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Exploring the Use of a Physical 3D Model-Based Interactive Game in Teaching the Water Cycle: Impact on Academic Achievement and Student Perspectives

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Abstract: ***This study evaluates the impact of using a physical 3D model-based interactive game in teaching the water cycle to Grade 4 students, focusing not only on academic performance but also on their perceptions. This study utilized a mixed-methods approach, particularly the exploratory sequential design, involving thirty (30) Grade 4 pupils from Section Charity at San Vicente Elementary School. The quantitative data were collected through pre-test and post-test assessments, which helped determine the changes in students' academic performance. Qualitative data were collected through structured questionnaires with open-ended questions, allowing the students to share and elaborate on their experiences and perceptions regarding the use of the intervention. The findings revealed that the students' mean test score increased from 81.26% before the intervention to 86.87% after its implementation. The computed t-value of 13.61 exceeds the critical t-value of 2.045, and the p-value was found to be less than 0.001, which is below the significance level of 0.05. This suggests that the likelihood of achieving such results by chance is extremely low. Qualitative data also revealed positive student perceptions. Thematic analysis revealed four (4) themes, which included positive emotional reactions, enhanced understanding and active learning, increased motivation, and fun and enjoyment. These findings indicate that the physical 3D model-based interactive game is an effective tool for enhancing interest and students' understanding of the water cycle. This study underscores the potential of hands-on, interactive, and engaging learning tools like the physical 3D model-based interactive game in enhancing students' understanding of science concepts and stimulating their interest as well.***

Keywords: interactive learning, water cycle education, physical 3D model, student motivation, science teaching strategies

1. Introduction

Teaching science in elementary is fundamental as it lays foundation for learners' understanding of the natural processes and phenomena enabling them to make sound decisions about their environment and life. Furthermore, it develops the critical thinking, creativity, and innovative skills which are fundamental in dealing with the challenges in the 21st century. However, despite its importance, studies revealed that the Philippines faces significant challenges in science education, as evident in the Programme for International Student Assessment (PISA) study, which evaluates students' academic performance in reading, math and science globally. In accordance with the 2018 and 2022 PISA study results, the Philippines' performance remained essentially unchanged. From ranking second to last in 2018 to being third to last in 2022, the Philippines' rank remained near the bottom. These results indicates that Filipino students are struggling with science subjects emphasizing the need for innovative teaching method that will help improve Filipino students' understanding of complex scientific concepts.

Water cycle is an important scientific concept taught in elementary grades. Learning about it not only helps the learners comprehend the process but it also helps in understanding weather patterns, appreciating the importance of water in sustaining life and ecosystems as well as making informed decisions for the environment. However, the water cycle is a dynamic and abstract process, which can be difficult for students to fully grasp. Traditional teaching methods which uses textbooks, static diagrams or lectures often fall short in conveying the complexity and dynamic reality of water cycle. These methods tend to focus on rote memorization that hinders the development of learners' deeper understanding of the concept. Constantly recalling the information given without fully understanding its meaning may result in learners' difficulty visualizing how the water cycle functions in the real world, reducing their ability to understand the interconnected stages involved.

A study from Philippine Institute for Development Studies (PIDS) revealed that the educational institutions in the Philippines are among those in Asia with low internet and computer access. In the budget hearing of Department of Education, Commissioners of the Second Congressional Commission on Education (EDCOM 2) revealed that there are 1,775 sites that still needs electricity. This means that there are some schools that do not have access to electricity. In a study by Macayana et al. (2024), it revealed that the underlying reasons why Philippines lack science laboratory and equipment was due to budgetary constraints and underfunding as well as mismanagement and utilization of funds. The previous reports and studies only indicate that many schools in the Philippines face ongoing issues not just with access to technology and electricity but as well as budget constraints. Due to this, digital solutions may not always be the most practical option. Physical 3D models require minimal technological infrastructures and it can be made using simple, affordable and accessible materials. Therefore, it is the best alternative solution particularly for schools that face significant challenges with access to digital technologies.

