International Journal of Learning, Teaching and Educational Research
Vol. 25, No. 6, pp. 679-705, June 2026
https://doi.org/10.26803/ijlter.25.6.29
Received Apr 8, 2026; Revised May 29, 2026; Accepted Jun 3, 2026

Enhancing Geometry Achievement through Minecraft-Based Digital Game Learning: A Convergent Parallel Mixed-Methods Study

June Rey S. Sulatra*
Northern Iloilo State University
Estancia, Iloilo, Philippines

Shariz C. Publico
Sara National High School
Sara, Iloilo, Philippines

Abstract. The development of digital technologies has opened new avenues for improving teaching and learning in mathematics education. This study investigated the effect of digital game-based learning using Minecraft on Grade 9 learners' geometry achievement. A convergent parallel mixed-methods design was used involving 72 learners from a public secondary school in Iloilo, Philippines. The participants were divided into an experimental group (n=37) that received digital game-based instruction using Minecraft and a control group (n=35) that received non-game-based instruction. The learners' achievement was measured before and after a six-week intervention using a 30-item geometry achievement test. Quantitative analysis was performed using independent-samples and paired-samples t-tests, while qualitative data were gathered through semi-structured interviews with 32 selected learners from the experimental group and analyzed using thematic analysis. The results showed that both groups made progress; however, learners in the Minecraft-based instruction group significantly outperformed the other group on the post-test. Qualitative results showed that digital game-based instruction using Minecraft increased (1) learners' enjoyment in learning mathematics, (2) motivation and engagement, (3) creativity, (4) collaboration and communication, (5) afforded a challenging and engaging learning environment, and (6) enhanced critical thinking skills. The findings suggest that Minecraft-based digital game learning is an effective instructional approach for improving learners' geometry achievement and learning experiences. It is recommended that mathematics teachers integrate Minecraft-based digital game learning strategies to enhance learners' engagement and achievement in geometry.

Citation:
Sulatra, J, R, S., & Publico, S, C. (2026). Enhancing Geometry Achievement through Minecraft-Based Digital Game Learning: A Convergent Parallel Mixed-Methods Study. *International Journal of Learning, Teaching and Educational Research*, *25*(6), 679–705. https://doi.org/10.26803/ijlter.25.6.29

*Corresponding author: June Rey S. Sulatra; *junereysulatra@gmail.com*

Keywords: digital game-based learning; geometry learning; mathematics achievement; Minecraft; mixed-methods research.

1. Introduction

Digital game-based learning is a pedagogical approach that has recently been in the limelight and entails the incorporation of gaming elements into learning settings to foster motivation and engagement among learners (Al-Azawi et al., 2016; Plass et al., 2015; Trybus, 2015). Previous research has demonstrated that game-based learning can foster critical thinking, collaboration, and problem-solving skills and increase learners' interest in academic subjects (Hartt et al., 2020; Qian & Clark, 2016; Sung & Hwang, 2018). In contrast to traditional lecture-based instruction, digital game environments can provide students with opportunities for interactive learning that invite them to actively engage in and explore educational content through experiential learning.

With its open-ended design, Minecraft has proved one of the few promising educational tools among digital learning platforms Minecraft is a sandbox video game where players build structures and explore virtual worlds using textured cubes (Baek et al., 2020; Bos et al., 2014; Cipollone et al., 2014). In this sense, the platform has increasingly found its place in educational contexts, as it promotes creativity, collaboration, and experimentation among learners (Andersen & Rustad, 2022; Karsenti & Bugmann, 2018; Niemeyer & Gerber, 2015). Although previous studies have identified Minecraft as a useful tool for promoting collaboration and creativity in classroom instruction (Karsenti & Bugmann, 2018), limited studies have examined its effect on learners' geometry achievement using a mixed-methods approach, particularly in the context of secondary mathematics education in the Philippines.

