Brain, Digital, & Learning

pISSN : 2384-2474
eISSN : 2586-7490

RESEARCH ARTICLE

Development of A Metaverse-Based Teaching Material on Rainforest Ecosystem for Nigerian High School Biology

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메타버스 기반 나이지리아 고등학교 생물 영역의 열대우림 생태계 교수학습 자료 개발

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Abstract

This study focused on the development of a metaverse-based rainforest ecosystem for high school students and tested its effectiveness in terms of students' academic achievement and learning satisfaction. In this study, the metaverse platform ZEP is used to simulate a rainforest ecosystem. ZEP jointly developed by Supercat and Naver Z was formally launched in Korea on March 16, 2022. ZEP is a platform where users can integrate through avatars and integrates the metaverse's virtual space map, video conferences, materials, movies and presentations displayed in object form. Ease of access, cost-effectiveness, interactivity, and user-friendliness are some of the strengths of the ZEP metaverse platform. The ZEP metaverse materials for high school biology were developed to serve as a hybrid world between the real and the virtual world. Data collection for the metaverse group was carried out using the pretest-posttest method, comparing it with two control groups—one using textbooks and the other using videos. The results indicate that the experimental group with metaverse technology is effective in improving students' learning achievement and satisfaction. Therefore, it is proposed that the metaverse in education is valuable for teachers and learners because it could lead to student engagement and motivation in the classroom.

Keywords: Metaverse, biology teaching material, ZEP, rainforest ecosystem, academic achievement, learning satisfaction.

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OPEN ACCESS

Brain, Digital, & Learning
2023, Vol. 13, No. 4, 353-366
https://doi.org/10.31216/BDL.20230022

Received: December 05, 2023
Revised: December 20, 2023
Accepted: December 20, 2023

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Introduction

One of the most important uses of the metaverse that has a lot of promise for the future is education. As a result, the metaverse in education can be thought of as an educational environment enhanced by metaverse-related technologies that fuse with the elements of the virtual and the real educational environment (Prieto et al., 2022; Rospigliosi, 2022; Suzuki et al., 2020). The metaverse's enabling technologies, including cloud computing, virtual reality, digital twins, and artificial intelligence, have already been used in education with promising results, suggesting that the metaverse has a lot of potential for use in the classroom (Park & Kim, 2022; Shin, 2002). It also increases active engagement with learning materials (Hsu, 2017), increases knowledge transfer (Radianti et al., 2020), and enhances learning outcomes (Lee et al., 2010). The World Economic Forum (2020)'s "Education 4.0" concept, which advocates for the digital, information, and customized transformation of education, is in line with the experiential and embodied teaching found in the education metaverse.

The goal of ecosystem education is to promote environmentally sustainable behavior in learners. The conventional method of teaching ecological education is confined to the classrooms, resulting in the transfer of cognitive aspects of ecological education while neglecting the emotional experience of students. Zhang et al. (2022) described this form of learning is difficult to link with the direct experience of the subject, and it is hard to trigger an emotional learning mechanism. Metaverse technology can be utilized to effectively make up for the deficiencies identified in the conventional methods of teaching ecological education (Liu, X., 2022). The high-fidelity learning environment enabled by the metaverse enriches teaching content, resulting in more engaging ecology education lessons. This form of education has the potential to stimulate the ecological emotion of learners. The stimulation of learners' ecological emotions could lead to positive ecological actions.

Wenxiao et al. (2022) noted that ecological education in the metaverse makes learning about environmental protection easier with the use of embodied learning. People frequently are unable to perceive the negative effects of their own actions on the environment since ecological consequences are long-lasting and slow to become evident in real life, and changing the current state of ecological environmental protection is a challenging task. Unlike traditional knowledge-based ecological education, learning about the ecological environment with the aid of the metaverse's physical environment helps students develop positive ecological behaviors and plays a positive role in stimulating their ecological emotions. Through embodied learning, education can generate particular environments that elicit ecological emotions, develop into targeted practices for ecological conservation, and genuinely empower ecological education(Liu, X., 2022).