According to James (2023), the ability to visualize scientific concepts in a more engaging and interactive way is one of the most significant benefits of 3D modelling in science education. The physical 3D models provide visual representation of water cycle which they can manipulate and explore hands-on fostering active, engaging, and interactive learning environment. It can also encourage collaboration and exchanges of ideas among learners, helping them actively investigate the interconnected stages of water cycle. A study conducted by Tepla et al. (2022), revealed that 3D models can significantly increase student motivation to learn natural science. The use of physical 3D models transcends the traditional teaching methods that solely rely on textbooks with static diagrams or lectures, which can be less engaging for the learners. Physical 3D models can motivate the learners to actively participate and learn about water cycle because it is more dynamic and something new to them. They captivate learners' attention spark their interest. 3D models in science education facilitate conceptual clarity by offering a detailed representation of objects and phenomena and bridges the gap between abstract and concrete, according to Gupta (2023). Some scientific concepts are challenging to grasp when learners rely solely in text or lectures. These concepts sometimes involve abstract ideas and processes. By using physical 3D models learners acquire concrete representation of these concepts. The tangible nature of the 3D model provides learners the opportunity to directly interact with the concepts leading to deeper comprehension and enhanced retention of information. When learners are presented with accurate visual representation, they can better understand the concept. This hands-on approach not only deepens the learners' understanding but also enhances information retention as visual representation play a significant role in storing information more effectively than text (Jandhyala, 2021). Since we respond better to visuals compared to text, physical 3D models further aid in information retention.

Even with the recognized advantages of using the 3D models in teaching science concepts, there remains a significant gap in research specifically addressing their application within the Philippine educational context, particularly concerning the use of physical 3D models in science instruction. Liwanag's (2022) study, highlights the effectiveness of using the 3D models in teaching cellular diversity. The results indicated a notable improvement in students' academic performance. Moreover, the results also revealed that regardless of the students' initial ability level, they all benefited from utilizing 3D models. A similar study conducted by Evangelista et al., revealed that 3D model of a prototype "Biokit" was an efficient instructional material for classroom instruction. These studies indicate that 3D models can serve as effective educational tools in enhancing science education in the Philippines, and physical 3D models are the best alternative, especially in schools where digital resources may be limited.

In response to the changes in the Philippine education landscape, the Department of Education implemented DepEd Order No. 42, Series of 2017 or commonly known as Philippine Professional Standards for Teachers (PPST). It highlights the importance for teachers to continuously improve their skills and knowledge to deliver quality education to 21st century learners. Furthermore, it emphasizes the need to use variety of teaching approaches and instructional materials suitable to the learners and learning goals. In accordance with this, this study aims to explore the effectiveness of physical 3D model based by incorporating interactive game element in teaching the water cycle. This study aims to evaluate not only the academic performance of students but also their experiences and perceptions regarding the use of a physical 3D model-based interactive game as a learning tool. By examining these aspects, this study contributes to ongoing efforts to enhance science teaching practices in the Philippines, particularly through the integration of affordable and effective instructional materials like physical 3D models.

Objectives of the Study

This study aims to evaluate the effectiveness of physical 3D model-based interactive game in teaching water cycle considering the academic performance and perceptions of students. Specifically, it seeks to answers the following questions:

1) How effective does physical 3D model-based interactive game in enhancing students' understanding of the water cycle?
2) What are the perceptions of students regarding the use of physical 3D model-based interactive game in teaching the water cycle?

2. Methodology

This study utilized mixed methods approach, particularly the exploratory sequential design. To gather data, the researchers employed two main research instruments designed to comprehensively gather valuable numerical data and insights to address the objectives of this study. The quantitative data were collected through pre-test and post-test assessments which helped determine the changes in students' academic performance. The pre-test assessed what the students already knew about the topic, while the post-test evaluated the effectiveness of the physical 3D model-based interactive game in enhancing students' understanding of water cycle after using the intervention. Qualitative data were collected through structured questionnaires with open-ended questions, allowing the students to share and elaborate their experiences and perceptions regarding the use of the intervention. The participants of this study included thirty (30) pupils from Grade 4 section Charity in San Vicente Elementary School, selected using the census method since all pupils in the section were included.

The pre-tests and post-tests consisted of ten (10) multiple choice questions, five (5) true or false, and five (5) identification for a total of 20 questions. Before the data collection phase began, a formal letter of request to conduct a study was sent to San Vicente Elementary School's principal's office on March 20, 2025. On the same day that the request was granted, the researchers immediately administered a pre-test among the Grade 4 Section Charity learners. When the learners were done answering the pre-test, the researchers presented the water cycle physical 3D model-based interactive game and clearly explained how to use the said learning material. After the orientation, the intervention was left under the care of the class adviser for more than two weeks for the pupils to use. On April 4, 2025, the researchers came back to retrieve the material and conduct a post-test and disseminate the structured questionnaire. Students' responses were translated into English for analysis.