Despite reforms and curriculum developments, mathematics achievement remains a serious issue across many educational systems and international assessments, such as the Program for International Student Assessment, have shown that students from a number of countries, including the Philippines, perform relatively poorly in mathematics (Capate & Lapinid, 2015; Organization for Economic Co-operation and Development, 2019; Pandey, 2017). Such results emphasize the importance of exploratory pedagogies that enhance students' insight into the connections between concepts and augment their learning in mathematics.

Thus, this study examined the effect of digital game-based learning through Minecraft on the geometry achievement of Grade 9 learners. Specifically, it sought to answer the following research questions:

1. Is there a significant difference in the pre-test mathematics achievement between learners exposed to Minecraft-based digital game learning and those exposed to non-game-based instruction?
2. Is there a significant difference between the pre-test and post-test mathematics achievement of learners in both the Minecraft-based and non-game-based instruction groups?

3. Is there a significant difference in the post-test mathematics achievement between learners exposed to Minecraft-based digital game learning and those exposed to non-game-based instruction?
4. What are the learners' experiences in using Minecraft-based digital game learning in geometry?

2. Methodology

2.1 Research Design

The study used a convergent parallel mixed-methods design to compare the effectiveness of digital game-based learning in Minecraft on students' geometry achievement. This design was considered appropriate because it allowed the researchers to obtain both quantitative evidence of learners' achievement and qualitative insights into learners' experiences during the intervention. In this design, quantitative and qualitative data are collected simultaneously, analyzed separately, and then combined for interpretation to present a holistic understanding of the research problem (Creswell, 2014; Creswell & Plano Clark, 2017).

The quantitative part focused on comparing learners' Mathematics achievement between pre-test and post-test scores before and after the implementation of the instructional intervention, while the qualitative part explored learners' experiences throughout the implementation of Minecraft-based learning activities. This approach enabled triangulation of the findings and reinforced the validity of the results.

2.2 Participants and Research Setting

The study participants involved 72 Grade 9 students from one of the secondary schools in the 5th District of Iloilo, Philippines, during the school year 2024–2025. The study used two intact classes, with one serving as the experimental group (n = 37) exposed to digital game-based learning through Minecraft, and the other as the control group (n = 35) exposed to non-game-based instruction. Group assignments were based on existing class sections, as random assignment of individual learners was not feasible in the natural classroom setting.

The study employed a non-random, purposive sampling approach, commonly used in educational research, to preserve the natural classroom environment during the implementation of interventions (Fraenkel & Wallen, 1990). Although the groups differed slightly in size, the difference was minimal and did not substantially affect the conduct of the intervention. To minimize threats to validity, both groups were provided with the same learning objectives, instructional duration, assessment procedures, and learning topics throughout the study. However, since random assignment was not employed, the study may still be subject to selection bias and limited control over pre-existing differences and learners' prior technological experiences.

2.3 Research Instrument

Mathematics achievement was assessed using a 30-item, multiple-choice geometry test composed of topics from the Grade 9 curriculum guide, including

quadrilaterals, properties of quadrilaterals, and similarity of figures and triangles. The instrument was developed based on the Most Essential Learning Competencies (MELCs) from the Department of Education.

For content validity, the test was assessed by five experts, four mathematics teachers and one language expert, so as to ensure that the test items were sufficiently clear and aligned to the learning competencies. To assess the instrument's reliability, a pilot test was conducted with a group of learners who did not participate in the study, yielding a Cronbach's alpha coefficient of 0.771, suggesting an acceptable level of internal consistency for research instruments in educational contexts.

2.4 Data Collection Procedure

Data collection was conducted in three phases: pre-experimental, experimental, and post-experimental.

Pre-Experimental Phase. Before the intervention, approval to conduct the study was obtained from school authorities, and participants and their parents or legal guardians provided informed consent. Ethical issues were addressed to ensure ethicality, uninfluenced participation, and privacy. In this phase, a pre-test was administered to both groups to assess learners' prior knowledge and baseline understanding of geometry concepts before the instructional intervention.