For instance, people's emotional experiences can be significantly improved by using the metaverse to speed up the natural breakdown of polyethylene plastic waste, allowing them to feel the ecological effects of improper disposal and plastic consumption. The integration of ecological education and cultural tourism resources can also be realized through the metaverse. By utilizing the virtualization features of the metaverse, learners can be inspired to love nature by experiencing the breathtaking scenery of mountains, flowing water, the ocean, and jungles. By combining historical studies with ecological education, students can visit historical cultural sites and gain a thorough understanding of how nature and humans interact. The metaverse's use of immersive virtualization differs from the simplicity of earlier pure knowledge instruction. Students' motivation to learn can be increased by creating an immersive learning environment through the metaverse (Tlili et al., 2022). Active information cognitive activities can be formed from a variety of active interactions that take place in the metaverse's virtual learning environment to promote an understanding of the evolution of the human-nature relationship, in order to support learners' conscious environmental behavior and the achievement of environmental protection goals. Compared to passive knowledge acquisition, this is more effective. (Jeon & Jung, 2021).

In the field of education, the metaverse is also widely used and shows educational effects. Lee et al (2022) developed aircraft maintenance simulation based on the VR and Metaverse-oriented approach, an experiment was conducted to compare the proposed system with a traditional video training-based approach. To measure the effectiveness of both approaches, knowledge acquisition, and retention tests were applied. The findings of the experiment revealed that the group that followed the VR and Metaverse-oriented approach scored higher on both knowledge tests than the group that followed the video training-based approach. Besides, the answers to the questionnaires indicated that the participants felt a sense of spatial presence, and it was concluded that the usability of the proposed approach was higher than the video training-based approach. In a study conducted in dentistry education, (Locurcio et al., 2022) presented different ways to use virtual environments that simulated operating room environments and focused on teaching students various stages of surgeries. The use of different scenarios during the training of dentists provided a crucial advantage in their education.

Furthermore, Jeon et al., (2021) proposed a metaverse-based platform for education. The platform was designed to model an online educational ecosystem, it represented the totality of educational activities that can be carried out in the metaverse. Using the metaverse, learners may have experiences that foster immersion and increase learning motivation. The spatial mobility feature available in the metaverse encourages self-directed learning. considering the technological and ethical concerns surrounding the metaverse, the authors suggested that focus should be made on the interaction learners experience in the metaverse environment. The year 2021 was described by Mark Zuckerberg as 'the year of the metaverse', following that declaration there was a spike in investments and research interests in the metaverse. (Tille et al., 2022) observed that no research related to Metaverse in education is from the Arab or African region. Studies on metaverse application in specific subjects at secondary school are lacking. Particularly in Nigeria Metaverse technology is a novel development, the Nigerian educational system does not have enough digital technology, which prevents it from using them effectively for teaching and learning (Adeoye, A. et. Al., 2014).

To cover this research gap, this study is aimed at designing and applying a Metaverse-based rainforest ecosystem teaching material for senior secondary schools. Theoretically, this study contributes to the existing body of knowledge in the field of Metaverse in Education. Pedagogically, it provides insights on the practical application of using metaverse in science education in general and biology education in particular. Therefore, the purpose of this study was to develop teaching materials based on the metaverse for the rainforest ecosystem. Additionally, the study aimed to determine statistical differences in terms of academic success and learning satisfaction among participants using teaching materials in the metaverse, traditional textbooks, and videos.

Methodology

Participants and Procedure

The participants of the study were 90 first-year high school science students (SS1) in Abuja, Nigeria. This study used a pre-test and post-test control group design. In this design, three groups, namely the experimental group, control group 1, and control group 2, were chosen randomly, and then given a pre-test to determine the initial state.

The experimental class was exposed to a metaverse-based rainforest ecosystem teaching material designed by the researcher. Control Group 1 utilized the lecture method, complemented by a printed textbook chapter covering the same content as the experimental group. Control Group 2, on the other hand, was instructed on the same topic with the assistance of video content. Each class was conducted by the same teacher, who possessed experience in traditional teaching methods, as well as with videos and metaverse contents.

Metaverse Platform and Teaching Materials

ZEP, the metaverse platform used in this study, is a platform where users can engage through avatars. It integrates the metaverse's virtual space map, video conferences, data exchange, and education. The interactive features of ZEP include real-time communication, digital identities (i.e., avatars), media embedding, portals, quizzes, games, and mini-apps. To engage students and make learning enjoyable, simple activities and quizzes are incorporated.

