study seeks to explore the use of the metaverse as an immersive supplementary tool for training mathematics teachers. Specifically, the study aims to assess the developed metaverse-based tool (MATHVerse PH) based on facilitators' perceptions of its social, cognitive, and teaching presence, as reflected in their personal stories of using it, by answering the following questions: (1) What do facilitators' stories reveal about the developed metaverse-based tool? (2) How can it be used as an immersive supplementary tool for training mathematics teachers? (3) How can it be improved? (4) How can it be utilized effectively?

2. Methodology

Research Design

A narrative approach was utilized in this paper. In particular, we adopted the Story Circle method described in [7] for data collection and analysis. This method is used to collect a large amount of narrative data from participants through focus group interviews to identify shared patterns in the analyzed data. It is highly appropriate to use this method in this study, for the objective is to explore the use of MATHVerse PH as an immersive supplementary tool for Mathematics Teachers' Training, as reflected in the shared stories or narratives of the breakout sessions' facilitators.

Research Participants

The three respondents, Hera, Olivia, and Nath (pseudonyms), were facilitators of the previously conducted Mathematics Teachers' Training. They have voluntarily consented to share their stories and experiences with the premise of anonymity and confidentiality.

Data Collection

A Story Circle is defined as a group of people sharing their personal experiences through stories in a relaxed social environment [10]. Hence, a group interview was conducted to elicit stories and narratives about the facilitators' experiences in handling breakout sessions where the metaverse was utilized. The group interview was held online after the Mathematics Teachers' Training via Zoom. This is the most convenient and flexible setup for respondents who are not in the same location at that moment. Nevertheless, it did not hinder the seamless interaction and sharing of the participants during the interview that lasted for sixty-nine (69) minutes. A member of the research team monitored the group interview. Slides containing the interview questions were presented to the respondents through screen sharing. The interview questions were meticulously crafted, taking into account the elements of CoI indicated in MeILE. These questions were stated in a neutral and unbiased manner, allowing the respondents to express their thoughts and share their stories freely. A recording of the session was secured using the Zoom application recording feature. The interview was then transcribed using Microsoft Word and was transferred to Google Sheets for analysis.

Data Analysis

The narratives of the three facilitators were analyzed using the following steps: identifying narratives, coding narratives, identifying narrative themes, and counting narrative themes. Google Sheets was used throughout the process, allowing collaboration among researchers. The application's built-in features were utilized to organize, code, categorize, and count the narratives.

Identifying Narratives

Upon gathering and transcribing the data from the group interview, we noticed that the narratives stated the facilitators' observations on the behavior and actions of the training participants. They narrated how the participants interacted with them and how they resolved challenges that arose during the session. It can also be found in the narratives that these facilitators share similar sentiments and thoughts about some aspects involved in the use of the metaverse. This is also evident in how they nodded, as an indicator of agreement, verbally stating that they share the same thoughts "...as N said...", or mouthing "True". Some of the narratives include phrases such as "Ayun po" or "Yun lang", which signal that it is the end of the story, or "So ayun" to indicate that their next statement is an implication of the first one. After each narrative was identified, a number (H1, N1, O1,...) was given to each of the narratives shared by Hera (H), Nath (N), and Olivia (O). A large number of narratives were elicited. A total of sixty-one (61) small stories were generated throughout the 69-minute group interview.

Coding Narratives

Each narrative was examined and coded using Labov's Evaluation Model of Narrative in [4], which was followed in [7]. According to this model, a complete narrative structure includes the following parts: abstract, orientation, complicating action, evaluation, result, and coda. The abstract is said to be an overview of the story. The orientation includes the time, location, and characters of the story. The complicating action pertains to the event progression constituting the bulk of the narrative text. The evaluation component involves the narrator's or the characters' perspectives and opinions on events. The result is the resolution of the conflict [5]. Codas mark the conclusion of the

story [8]. However, a narrative may not possess all six elements; one or two elements are seldom found [5]. An example of narrative coding performed in this study is provided in Table 1. Note that the narratives were mostly shared in a combination of Filipino and English, but were translated into pure English for presentation in this paper.