Experimental Phase. During the experimental phase, the instructional intervention was implemented for six weeks. In the experimental group, learners were introduced to a game-based digital activity in Minecraft, in which they built geometric shapes within the game world to illustrate mathematical concepts. Conversely, the control group was given regular instruction with teacher-centered discussion, problem-solving tasks, and guided practice. Both groups received the same course learning objectives, instructional time, and assessment tasks, with the primary variable being the instructional strategy. Qualitative data were collected throughout the intervention through classroom observations and informal interviews with selected learners from the experimental group to document their experiences in using Minecraft-based learning. Classroom observations focused on learners' participation, engagement, collaboration, and interactions during the activities, while interview responses were transcribed, coded, and analyzed thematically to identify recurring patterns and themes.

Post-Experimental Phase. The same achievement test instrument was used as a post-test for both groups after the intervention, the aim being to assess the effect of the intervention on learners' mathematics achievement.

2.5 Data Analysis

The Statistical Package for the Social Sciences (SPSS) software was used for statistical data analysis. Prior to conducting the inferential tests, assumptions of normality and homogeneity of variance were examined to determine the appropriateness of the statistical procedures. To compare the pre-test and post-test scores of the experimental and control groups, an independent-samples t-test was conducted while a paired-samples t-test was used to examine within-group

differences in pre- and post-test scores. All statistical analyses were performed at a 0.05 level of significance.

Thematic analysis was used to analyze qualitative data, involving coding and grouping patterns in learners' responses. To ensure trustworthiness of the qualitative findings, triangulation through classroom observations and interviews was employed, while recurring themes were carefully reviewed and validated based on the consistency of participants' responses.

2.6. Ethical Considerations

Ethical standards were strictly observed throughout the study. Learners' participation was voluntary and informed consent was obtained from both learners and their parents or guardians. Furthermore, learners were assured that their responses would remain confidential and would be used solely for research purposes. To protect participants' identities, pseudonyms were used during data analysis and reporting of results. All collected data were stored securely and handled in accordance with ethical research guidelines.

3. Results and Findings

3.1 Quantitative Findings

3.1.1 Difference in Pre-Test Achievement in Geometry

Table 1 presents the difference in pre-test mathematics achievement in geometry of learners before exposure to digital game-based learning using Minecraft and non-game-based learning.

Table 1: Difference in Pre-Test Mathematics Achievement in Geometry

Group	Mean	SD	MD	df	t	p	Eta-squared
Experimental	9.57	2.66	0.11	70	-0.17	0.86	0.0004
Control	9.46	2.80					

The result shows that before exposure to digital game-based learning using Minecraft ($M = 9.57$, $SD = 2.66$) and non-game-based learning ($M = 9.46$, $SD = 2.80$), the learners did not differ significantly in their pre-test achievement, $t(70) = -0.17$, $p = .86$. The mean difference ($MD = 0.11$) was minimal and the computed effect size ($\eta^2 = 0.0004$) negligible, suggesting that the difference between the two groups was practically not significant.

This result indicates that both groups had comparable prior knowledge of geometry before the intervention. Establishing baseline equivalence is essential in experimental research, as it ensures that any observed differences in post-test performance can be attributed to the instructional intervention rather than pre-existing differences between groups (Creswell & Plano Clark, 2017; Fraenkel et al., 2012).

3.1.2 Difference between Pre-Test and Post-Test Achievement in Geometry

Table 2 presents the difference between pre-test and post-test mathematics achievement in geometry for learners exposed to digital game-based learning using Minecraft and to non-game-based learning.

Table 2: Difference Between Pre-Test and Post-Test Achievement in Geometry

Group	Pre-test Mean (SD)	Post-test Mean (SD)	MD	df	t	p	Eta-squared
Experimental	9.57 (2.66)	24.65 (5.02)	15.08	36	22.68	<.001	0.93
Control	9.46 (2.80)	17.46 (2.67)	8.00	34	15.19	<.001	0.87

Results show a statistically significant improvement in learners' mathematics achievement when exposed to digital game-based learning using Minecraft. The mean score increased from M = 9.57, SD = 2.66 in the pre-test to M = 24.65, SD = 5.02 in the post-test, resulting in a mean gain of MD = 15.08. This improvement was found to be statistically significant ($t(36) = 22.68$, $p < .001$), with a very large effect size ($\eta^2 = 0.93$), indicating a substantial impact of the intervention on students' learning. The very large effect size suggests that Minecraft-based learning strongly influenced learners' geometry achievement, possibly due to its interactive, immersive, and collaborative nature, which promoted active engagement, concept visualization, and meaningful learning experiences.