The quantitative data collected from the pre and post intervention tests, as well as the qualitative data from students' insights, were analyzed using the appropriate data analysis method. For the quantitative data, descriptive analysis was used to analyze the results from the pre-test and post-test. The researchers calculated the distribution of test scores across different grading scales to identify the percentage of students in each performance descriptor before and after using the physical 3D model-based interactive element. The total mean performance of students for each assessment was also computed to provide the overall measure of central tendency. A paired t-test was also administered to compare the mean scores of the students before and after using the intervention. The qualitative data collected from the structured questionnaire were analyzed using thematic analysis, where researchers familiarized themselves with the data, coded common responses, and identified potential themes that reflect students' experiences and perceptions in using the physical 3D model.

3. Results and Discussion

This section presents the finding from the data that were collected and carefully analyzed by the researchers to answers the research objectives.

1) Academic Performance of Grade 4 Charity Learners Before the Utilization of Intervention

Table 1: Academic Performance of Grade 4 Charity Learners Before Using the Water Cycle Physical 3D Model Based Interactive Game

Grading Scale	Frequency	Percentage	Description
90-100	3	10%	Outstanding
85-89	7	23%	Very Satisfactory
80-84	6	20%	Satisfactory
75-79	6	20%	Fairly Satisfactory
Below 75	8	27%	Failed
Total	30	100%	
Mean Performance	81.26%		

Table 1 presents the academic performance of Grade 4 learners prior to using the physical 3D model-based interactive game. It shows that 10% (3 students) achieved an "Outstanding" rating with scores ranging from 90 to 100, indicating that only a few students attained a high-performance level. The table also reveals that 23% of the class (7 students) received a "Very Satisfactory" rating with scores between 85 and 89, while another 20% (6 students) were rated "Satisfactory" with scores from 80 to 84. This suggests that a significant portion of the class demonstrated an average performance level. Additionally, 20% (6 students) were rated "Fairly Satisfactory" with scores between 75 and 79, and 27% (8 students) failed with scores below 75, representing the largest group in the distribution. The computed mean performance is 81.26%, reflecting a satisfactory level, indicating that the overall class average is passing. However, this also suggests that while some students are performing well, others are struggling with the content.

2) Academic Performance of Grade 4 Charity Learners After the Utilization of Intervention

Table 2: Academic Performance of Grade 4 Charity Learners After Using the Water Cycle Physical 3D Model Based Interactive Game

Grading Scale	Frequency	Percentage	Description
90-100	12	40%	Outstanding
85-89	5	17%	Very Satisfactory
80-84	13	43%	Satisfactory
75-79	0	0%	Fairly Satisfactory
Below 75	0	0%	Failed
Total	30	100%	
Mean Performance	86.87%		

Table 2 presents the academic performance of Grade 4 learners after using the physical 3D model-based interactive game. It shows that 40% of the class (12 students) achieved an "Outstanding" rating with scores ranging from 90 to 100. This marks a 30% increase from the 10% (3 students) who attained "Outstanding" before the intervention. On the other hand, 17% of the class (5 students) received a "Very Satisfactory" rating with scores between 85 and 89, indicating a decrease from the 23% who were rated "Very Satisfactory" prior to the intervention. Nevertheless, this still represents a substantial portion of students performing at a high level. Additionally, 43% of the class (13 students) scored between 80 and 84, earning a "Satisfactory" rating. Notably, no students scored in the "Fairly Satisfactory" (75–79) or "Failed" (below 75) categories, contrasting with the 20% and 27%, respectively, who were in these categories before the intervention. This suggests a significant improvement in students achieving acceptable performance levels. The computed mean performance after using the interactive game is 86.87%, reflecting a 5.61% increase from the pre intervention mean of 81.26%. This indicates a positive impact on students' performance following the use of the physical 3D model-based interactive game.