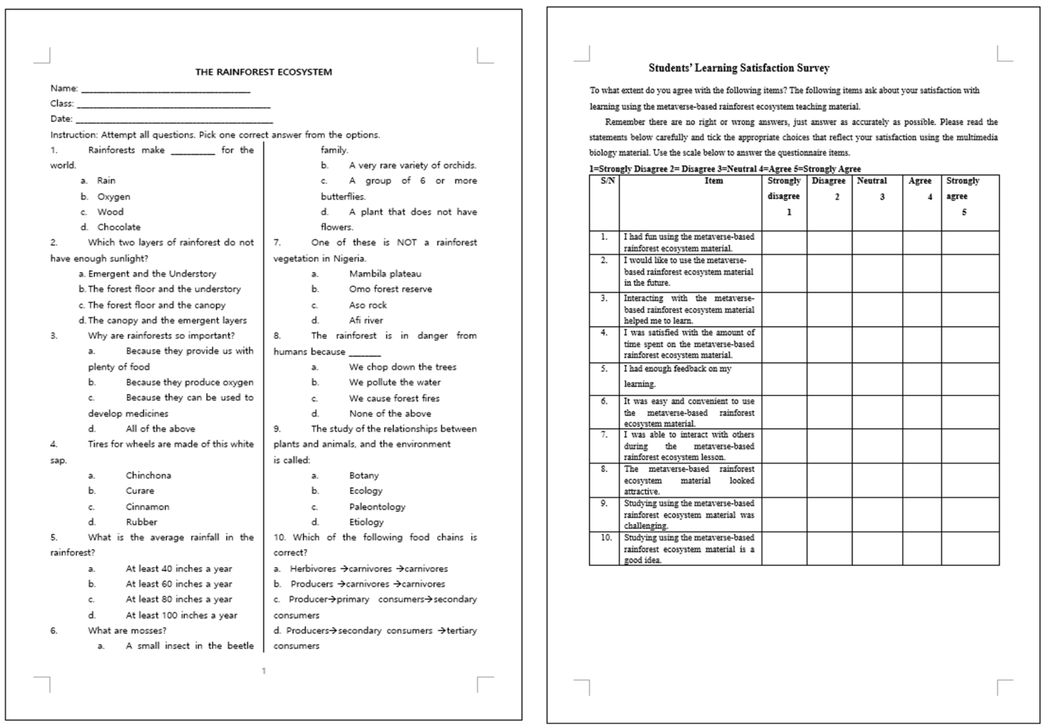
The researcher designed ecosystem teaching materials based on the ZEP metaverse platform, aligning them with the Nigerian High School Biology Curriculum. The focus was on a specific topic: the rainforest. The ZEP metaverse platform functions as a "hybrid world," bridging the gap between the real and virtual worlds. In this platform, teachers and learners participate using their real identities and convene in a physical classroom at predetermined times, adhering to the class schedule and school timetable. Alternatively, learners can join classes when a teacher initiates a meeting on the video conferencing platform. The lesson extended for 55 minutes, encompassing various components: a 5-minute ZEP introduction, layers of the rainforest, flora and fauna of the rainforest, adaptive features of organisms in the rainforest, and the food chain in the rainforest.

The developed metaverse materials were confirmed as valid metaverse-based lesson materials by five Korean experts in metaverse-based education. Additionally, the textbook and video materials were verified as contents for lessons on the rainforest ecosystem.

The Data Collection Instruments

The academic achievement test was developed for use in pre-test and post-test experimental studies. The achievement test consists of 10 multiple-choice questions based on the concept knowledge of the rainforest ecosystem. The achievement test underwent validation by four heads of the Nigerian Department of Science Education and ten high school biology teachers. They affirmed that the academic achievement test is valid in terms of relevance, clarity of language, suitability of the material's content, and the pattern of answers, with an overall agreement rate of 89.1%.

The students' learning satisfaction before and after lessons using three teaching materials was adapted from Moon & Kim (2001). The learning satisfaction instrument consisted of perceived usefulness, perceived ease of use, perceived playfulness, attitude towards use, and behavioral intention to use. According to Moon & Kim, it was broadly used as a tool for students' learning satisfaction.