Table 1. Example of Analysis of Narratives Coding Using Labov's Evaluation Model of Narratives Narrative 21 of Hera (H21)

	Valuable features of the metaverse: Metaverse's embedded activity feature
Abstract	For me, well, yes, MATHVerse is really unique because you can't imagine thinking, "Wow! You can actually do this, huh?"
Orientation	As you know, after Activity 2,
Complicating Action	I hope there's also something like a campus tour that they can do.
Result	Because the whole world will be opened at that time.
Evaluation	So, even though they are far apart, or even if it is just virtual, at least they will hopefully get to experience being in the university.
Coda	That's it.

Identifying Narrative Themes

After the narratives had been coded, we studied each narrative and its components, noting the participants' perceptions of the application of the metaverse-based tool during the breakout sessions based on its social, cognitive, and teaching presence. Each of the narratives was assigned an initial subtheme based on its content and evaluation component. We then clustered the stories considering their commonalities. These subthemes were then reexamined and modified until the following overarching themes were successfully identified: (1) valuable features of the metaverse, (2) barriers to participants' successful use of the metaverse, and (3) approaches for facilitators' effective utilization of the metaverse.

Counting Narrative Themes

For the final step of the analysis, the total number of narratives per theme was counted. Counting narrative themes is a step to provide numerical evidence that the analysis of data was executed with careful attention to detail and fairness [8]. Table 2 shows the summary of the narrative counts.

Table 2. Number of Stories by Theme

Theme	Total	Percentage (%)
(1) Valuable features of the metaverse	22	36.07%
(2) Barriers to participants' successful use of the metaverse	18	29.51%
(3) Approaches for facilitators' effective utilization of the metaverse	21	34.43%
Total	61	100%

3. Results and Discussion

The discussion of the results is presented in three sections, focusing not only on the identified overarching themes but also responding to the research questions previously presented.

Valuable features of the metaverse

The narratives pointed out various beneficial functionalities of the metaverse. One of these was the metaverse's emergency response feature, as highlighted in Nath's third narrative (N3):

There are just a few, those who have just entered [the world]. So, I have to instruct them that the hack, the one where they can go to the corner of the room. Then, they can activate the option to, like, access the questions. Yeah. But, for aah, there are just a few, maybe 2 or 3, that had to do the same thing, where they needed to go to the corner to access the questions, they were able to do it.

The metaverse's emergency response feature includes an enabling mechanism that provides training participants with prompt access to questions and instant assembly at a location. These properties enhance teaching presence by enabling facilitators to support the participants immediately. Additionally, the metaverse's learning progress monitoring feature, which involves observing participants' avatars and reviewing a summary of participants' responses to activities, can also elevate teaching presence, ensuring the achievement of the training objectives.

Another key attribute identified is the metaverse's real-time communication feature enabled through the use of avatars, microphone, and chat. Participants were able to seek the facilitator's assistance with this feature. It also allowed collaborative discussions among participants and with the facilitator. This boosts the social and teaching presence of the metaverse. Consequently, cognitive presence can be heightened as the facilitators guided the participants in understanding the necessary solutions to arrive at the correct answers. For instance, based on Hera's thirteenth narrative (H13):

...In the activity 2…a participant raised his/her hand and said, perhaps, this is what should be done, So we tried-, ah show-, so it's like with the guidance of the participant, I wrote it on the screen. For everyone to see. So, we simultaneously answered it...

Through the metaverse's real-time communication feature, the facilitator consistently guides participants in answering questions embedded in the themed booths in the second activity. This is as they simultaneously answer the questions. Enabling the facilitator to immediately correct misconceptions and share techniques on how to solve problems involving combinations and permutations, including permutations of distinguishable objects, permutations with identical objects, and circular permutations. These problems can sometimes be confusing to some, hence, require guidance from the facilitators and collaboration with other participants.

The metaverse's self-exploration feature can also enhance cognitive presence by allowing participants to navigate and complete activities by themselves, as the metaverse provides immediate feedback. The instant responses of the metaverse offer participants support in their discovery of the appropriate steps to undertake as they try to solve and find the correct answer. For instance, in determining the number of possible outcomes in a given scenario, participants can repetitively solve the problem until they reach the correct answer. If their answer is incorrect on the first attempt, they try again, applying other techniques and strategies, until they arrive at the right number of possible outcomes.

As we continued analyzing the narratives, the metaverse's embedded activity feature also emerged from the sharing of the story circle participants. This feature can be gleaned from the fifteenth narrative of Olivia (O15).