Similarly, learners exposed to non-game-based learning also demonstrated a significant improvement in mathematics achievement. The mean score increased from M = 9.46, SD = 2.80 in the pre-test to M = 17.46, SD = 2.67 in the post-test, with a mean gain of MD = 8.00. The improvement was statistically significant, ($t(34) = 15.19$, $p < .001$), with a large effect size ($\eta^2 = 0.87$), indicating that regular classroom instruction also contributed substantially to learners' understanding of geometry concepts through structured discussions, guided practice, and problem-solving activities.

These findings indicate that both instructional approaches contributed to improvements in learners' mathematics achievement in geometry. Instructional interventions that provide structured learning experiences are known to enhance students' conceptual understanding and performance (Bransford et al., 2000; Hiebert & Grouws, 2007).

3.1.3 Difference in Post-Test Achievement in Geometry

Table 3 presents the difference in post-test mathematics achievement in geometry between learners exposed to digital game-based learning using Minecraft and non-game-based learning.

Table 3: Difference in Post-Test Achievement in Geometry

Group	Mean	SD	MD	df	t	p	Eta-squared
Experimental	24.65	5.02	7.19	70	-7.53	<.001	0.45
Control	17.46	2.67					

The results revealed a statistically significant difference in post-test achievement between learners exposed to digital game-based learning using Minecraft (M = 24.65, SD = 5.02) and those exposed to non-game-based learning (M = 17.46, SD = 2.67), with $t(70) = -7.53$, $p < .001$. The mean difference (MD = 7.19) indicates a substantial, consistent difference. The effect size ($\eta^2 = 0.45$) is large, suggesting that the instructional intervention had a strong practical impact on students' mathematics achievement. The large effect size further implies that Minecraft-

based learning effectively enhanced learners' understanding of geometry concepts, possibly through interactive visualization, active participation, collaboration, and experiential learning opportunities provided within the digital environment.

This finding indicates that digital game-based learning using Minecraft is more effective than traditional instruction in improving learners' geometry achievement. The results support previous research showing that digital game-based learning enhances academic performance by fostering engagement, collaboration, and higher-order thinking skills (Qian & Clark, 2016; Sung & Hwang, 2018). Additionally, interactive environments such as Minecraft allow learners to visualize and construct mathematical concepts, which strengthens conceptual understanding (Baek et al., 2020; Bos et al., 2014).

3.2 Qualitative Findings

The qualitative data revealed several themes describing learners' experiences in using Minecraft as a digital game-based learning tool in geometry. The major themes that emerged include: (1) enjoyed learning mathematics, (2) excited and motivated, (3) developed creativity, (4) promoted collaboration and communication, (5) experienced a challenging and engaging environment, and (6) enhanced critical thinking skills.

3.2.1 Theme 1: Enjoyed Learning Mathematics

Game-based learning can enhance student learning by fostering a sense of enjoyment (Pho & Dinscore, 2015). It also offers the possibility of higher student participation since the incorporation of pleasant or entertaining gaming elements into instructional content makes it more appealing (Al-Azawi et al., 2016). Lipnevich et al. (2011) noted a relationship between math success and happiness. Game-based learning has become a cutting-edge educational strategy that can raise student engagement, motivation, and enjoyment (Hartt et al., 2020).

Students reported that they really appreciated having to reconstruct while playing Minecraft in class, which they found to be "extremely" enjoyable (Karsenti & Bugmann, 2018). Students also reported greater enjoyment while learning through Minecraft-based digital game-based learning since anything they want that brings them happiness can be built. Students were found to experience varying levels of satisfaction with the game when given time to play.