THE RAINFOREST ECOSYSTEM

Name: ______________________

Class: ______________________

Date: ______________________

Instruction: Attempt all questions. Pick one correct answer from the options.

1. Rainforests make ________ for the world.
   a. Rain
   b. Oxygen
   c. Wood
   d. Chocolate
2. Which two layers of rainforest do not have enough sunlight?
   a. Emergent and the Understory
   b. The forest floor and the understory
   c. The forest floor and the canopy
   d. The canopy and the emergent layers
3. Why are rainforests so important?
   a. Because they provide us with plenty of food
   b. Because they produce oxygen
   c. Because they can be used to develop medicines
   d. All of the above
4. Tires for wheels are made of this white sap.
   a. Chinchona
   b. Curare
   c. Cinnamon
   d. Rubber
5. What is the average rainfall in the rainforest?
   a. At least 40 inches a year
   b. At least 60 inches a year
   c. At least 80 inches a year
   d. At least 100 inches a year
6. What are mosses?
   a. A small insect in the beetle family.
   b. A very rare variety of orchids.
   c. A group of 6 or more butterflies.
   d. A plant that does not have flowers.
7. One of these is NOT a rainforest vegetation in Nigeria.
   a. Mambila plateau
   b. Omo forest reserve
   c. Aso rock
   d. Afi river
8. The rainforest is in danger from humans because ______
   a. We chop down the trees
   b. We pollute the water
   c. We cause forest fires
   d. None of the above
9. The study of the relationships between plants and animals, and the environment is called:
   a. Botany
   b. Ecology
   c. Paleontology
   d. Etiology
10. Which of the following food chains is correct?
   a. Herbivores →carnivores →carnivores
   b. Producers →carnivores →carnivores
   c. Producer→primary consumers→secondary consumers
   d. Producers→secondary consumers →tertiary consumers

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Students' Learning Satisfaction Survey

To what extent do you agree with the following items? The following items ask about your satisfaction with learning using the metaverse-based rainforest ecosystem teaching material.

Remember there are no right or wrong answers, just answer as accurately as possible. Please read the statements below carefully and tick the appropriate choices that reflect your satisfaction using the multimedia biology material. Use the scale below to answer the questionnaire items.

1=Strongly Disagree 2= Disagree 3=Neutral 4=Agree 5=Strongly Agree

S/N	Item	Strongly disagree 1	Disagree 2	Neutral 3	Agree 4	Strongly agree 5
1.	I had fun using the metaverse-based rainforest ecosystem material.					
2.	I would like to use the metaverse-based rainforest ecosystem material in the future.					
3.	Interacting with the metaverse-based rainforest ecosystem material helped me to learn.					
4.	I was satisfied with the amount of time spent on the metaverse-based rainforest ecosystem material.					
5.	I had enough feedback on my learning.					
6.	It was easy and convenient to use the metaverse-based rainforest ecosystem material.					
7.	I was able to interact with others during the metaverse-based rainforest ecosystem lesson.					
8.	The metaverse-based rainforest ecosystem material looked attractive.					
9.	Studying using the metaverse-based rainforest ecosystem material was challenging.					
10.	Studying using the metaverse-based rainforest ecosystem material is a good idea.					

Fig. 1. Data collection instruments to measure the academic achievement and learners' satisfaction respectively

To ensure the validity of the instruments, the Academic Achievement Test (AAT) was validated by 4 heads of the department of science education and 10 senior secondary school science teachers. The validation criteria included the instrument's content and the subject matter to be taught in terms of relevance, clarity of language, suitability of the material's content, and pattern of answers. The recommendations given were included in the final questions before being assigned to students.

Twenty (20) students answered the 10 items that made up the reliability statistics table in the Cronbach's alpha column. The value of reliability was 0.87 that was regarded as reliable in the upper category. Consequently, it was determined that the questions were worthy of testing and may be given to students. The instrument reliability of learner's satisfaction was 0.82 which was appropriate to use as test tool in this study. The results of the reliability test on the instruments are shown in Table 1 below.