Ahh, I'll just add more later if I think of anything else. For now, my unique experience was realizing that those kinds of things, that, even though the seminar is held online, or the training, there seems to be a way, a chance for the participants to experience or to feel like they're in the actual place. And then, the questions were embedded [in the world]. That's what I found to be a unique experience. And then, the feeling that you're all in one place together. That's all for now.

This metaverse's embedded activity feature, together with all the other previously identified features, contributed to the participants' immersive experience, as evident from Olivia's narrative.

Through the metaverse's embedded activity feature, the activities intended to be accomplished during the breakout session were all installed in the booths located on the virtual UPLB campus, as shown in Figure 1. This makes participants feel they are in the actual place, working on activities alone through the support of the metaverse's self-exploratory feature, or with other participants enabled through the metaverse's real-time communication feature, and with the facilitator empowered by the metaverse's learning progress monitoring and emergency response features, even though the training was held virtually. This is because the metaverse made 3D storytelling possible. This enables users to interact within active and participatory environments. Thus, it permits the users to "become part" of the narrative instead of just being spectators [6]. This is vital because, as the participants feel as if they were in the actual training venue, interacting with their co-participants and their facilitator, they become more engaged and motivated in practicing solving and in sharing the optimal solving strategies that they think could help them better teach the concepts to their students when they return to their respective stations.

Figure 1. Screen Captures from the Interface of Mathverse PH
Taken During the Actual Breakout Session

Through the facilitators' stories highlighting all the metaverse's valuable features, it is evident that MATHVerse PH served as a supplementary tool, allowing participants to have an immersive experience as they attended the Mathematics Teachers' Training. The use of the metaverse, leveraging its beneficial functionalities, served as a platform for participants' meaningful collaboration and further content enrichment during the breakout session. As a result, it has been instrumental in realizing the training session's goal of enabling the participants to apply content knowledge and pedagogy on fundamental concepts of "Counting Techniques".

Barriers to participants' successful use of the metaverse

We have also discovered that the narratives reflect some of the challenges encountered, impeding the participants' successful use of the metaverse. One of these was the participants' problem of gaining entry to the metaverse. The narratives suggest that the source of the participants' problem of gaining entry to the metaverse was the limitations of the device used and the internet connectivity. Even though the metaverse can be accessed using a cellphone, tablet, desktop computer, laptop, or virtual reality (VR) devices, some of these gadgets may not be able to load the platform successfully due to the possible limitations of their devices' specifications. Another probable reason is the virtual world's participant limit in the Spatial.io subscription, which is the platform used. The limit is only fifty (50), which is less than the number of training participants. Unfortunately, this limitation was found only during the training. The struggle to gain initial access to the metaverse might significantly impact its social, cognitive, and teaching presence. This is because, to fully benefit from its key features, a smooth navigation within the

virtual environment is essential. With that, for future use, the metaverse underwent refinement by creating multiple identical worlds that can accommodate ten (10) people each. This does not need a subscription and has fewer avatars in each world. Moreover, the terrain and vegetation were simplified. These improvements will consequently result in faster rendering for each participant. However, this will require a larger number of facilitators.

Some narratives also reflect the participants' minimal collaboration with each other, which impacted their optimal application of the metaverse to achieve the training's objectives. This also influences the metaverse's social presence, which can be gauged by the participants' engagement in "group discussions and collaborative group activities" [9]. Nonetheless, this problem can be resolved through the effective use of the metaverse's real-time communication features. Although some participants were able to use these features, they failed to utilize them fully. The revision of the metaverse into multiple worlds, with at most ten (10) people each, can improve communication and collaboration among participants. Smaller groups foster more rapport among participants and a greater chance for each participant to speak and be heard. Facilitator-participant interaction may also be reinforced since this revision will result in a smaller facilitator-to-participant ratio. Therefore, this could enhance the teaching presence with facilitators being able to provide "on-the-spot, real-time instructions" [9] to participants in smaller groups.

Additionally, Nath's 13th narrative (N13), written below, is indicative of the participants' reduced engagement in the activity.

...I tried to initiate interaction with the participants. But most of them are unresponsive. Also, as you know, they're allowed to choose what they want to solve, their preferred booth [questions embedded on the booths] to solve. So, I thought that it might be disruptive if, like, I kept on talking instead of letting them solve (O nodding)...