This is supported by the statement of Student 1 that

> "*Nalingaw gid ko ya maghampang Minecraft labi nagid mag-ubra sang shapes*" [I really enjoyed playing Minecraft especially in making shapes].

Student 2 also added

> "*Ako man, namian ko maghimo sang lain lain nga shapes kag butangan design*" [Me too, I like making different shapes with added designs].

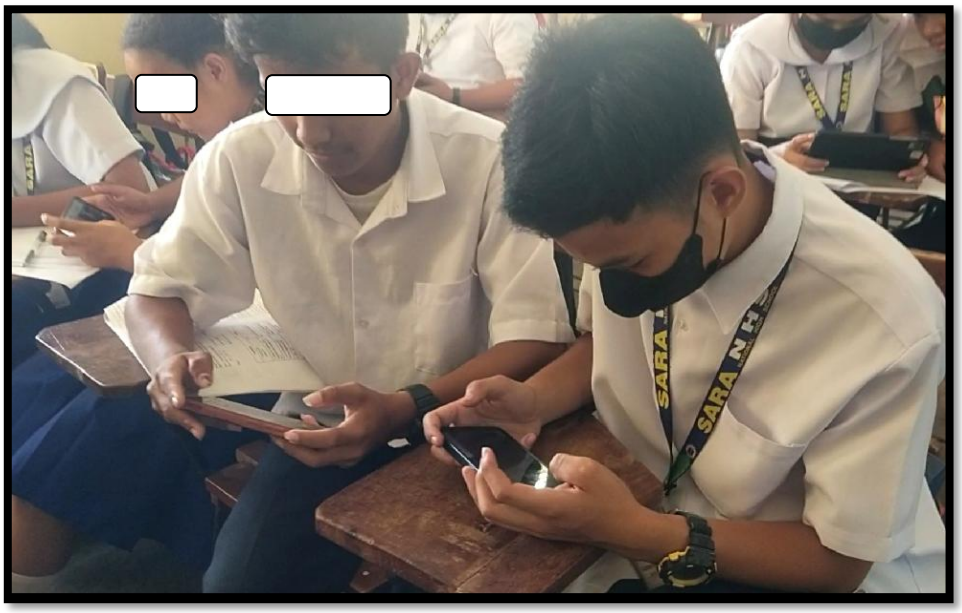

Figure 1: Student 1 and Student 2 enjoying Minecraft activity

In making trapezoids, Student 3 stated that

> *"Nalipay ako sang nag-ubra ako sang trapezoids sa Minecraft kay kanamisang ubra ko"* [In making trapezoids in Minecraft gave me happiness because I made beautiful trapezoids]

In support, Student 4 said

> *"Oo kasadya, tapos pagusto ka kung paano mo ubrahon and trapezoid nga gusto mo"* [Yes, it's fun, you can decide how to create the trapezoid you want].

Figure 2: Student 3 and Student 4 outputs in trapezoids

Also, Student 5 stated that

> *"Nalipay gd ako sang ginpagwa sa TV ang akun ubra nga trapezoid with midline kag gincheck kung insakto ang theorem lalo na insakto gali"*[I

like the most when my work of trapezoid with midline was flashed in the TV screen to check if it proves the theorem, especially it turned out right].