Table 1. Reliability tests of academic achievement and learners' satisfaction

	Cronbach's Alpha	N of Items
Academic achievement	.87	10
Learner's satisfaction	.82	10

Data Collection and Analysis

This study design is a part of experimental research that offers Metaverse-based content as a learning tool for the experimental class and printed Textbooks and Videos for the Control-1 and Control-2 groups respectively. The instructional objective, contents, and stages of the program were operated equally in all three groups. However, in the teaching method, the experimental group was conducted with the metaverse class, and the control groups were conducted with a printed textbook and video use classs, respectively. In the experiment, the students had no prior knowledge of or experience with the class instrument for the experimental and control groups. The instructor runs the class in three groups based on the proposed methodology. The lesson delivery plan for the experimental group is outlined in Table 2 below:

Table 2. Lesson delivery plan for experimental group

Activity	Details	Duration
Pre-test	Students respond to the pre-test questions before the lesson.	5 minutes
Introduction	Instructor introduce the learning space in ZEP's main space and introduce the roles of objects and spaces. Students who use ZEP for the first time will be taught how to move their avatars by pressing the left, right, up, or down arrows on the keyboard (a, s, d, and w) and return to the main entrance of the map. This will happen prior to the main classroom.	10 minutes
Synchronization	Play a simple game to familiarize yourself with the operation method.	5 minutes
Learning objective 1 Layers of the rainforest ecosystem	Move to the layers portal	10 minutes
Learning objective 2 Flora and fauna of the rainforest ecosystem	Move to the flora and fauna portal	10 minutes
Learning objective 3 Adaptative features of organisms in the rainforest ecosystem	Watch the video on the adaptative features of organisms in the rainforest	10 minutes
Learning objective 4 Food chain in the rainforest ecosystem	Move to the media zone and watch the video on the food chain in the rainforest	10 minutes
Post-test	The teacher administers post-test questions to students	
Learners' Satisfaction Survey	Students respond to the survey questions	

Data collection was carried out by administering pre-test and post-test questions to students, followed by a survey on students' academic achievement and learning satisfaction. The researcher also conducted an interview with the instructor to gather her opinion on her experience using the metaverse-based teaching material.

The data analysis employed in this study includes the descriptive statistics test, one-way ANOVA test, and Tukey's HSD test (post hoc). Initially, a descriptive statistical test was conducted to determine the mean, standard deviation, and variance, followed by Levene's test for homogeneity of variance. Then, a one-way ANOVA test was performed to ascertain whether there was a statistically significant difference between the pre-test and post-test in the three groups. Finally, a Tukey's HSD test was conducted to determine the exact means that are statistically significantly different from each other.

Results

Developed Metaverse-based Teaching Material

A virtual rainforest ecosystem was created on the ZEP metaverse platform. The space was modified and reorganized to align with the class's objectives, utilizing the free map 'Forest playground' provided by ZEP, as illustrated in (Fig. 2-a). Each portal in the Metaverse content represents one of the four (4) lesson objectives/lesson steps. If the avatar approaches the blue portal, it directly connects to a new space, as depicted in (Fig. 2-b). The first portal, functioning as the entry map, covers 'Introduction to the Rainforest Ecosystem.' Upon moving to the second portal, an engaging interaction between the flora and fauna of the Rainforest unfolds (Fig. 2-c). Sliding across each representative object triggers the display of the image, name, and description of each plant and animal. Adjacent to this portal is the 'Layers of the Rainforest', illustrating the characteristics of the four layers of a Rainforest (Fig 2-d). Students can explore the plant and animal life in each layer. To further elucidate the concepts of the food web and food chain, there are two videos on plants and animals' adaptation in the Rainforest Ecosystem. The last portal, also referred to as 'the media zone,' contains audio-visual materials describing the process of food production and consumption in the Rainforest Ecosystem (Fig. 2-e).