This problem with participants' engagement could be due to the design of the activities. In response, we upgraded the metaverse by supplementing additional instructions within each activity area, adding hints, placing leaderboards, and creating a reward scheme. These improvements may make training participants more active and motivated, since they are now informed of their current status in the activity proper. In addition, a whiteboard was also placed in the metaverse. The facilitator can use it to discuss solutions to activity items, especially those that participants find difficult, which weakens their determination to participate and complete the activity. This addition could strengthen the metaverse's teaching, social, and cognitive presence, as facilitators helped participants work together to apply what they learned to answer the items. Moreover, slides that contain descriptions and explanations were added, which can aid participants in reviewing topics they struggle with. For instance, slides describing counting methods, such as systematic listing, tabular method, and the use of a tree diagram, were incorporated.

The revisions to the tool were made to address the challenges encountered by participants as observed by the facilitators during the training. Enhancing its functionalities and maximizing the use of its valuable features. The improvements could make the tool more effective in aiding participants to grasp the content and achieve the training objectives. The revised version of the MATHVerse PH can be accessed through this link: https://bit.ly/MATHVersePHBreakoutRoom5Rev.

Approaches for facilitators' effective utilization of the metaverse

The rich volume of narratives also allowed us to identify the strategies and approaches that facilitators can apply to effectively utilize the metaverse. Such is the facilitators' open communication with the participants. The 5th narrative of Hera (H5) demonstrates this.

> *In those times that we communicated [facilitator and participants]. So, most of it is for the exchange of questions: "Why did you choose this technique to answer this question?" or*

"What other way to answer this question?". And then, of course, if the solution is, if it's not clear to them, right- they ask. For example, if they have an alternative solution, they will be the ones to tell or to teach it to their co-participants…

It is evident in the narrative that Hera maintained a meaningful exchange of ideas with the participants. She facilitated the discourse and collectively provided solutions to the embedded questions. It's an indicator of the metaverse's teaching presence. This, in turn, heightens the cognitive presence of the participants as they answer questions of varying degrees of difficulty. It is also apparent from the narrative that participants were permitted to express their thoughts and share the methods they had utilized. They were allowed to work with their co-participants to arrive at the correct answer, which promotes "group cohesion" [9]. Thus, it enhances the metaverse's social presence. During the session, techniques for solving were shared, and fundamental concepts were reiterated. This then enabled participants to apply the content knowledge and pedagogy on concepts of Basic Probability, specifically in "Counting Techniques", resulting in achieving the training session's objective.

Subsequently, the facilitators' attentive supervision of participants' progress was highlighted in the 4th narrative of Olivia (O4), which was provided below.

…then, I share my screen to explain the given problem. I draw [illustrate] there (inaudible), "arrange in how many ways" and something like that, "arrange this situation". What I do is, I draw the, or like a symbol wherein, I do not state the final answer, I guide them regarding what is being asked. Then, they will be the ones to identify the correct answer…

Olivia's narrative indicates how she closely monitors the participants' development and helps them arrive at the correct answer. For instance, she illustrated some of the stated scenarios provided in the given items. One example of these items is as follows: "Three books are calculus, three are combinatorics, and two are geometry books. If books with the same subject must remain together, in how many ways can the books be arranged?". According to Olivia, she illustrated the scenario and drew how the books may be grouped and arranged accordingly. This is to help the participants visualize the conditions provided. This made the identification of the number of ways the books can be arranged easier for the participants. This facilitator's approach, in conjunction with the metaverse's learning progress monitoring and real-time communication features, supported participants in understanding and solving the problem. The facilitators' attentive supervision of participants' progress as they answer questions and navigate through the metaverse is vital in ensuring that participants can still follow the instructions and fully understand the concepts taught. Strengthening the teaching and cognitive presence of the metaverse.