3) Comparison of Academic Performance of Grade 4 Charity Learners Before and After Using the Water Cycle Physical 3D Model Based Interactive Game

Table 3: Comparison Table: Before and After Using the Water Cycle Physical 3D Model Based Interactive Game

Grading Scale	Description	Before Intervention	After Intervention	Change
90-100	Outstanding	3 students (10%)	12 students (40%)	+30%
85-89	Very Satisfactory	7 students (23%)	5 students (17%)	-6%
80-84	Satisfactory	6 students (20%)	13 students (43%)	+23%
75-79	Fairly Satisfactory	6 students (20%)	0 students (0%)	-20%
Below 75	Failed	8 students (27%)	0 students (0%)	-27%
Mean Score		81.26%	86.87%	+5.61%

Table 3 presents a comparison of the academic performance of Grade 4 Charity learners before and after using the physical 3D model-based interactive game. The data reveals a significant improvement in student outcomes. The percentage of students achieving an "Outstanding" rating increased by 30%, from 10% (3 students) to 40% (12 students). Similarly,

the proportion of students rated "Satisfactory" (80–84) rose by 23%, from 20% (6 students) to 43% (13 students). Notably, students who previously fell into the "Fairly Satisfactory" (75–79) and "Failed" (below 75) categories were completely eliminated after the intervention, decreasing by 20% and 27%, respectively. The table also indicates a substantial increase in the mean performance score, rising by 5.61%, from 81.26% to 86.87%. These results suggest that the physical 3D model-based interactive game positively impacted students' understanding of the water cycle.

4) Significant Difference Between the Academic Performance Level of Grade 4 Charity Learners Before and After the Utilization of the Water Cycle Physical 3D Model Based Interactive Game

Table 4: Statistical Analysis of Academic Performance Changes Pre and Post-Intervention

Statistical Bases	Statistical Analysis
Degree of Freedom	29
Level of Confidence	5% (0.05)
T-critical Value	2.045
Computed t-value	13.61
P-value	$p < 0.001$
Decision on H	Rejected
Conclusion	Significant

Table 4 presents the results of the statistical analysis conducted to determine whether there is a significant difference in the academic performance of Grade 4 learners before and after using the physical 3D model. The t-test revealed a t-value of 13.61, which is greater than the critical t-value of 2.045, indicating a significant improvement in students' understanding of the water cycle following the intervention. Additionally, the p-value was found to be less than 0.001, which is below the significance level of 0.05, suggesting that the probability of obtaining such a result by chance is extremely low. Based on these findings, the researchers rejected the null hypothesis and concluded that there is a significant difference in students' academic performance before and after using the water cycle physical 3D model–based interactive game.

5) Thematic Analysis of Students' Perceptions in Using Physical 3D Model Based Interactive Game in Teaching the Water Cycle

Table 5: Themes, Descriptions, and Respondent Data on Students' Perceptions with Water Cycle Physical 3D Model Based Interactive Game

Themes	Description	Students' Responses
Positive Emotional Reactions	The students reacted positively to using the physical 3D model-based interactive game (happiness, excitement, confidence, pride, etc.), which helped them to be motivated in the learning process and enhanced engagement.	• "I felt happy because I understood the water cycle better." *("Nag-enjoy ako kay mas naintindihan ko an water cycle.")* • "I felt confident because I could see how it worked." *("Nagkamay'on ako san kumpiyansa kay naimod ko kun pano ini nag gagana.")* • "I felt excited because it was fun and different." *("Naexcite ako kay kakaiba siya nan makaruyag.")* • "I felt good because I could see everything clearly and it was fun to learn." *("Naruyag ako kay naiimod ko intero na proseso nan makaugma adalan.")* • "I felt proud of myself because I finished the game and remembered the water cycle." *("Proud ako sa sadiri ko kay natapos ko an uyag nan nadumdoman ko an proseso san water cycle.")* • "I felt curious because it looked cool." *("Nacurious ako kay bagan kakaiba siya.")* • "I felt happy because I learned better than just reading." *("Makaugma kay mas nakaaram ako didi kaysa mag basa lang.")* • "I felt excited because of the game." *("Naexcite ako dahil sa uyag.")* • "I felt happy because I finally understood the topic." *("Naugma ako kay naintindihan ko na an topic.")* • "I felt more interested in learning because I could follow each step in the game." *("Mas naging interesado ako mag adal kay nasusundan ko an kada step san water cycle.")*
Enhanced Understanding and Active Learning	The physical 3D model-based interactive game provides a clear visual representation of the stages of the water cycle, which helped students understand the water cycle better. The physical 3D model-based interactive game actively engages learners with the game and the water cycle model, fostering a hands-on learning approach.	• "I understood because the game explained the water cycle process very well." *("Naintindihan ko kay malinaw an paka explain san model sa water cycle.")* • "The game helped me see how each part of the cycle connects. I liked how the water moves around." *("Nakadanon an uyag na maimod ko kun pano konektado an kada stage. Nagustuhan ko kun pano naglibot an tubig.")* • "It showed me how the water cycle works step by step and I understood it better." *("Nakadanon siya a ako kay napapaimod niya an pagkakasunod sunod kaya naintindihan ko an water cycle sin mayad.")* • "The game helped me understand the stages because I could touch the water and see where it goes." *("Nakadanon siya sa ako na maintindihan an water cycle kay nakakaputan nan naiimod ko an tubig.")* • "I liked how the water moved in the game. It made learning fun." *("Nagustuhan ko*