Fig. 2. The developed metaverse-based teaching material on rainforest ecosystems for Nigerian high school students

Comparison of Academic Achievement

The study further compared the academic achievement between the Control_1, Control_2, and Experimental groups. The result of the ANOVA test showed that there were statistically significant differences between the academic achievement of the three groups, [*F (2,87) = 7.017, p=0.001]* (Table 3). The individual variances among the mean scores were analyzed using Tukey's HSD posthoc test based on Levene's test result *(p>0.01).*

Post Hoc comparisons using Tukey's HSD test indicated that the mean score for the Control1_Textbook group *(M=8.38, SD=0.83)* was statistically significantly different from the Control2_Video group *(M=7.58, SD=0.94).* Also, the Experimental_Metaverse group *(M=8.15, SD=0.77)* was statistically significantly different from the Control2_Video group *(M=7.58, SD= 0.94)*. However, the Experimental_Metaverse group *(M=8.15, SD=0.77)* did not significantly differ from Ctrl1_Textbook group *(M=8.38, SD=0.83).*

Table 3. Mean variances of academic achievement test among three groups (ANOVA)

Groups		N	M	SD	F	p
Ctrl1_Textbook	Pre-Test	30	7.07	1.39	7.017	.001
	Post-Test	30	9.70	0.59		
Ctrl2_Video	Pre-Test	30	6.23	1.33		
	Post-Test	30	8.93	1.05		
Exp. Metaverse	Pre-Test	30	6.60	1.22		
	Post-Test	3-	9.70	0.65		

Note. N=population, M=mean, SD= standard deviation, p=significance, Exp.=Experimental

Comparison of Learning Satisfaction

The subsequent ANOVA and Tukey's HSD post-hoc tests were conducted to analyze students' satisfaction among the three groups. The ANOVA test showed that the effect of learning satisfaction among Control_1, Control_2, and Experimental groups was statistically significantly different *[F (2,87) = 8.622, p=0.000]* as shown in Table 4. The Post Hoc comparisons using Tukey's HSD test indicated that the mean score for the Control1_Textbook group *(M=3.77, SD=0.42)* was statistically significantly different from the Experimental_Metaverse group *(M=4.20, SD=0.37).* However, the Experimental_Metaverse group did not significantly differ from the Control2_Video group. The Control1_ Textbook group *(M=3.77, SD=0.42)* was not statistically significantly different from the Control2_Video group *(M=3.99, SD=0.44).*

Table 4. Students' Learning satisfaction in three groups using ANOVA analysis

Groups	N	M	SD	F	p
Ctrl1_Textbook	30	3.77	0.42	8.622	.000
Ctrl2_Video	30	3.99	0.44		
Exp. Metaverse	30	4.20	0.37		

Note. N=Population, M=mean satisfaction, SD=standard deviation, Exp.=Experimental

The mean score for students' learning satisfaction on the survey questions for the Control-1, Control-2, and Experimental groups are shown in Table 5.

Table 5. Mean of the groups' learning Satisfaction

Groups	Tools	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
Ctrl_1	Textbook	4.03	3.70	4.47	3.83	3.67	3.80	3.30	3.87	2.70	4.30	3.77
Ctrl_2	Video	4.33	4.63	4.23	3.77	4.17	4.03	3.43	4.73	1.90	4.67	3.99
Exp.	Metaverse	4.63	4.63	4.53	3.93	4.40	4.50	4.13	4.70	1.83	4.77	4.21

Note. Ctrl_1= control 1, Ctrl_2= control 2, Exptl= Experimental, Q1…Q10= number of questions

Discussions

Development of the Metaverse-based Teaching Material

In this study, the metaverse platform called ZEP was utilized for teaching and learning applications within the ecosystem. The link and QR code for the ZEP space named RAINFOREST ECOSYSTEM were sent to the instructor. To enhance interactivity with the content, the researcher embedded additional elements such as students' lesson notes, background music, and quizzes. Portals and teleporting functions facilitated easier and more engaging navigation. The metaverse-based teaching material proved effective in improving students' academic achievement and satisfaction with their learning. These results are consistent with previous studies, which highlighted the various advantages of educational metaverses, including improved cognitive and affective outcomes (Calvert & Abadia, 2020). The findings from the study suggest that metaverse teaching content can enhance interactivity, immersion, and overcome the limitations of time and space in the classroom. This may also imply that the metaverse-based contents in this study are beneficial for students classroom learning. Gamage et al. (2020) and Myburgh (2022) also insist that the educational metaverse develops a new learner-centered educational paradigm. This paradigm aims to enhance students' motivation and autonomy in the classroom, facilitating customized instruction.