Another approach that emerged in the analysis of narratives is the facilitators' adequate preparation to facilitate the activity using the metaverse. A series of practice sessions was conducted before the actual training. Facilitators had put in a lot of practice using the metaverse. Hence, even though an issue surfaced before the actual execution that could have hindered the effective application of the metaverse, they managed to resolve it and have not encountered the same error in carrying out the actual breakout session. Also, the facilitators' firm determination to fully utilize the metaverse in the activity played a crucial role in the effective application of the metaverse. Even though there have been barriers to the successful use of the metaverse, facilitators have shown determination in fully utilizing it in the activity by providing additional detailed instructions to participants as they work their way through the virtual environment. Their determination drives participants' engagement in the activity, making sure that the training's objectives are achieved despite the challenges encountered.

4. Conclusion

The narratives of the facilitators have been instrumental in exploring the use of the metaverse as an immersive supplementary tool for training mathematics teachers. Their stories have provided insights into the assessment of the MATHVerse PH, taking into account its social, cognitive, and teaching presence. Based on the results, we have identified three overarching themes: valuable features of the metaverse, barriers to participants' successful use of the metaverse, and approaches for facilitators' effective utilization of the metaverse. Each of which offered notable insights on the use of the MATHVerse PH as an immersive supplementary tool for training mathematics teachers. The enabling functionalities of MATHVerse PH, coupled with the beneficial strategies employed by the facilitators, helped in the attainment of the training's objective of aiding the participants apply content knowledge and pedagogy on the fundamental concepts of Probability, specifically on the topic "Counting Techniques". Revisions to the tool were also implemented based on the study's findings. Its use may further be studied for future applications.

References

[1] Aziz, F., Li, C., Khan, A.U. (2025) *Immersive Learning in Virtual Worlds: A Two-Step Analysis SEM And NCA For Assessing the Impact of Metaverse Education on Knowledge Retention and Student Collaboration*. Technology in Society, 81, 102871, ISSN 0160-791X, https://doi.org/10.1016/j.techsoc.2025.102871

[2] Dwivedi, Y. K., Hughes, L., Baabdullah, A. M., Ribeiro-Navarrete, S., Giannakis, M., Al-Debei, M. M., Dennehy, D., Metri, B., Buhalis, D., Cheung, C. M., Conboy, K., Doyle, R., Dubey, R., Dutot, V., Felix, R., Goyal, D., Gustafsson, A., Hinsch, C., Jebabli, I., . . . Wamba, S. F. (2022). *Metaverse Beyond the Hype: Multidisciplinary Perspectives on Emerging Challenges, Opportunities, And Agenda for Research, Practice and Policy*. International Journal of Information Management, 66, 102542. https://doi.org/10.1016/j.ijinfomgt.2022.102542

[3] Hwang, Y., Shin, D., Lee, H. (2023). *Students' Perception on Immersive Learning Through 2D And 3D Metaverse Platforms*. Education Tech Research Dev, 71, 1687–1708. https://doi.org/10.1007/s11423-023-10238-9

[4] Labov, W. (1972). *Language in the Inner City: Studies in the Black English Vernacular*. University of Philadelphia Press.

[5] Lima, L.S., Ristum, M. (2025). *Narrative Analysis: Methodological Contributions to Qualitative Research in Developmental Psychology.* Trends in Psychol. https://doi.org/10.1007/s43076-025-00442-2

[6] Lowry, P. B., Boh, W. F., Petter, S., & Leimeister, J. M. (2025). *Long Live the Metaverse: Identifying the Potential for Market Disruption and Future Research.* Journal of Management Information Systems, 42, 3–38. https://doi.org/10.1080/07421222.2025.2455770

[7] Parks, P. (2023). *Story Circles: A New Method Of Narrative Research.* American Journal of Qualitative Research, 7, 58-72.

[8] Sheikh, A.R., Awan, N.A., Sheikj, F. R. (2021). *The Application of Labov's Sociolinguistic Model of Narrative Analysis to a Short Story the Lottery By Shirley Jackson.* Pakistan Journal of Society, Education and Language (PJSEL), 8, 284-295.

[9] Singh, M., Sun, D., Zheng, Z. (2024). *Enhancing University Students' Learning Performance in a Metaverse-Enabled Immersive Learning Environment for STEM*

Education: A Community of Inquiry Approach. Future in Educational Research, 2, 288–309.

[10] Sweeder, L., Hill, N., Whitaker, E., Tiwari, A., Doan, W. (2019). *Story Circles as a Methodology: A Pilot Study Exploring Cognitive Problems in Aging.* Innov Aging. 3, 661.