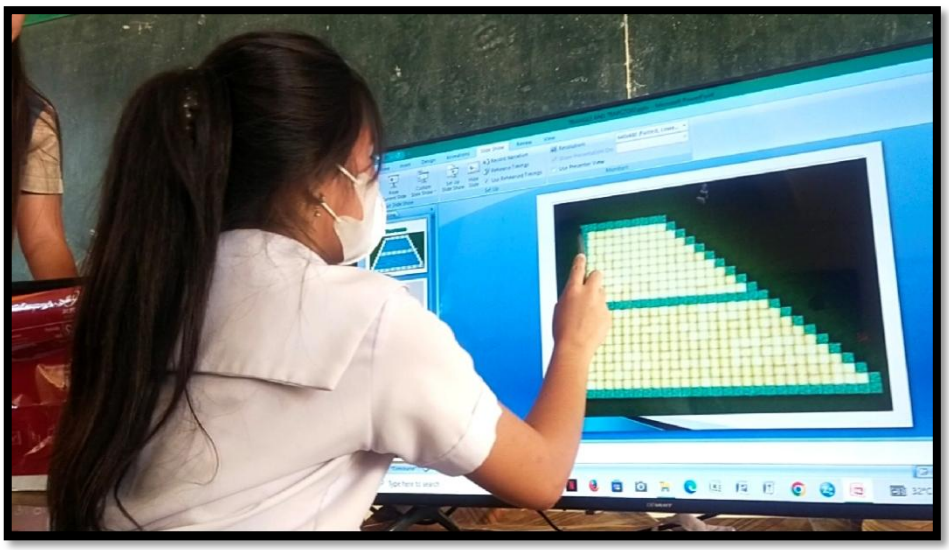

Figure 3: Student 5 proving the theorem in the midline of the trapezoid with her output in Minecraft

While having a "Minecraft Day," Student 6 said

"Mahampang na lng ta bala Minecraft ka da adlaw ma'am" [Ma'am, can we play Minecraft every day?].

Student 7 also added

"Bisan maghampang pa kita Minecraft bilog nga adlaw okay gid sa amun" [Yes ma'am, even we play Minecraft all day, it's super okay with us].

Figure 4: Student 6 and Student 7 enjoying playing Minecraft

In making similar triangles in Minecraft, Student 8 said

> *"Nalingaw ako mag-ubra sang similar triagles, bisan mauti nga isipon gid ang blocks kay kacute lantawon pagkatapos"* [I enjoy making similar triangles, even you need to count every number of blocks, it's cute after making it].

Student 9 added

> *"Ako man nalingaw, lalo na pagusto ka pili kung ano gamiton mo nga materials basta mapakita mo nga proportion sila, similar na ina"* [Me too, I enjoyed, especially you can choose what materials you want to use as long as they are proportionate, they are similar].