The biology curriculum, ease of use, and accessibility were all taken into consideration when creating the metaverse content. The researcher designed and administered the content based on the Nigerian High School Biology Curriculum for high school students, focusing specifically on a particular topic—the rainforest. The results have shown that the metaverse-based ecosystem content was applicable as learning material in terms of students' academic achievement and learning satisfaction. These results are valuable for various researchers interested in metaverse education. For example, Liu, X. (2022) simulated a rainforest ecosystem using the metaverse to provide a new way of interacting with nature through immersive three-dimensional virtual worlds. Additionally, researchers have pointed out that embodied learning using the metaverse could be employed to solve the problem of ecological education (Liu, J., 2022). For instance, immersive experiences help people intuitively feel the ecological consequences that cannot be experienced in real life. The metaverse embodied environment creates a learning environment without space constraints, thereby promoting student-centered teaching, learning immersion, and high-order thinking (Li & Wang2022). Therefore, ecological education using the metaverse can be seen as the extension of physical ecological education, constantly enhancing the content, pedagogy, and environment of ecological education.

In addition, to be captivating in the classroom, pupils must first become accustomed to its components and settings. Both the teacher and students also need a certain level of technological proficiency to navigate the metaverse platform.

According to the instructor, challenges encountered in using metaverse teaching content include a shortage of time, unstable electricity, high costs of internet bandwidth, and insufficient digital resources for students' use. Dewantara et al. (2022) also express concern that metaverse technology poses challenges for students in acquiring both the necessary equipment and practical tools in laboratory practices.

Students' Academic Achievement

The first control group had 30 participants taking part in the pre-and post-test. They were taught in the conventional method with the aid of printed textbooks. Conventional learning students were more passive because they only listened to the teacher's explanation. Some students took note of what the teacher was saying while others did not concentrate on the material being studied in the teaching and learning process.

In the pre-test, the average score was 7.07, the highest score was 9, and the lowest score was 6. The post-test results were then calculated, and the increase was found; the average score was 9.70, the highest score was 10, and the lowest was 9. The mean difference between the pre-test and the post-test was found to have increased by 2.63. this may be due to the conventional method of learning that students are familiar with which does not spark interest and tends to be boring because of teacher-centeredness. Students became less motivated to ask questions and explore the material.

In the 2nd control group, 30 participants took part in the pre-test and posttest. These participants were taught the rainforest ecosystem with the aid of YouTube videos. The average score for the pre-test was 6.23, the highest score was 9 and the lowest score was 2. The participants were then given a post-test, and the post-test results were calculated, the average score was 8.93, the highest score was 10 and the lowest was 7. Though a 2.7 increase was found between the pre-test and post-test it should have been higher. This may be caused by several factors including the speed of the video, the language of the presenter, and a lack of feedback on learning. generally, students learning through video lessons is still characterized by passive learning.

In the experimental group, 30 participants took part in the pre-test, treatment, and post-test. The students were taught with the aid of the metaverse-based rainforest ecosystem teaching material. These participants were asked to follow the treatment until it was finished. When the treatment finished, the participants were then given a post-test. For the pre-test, the average was 6.60, the highest score was 9 and the lowest was 4. The post-test result was then calculated, and an increase was found. The average score was 9.70, the highest score was 10 and the lowest was 7. The result indicated an increase between the pre-test and post-test to 3.1. Based on the results, it can be concluded that participants in the experimental group indicated a positive trend by increasing achievement from their pre-test and post-test.

The effectiveness of active learning within the ZEP metaverse platform made it easier for students to learn, this can be seen from the students' cognitive outcomes. The existence of the metaverse-based content caused increased students' learning outcomes in learning the concepts of rainforest ecosystem teaching material. This finding is supported by Jiaxin, L., 2022 who stated that :

"Using the metaverse is of great significance to teaching: creating a virtual environment to provide rich teaching resources for teachers and students; changing teaching methods to bring a new experience of teaching activities to

improve the results of teaching; innovating teaching interaction, new interactive methods are used in teaching activities to improve teaching efficiency."