		kun pano nagdadaloy an tubig sa model kaya makaugma mag adal.") • "It was interesting because the water moving around." *("Interesting siya kay naglilibot libot an tubig.")* • "I felt proud of myself because I finished the game and remembered the water cycle." *("Proud ako kay natapos ko an game nan naalala ko an water cycle.")* • "It helped me understand the stages because I could touch the water." *("Nakadanon siya sa ako na mas masabutan sin mayad an water cycle kay nakakaputan ko an tubig.")* • "I felt excited because I got to control the water." *(Naexcite ako kay nabubutangan ko tubig an model nan nacocontrol ko an tubig na ibubutang ko.")*
Increased Motivation	The physical 3D model-based interactive game made the students feel motivated and engaged because they engaged and interacted with the model, which contributed to their sustained interest in learning.	• "I felt more focused because I could interact with the game." *("Mas nakafocus ako kay nakauyag ako.")* • "I felt motivated to learn more." *("Naiinspire ako mag adal.")* • "I liked how the game had bright colors, it made me want to keep playing." *("Nagustuhan ko kay makulayon an 3D kaya sige ko an uyag.")* • "I felt challenged but motivated to learn more." *("Medyo mapagal para sa ako pero mas na challenge ako na mag adal pa san mayad.")*
Fun and Enjoyment	The interactive game nature and visual element of the intervention made the students' learning experience fun and enjoyable, more engaging, and less stressful.	• "I liked how the water moved in the game. It made learning fun." *("Nagustuhan ko an paghiwag san tubig kay mas napapaenjoy niyo an pag adal.")* • "I was excited because the model is colorful and can be touched." *(Naexcite ako kay nakakaputan siya nan makulayon.")* • "It was fun to see the rain and clouds in 3D, like they were right in front of me." *("Makaugma kay bagan totoo an uran nan dampog sa model.")* • "I felt like I was only playing that's why it was fun to learn." ("Feeling ko nag *uuyag lang ako kaya mas enjoy an pag adal.")* • "I felt good because I could see everything clearly and it was fun to learn." *("Maugma ako kay napaimod ko siya sin mayad kaya mas maka enjoy mag adal.")* • "I felt like I was playing a game, so it was fun to learn." *("Bagan lang ako nag uuyag kaya naka enjoy talaga mag adal.")*

Table 5: Presents the responses of the students and the themes that emerged from it.

Theme 1: Positive Emotional Reactions

This theme highlights the positive reactions of the students regarding the use of the intervention. The positive emotional reactions of the learners towards the physical 3D model-based interactive game increased their motivation and engagement in the learning process. As they interacted with the intervention, they felt positive emotions like happiness, excitement, curiosity, confidence, etc., which led them to become more actively engaged and eager to learn more about the topic. The positive emotions not only encouraged them to become motivated but also led to a better understanding of the concept. This only indicates that these positive reactions of the students helped them achieve better learning outcomes. This is related to a study conducted by Williams et al., (2013), which revealed that the positive emotions felt and experienced by students could lead to improved academic achievement. Such emotions can encourage them to participate in class discussions and attend classes. It also encouraged them to study and perform additional activities to enhance their understanding.