The analysis results showed that academic achievement before and after class treatment increased both in the experimental and two control groups, showing a statistically significant difference. It can be seen that there was an increase between pre-and post-test in all the groups, however, the degree of increase was higher in the experimental group than in the two control groups. Specifically, it shows that the use of metaverse-based teaching content is more effective in improving learning outcomes than YouTube videos and printed textbooks.

The analyzed results indicated a significant increase in academic achievement before and after class treatment for both the experimental and two control groups. While there was an observable rise in all groups between pre- and post-tests, the experimental group exhibited a higher degree of increase compared to the two control groups *(Pre-test = 6.60, Post-test = 9.70*). Specifically, the use of metaverse-based teaching content proved more effective in enhancing learning outcomes than YouTube videos and printed textbooks (Jiaxin & Gongjing, 2022). These results suggest that metaverse-based content is indeed effective in improving students' learning achievement and satisfaction.

Students' Learning Satisfaction

A survey on learning satisfaction was conducted by the instructor following the post-test. The results of the survey revealed that the conventional class in the control group, which used a textbook, had the lowest mean satisfaction score of 3.77. The second control group, which utilized video, had a mean score of 3.99, while the experimental group using metaverse content had the highest mean score of 4.21. These results suggest that students are disengaged with the traditional chalk-and-talk method of teaching. Students would rather embrace the educational metaverse due to its various benefits, such as increased active engagement with learning materials, as indicated in the study by Hsu (2017).

Many students aspire to incorporate metaverse-based rainforest teaching materials into their future classes. This inclination is driven by the captivating environment that instills motivation and interest in students for learning the material. The item garnering the highest mean score (M=4.77) for learners' satisfaction in the experimental group was Question 10, which focused on whether 'learning with the metaverse-based rainforest ecosystem content was a good idea." This response indicates the students' satisfaction with the metaverse content. On the other hand, Question 4 ("I had enough time using the metaverse-based content") received the lowest mean score (M=3.93). Despite this, based on the teacher's observations, students expressed satisfaction with using metaverse-based content. Given that this was their initial exposure to metaverse-based content in the classroom, they are eager to extend lesson hours due to the enjoyable experience they had during the process. Tlili et al. (2022) also observed that different forms of positive interactions that occur in the virtual learning situations of the metaverse can become active cognitive information activities.

Instructor's Opinions on the Teaching Material

Based on the interview with the teacher after the lesson, it was observed that both teachers and students had developed an interest in the metaverse-based rainforest ecosystem teaching material. The teacher expressed her desire to use metaverse-based teaching content in the future. She emphasized that it made her teaching easier and more effective; given a choice, she would pick metaverse-based content as the most suitable teaching method for biology.

The teacher also emphasized preparedness for the metaverse class before starting the class. The internet environment and the digital devices such as laptops, tablets, and smartphones if not adequate could be a hindrance to effectively connecting to the metaverse platform. There was an opinion that it was difficult for users to use the Metaverse platform because 5G internet access was not smooth, therefore it was necessary to check the class facilities before the class.

Conclusions and Implications

The researcher utilized the ZEP platform to develop teaching materials for a metaverse-based rainforest ecosystem. In this study, the metaverse content was incorporated into a Biology lesson for first-year high school students, and its effectiveness was subsequently verified. The instructional designs within the metaverse acted as bridges to grasp abstract and challenging concepts that are difficult to achieve in real-life situations.

The application of the metaverse in education could be contributed in a novel development in future education including Nigerian situation. The administrators, teachers, and students all embraced the idea with positive responses. It is anticipated that the metaverse application will be embraced by the Federal Ministry of Education, particularly in STEM subjects, as a means to address issues such as teacher shortages and the inadequacy of laboratory equipment and field trips.

However, due to constraints in time and resources, this research only developed a sub-unit of Biology teaching materials for first-year high school students and implemented it during a lesson in one school. Further research recommends expanding the material content, increasing the sample size across various grades and age groups, and conducting a survey among teachers to gauge their perceptions of metaverse utilization in education. These steps would significantly enhance the general applicability of the study.

In conclusion, metaverse technology can serve as a valuable teaching aid to enhance students' academic achievements and foster overall satisfaction.

Acknowledgments

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2022S1A5A2A0104319111).

Conflicts of Interest

The authors declared no conflicts of interest.

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