Theme 2: Enhanced Understanding and Active Learning

This theme emphasizes that the physical 3D model-based interactive game helped learners clearly understand the water cycle and its processes. The concise and clear visual representation of the water cycle presented by the physical 3D model enhanced students' understanding. They appreciated the way the model clearly showed them the connection of the stages of the water cycle, allowing for better comprehension. The visual elements and interactive nature of the game enhanced their comprehension of the concept. By transforming the complex and abstract process of the water cycle into a tangible and concrete experience, the intervention made the concept more accessible. This is related to a study conducted by Treagust (2008), which emphasized that multiple representations can develop deeper understanding of abstract concepts. With the visual representation provided by the physical 3D model, learners had a clear and concise understanding of the water cycle and its various stages. Additionally, the game's interactive nature encouraged active engagement, prompting learners to think critically and observe thoroughly in order to answer questions, earn points, and succeed in the game. In a study by Vlachopoulos et al. (2017), it was revealed that game and simulations can enhance student motivation and engagement leading to a more effective learning outcome. It provides the learners with the opportunity to interact, collaborate, and actively participate in a game-based and learner-centered environment. This suggests that the intervention not only offered a visual presentation but also improved students' comprehension of the water cycle. Since learners could directly interact with the model, encouraging a hands-on approach, it led to active learning. This active engagement allows for a better understanding of the topic than passive learning. A study by Linsey et al. (2006) demonstrated that incorporating hands-on activities into learning improve students' learning. This theme emphasizes the hands-on learning approach brought by the physical 3D model-based interactive game to the students. The active engagement of the students with the content and the model, such as touching the visual elements like the water, fosters a deeper understanding of the concept. The manipulation of elements in the model, backed up with game-based learning, helped the learners participate and be actively involved in the acquisition of their own knowledge. They observed and investigated the physical 3D model well in order to answer the questions and earn points to win the game. In a study conducted by Handayani et al., (2021) it showed that gamification positively influence active learning. Furthermore, it also revealed that awarding points can also improve students' performance.

Theme 3: Increased Motivation

The physical 3D model based interactive game increased students' motivation to learn. The visual and tangible elements of the model as well as the hands-on approach led students to engage more with the concept and stay focused. A study by Abdul et al. (2016) indicated that hands-on activities provide a more realistic learning experience and enhance cognitive understanding**.** The ability to be touched and manipulated, along with the colorful visuals, made the learners more interested and focused. They could engage and interact with the model directly, which could encourage them to explore the concept further. It also felt like they were only playing rather than attending a traditional lesson, which is why some of them were enjoying and at the same time learning. The colorful elements of the model also contributed to students' preference for using the physical 3D model-based interactive game in learning about the water cycle concept. It captures and holds their attention and interest. The enjoyment and fun they felt motivate them to learn more about the water cycle. In a study by Vlachopoulos et al. (2017), it was revealed that game and simulations can enhance student motivation

Theme 4: Fun and Enjoyment

This theme underscores the fun and enjoyable nature of the physical 3D model-based interactive game, which helped the learners understand the topic in an enjoyable way while learning. It helped them feel less stressed and simply motivated to learn. It transformed the learning experience into a meaningful, yet fun and engaging one. The game-like nature of the intervention provided the learners with the opportunity to not just engage and interact directly with the concept, but also with their peers. The colorful visual elements of the intervention made the students interested in learning. Visual elements like the rain and the clouds captured their interest, making them enjoy the learning process. The integration of game elements, which contrasts with the usual traditional method of teaching like lectures, helped them enjoy learning. They were not stressed, bored, or uninterested because, aside from the colorful visuals, they felt like they were playing instead of learning, leading them to like using the physical 3D model based interactive game for learning about the water cycle.

4. Conclusion

This study evaluates the impact of using a physical 3D model-based interactive game in teaching the water cycle to Grade 4 students, focusing not only on academic performance but also on their perceptions. The findings revealed that the students' mean test score increased from 81.26% before the intervention to 86.87% after its implementation. This indicates a significant improvement in academic performance, which is further supported by statistical analysis. The computed t-value of 13.61 exceeds the critical t-value of 2.045, and the p-value was found to be less than 0.001, which is below the significance level of 0.05. This suggests that the likelihood of achieving such results by chance is extremely low. Qualitative data also revealed positive student perceptions. The emerging themes included positive emotional reactions, enhanced understanding and active learning, increased motivation, and fun and enjoyment. These findings indicate that the physical 3D model-based interactive game is an effective tool for enhancing interest and students' understanding of the water cycle.

5. Recommendations

1) Schools and educators should consider incorporating physical 3D model-based interactive games into the teaching of complex scientific concepts like the water cycle. The significant improvement in academic performance and positive student perceptions suggest that these tools effectively promote active learning and conceptual understanding.
2) Organize training and workshops for teachers on how to effectively design, implement, and integrate interactive and tactile learning tools into their science curriculum. Empowering teachers with the skills to create engaging instructional materials can enhance teaching effectiveness.
3) Given the success in Grade 4 science, similar interactive learning strategies can be explored for other grade levels and subject areas where abstract or process-oriented concepts are taught, such as the solar system, plant life cycles, and physical processes in geography.
4) Use the 3D model-based games in group activities to foster collaboration and social interaction among students. This approach enhances not only cognitive learning but also interpersonal skills, engagement, and teamwork.

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