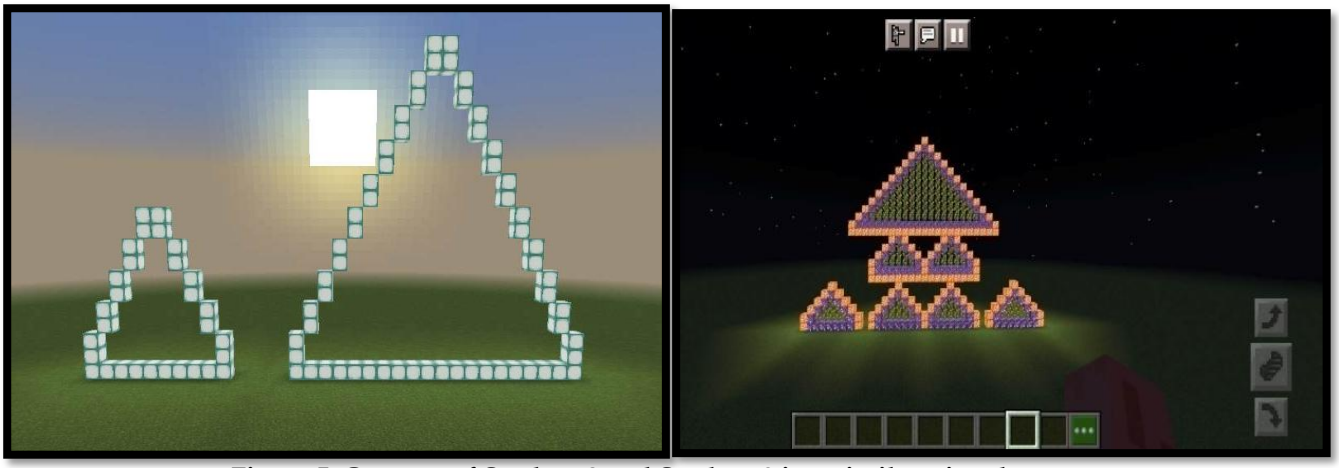

Figure 5: Outputs of Student 8 and Student 9 in a similar triangle

3.2.2 Theme 2: Learners were Excited and Motivated

Both the motivating features of employing mobile technology for learning and the motivational characteristics of learners can be improved (Ciampa, 2013). With growing interest in digital media and games, it supports Qian and Clark's (2016) claim that using games for learning has advantages for the development of 21st-century abilities. Game-based learning is a fun cutting-edge educational approach that can increase student engagement and motivation (Hartt et al., 2020). Sung and Hwang (2018) found that educational video games can improve students' academic performance and motivation to learn and it has been demonstrated that instructional strategies can improve student motivation and learning outcomes by using game-based and mobile learning applications (Chang & Hwang, 2018).

Minecraft, as implemented in classrooms, appears to effectively boost student interest and drive to learn while participating in regular classroom activities (Baek, 2020). Many students expressed excitement when attending class since Minecraft was treated as a special activity. As such, playing Minecraft at school has been found to have a significant impact on student motivation (Karsenti & Bugmann, 2018). On the first day of intervention, all learners were excited to install the Minecraft application.

Student 10 said

> *"Nag-eskwela gid ko bla ma'am kay mainstall subong Minecraft"* [I go

to school today ma'am, because we will install Minecraft].

Student 11 added
"Gani ma'am kami gani ya nag-install na una" [Yes ma'am, in fact we have already installed it in our cell phones].

Figure 6: Learners installing Minecraft and beginning to explore the game

Learners were all excited in class and were always present in every class discussion.

Student 12 said
"maeskwela na ko permi kay gusto ko maghampang Minecraft" [I'll always attend to class because I want to play Minecraft]

Student 13 added
"Gusto ko gani math na permi nga class kay para mahampang na Minecraft" [I always want to have a math class to play Minecraft].

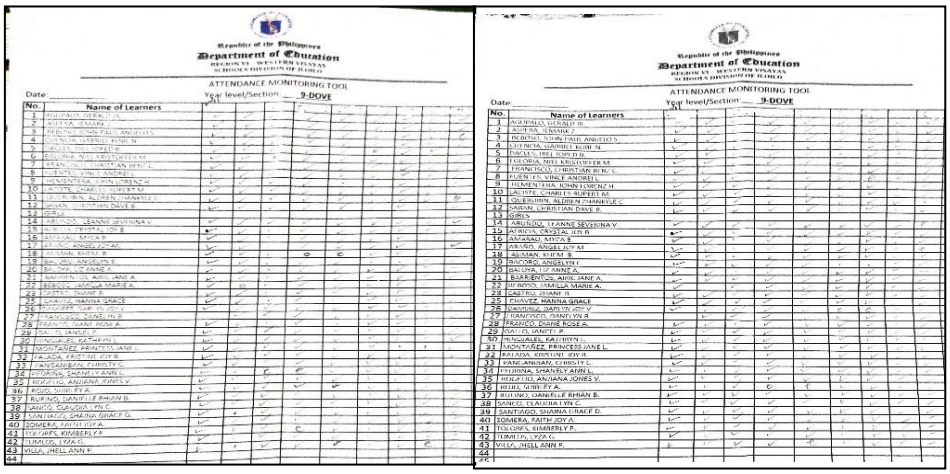

Figure 7: Learners' daily attendance

After each assigned task has to be completed within the given time, and learners then need to take a screenshot of their work and send it to the Messenger group chat for review. Learners were also motivated and could achieve all required outputs.

Student 14 said

> *"Basta ma'am ako una permi pasa sang output sa Messenger kag sakto tanan ko nga ubra"* [I'm the one who submitted the output first in Messenger and it's all correct].

Student 15 added

> *"Kompleto akun outputs ya ma'am halin sang umpisa"* [Ma'am, my outputs are complete from the beginning].

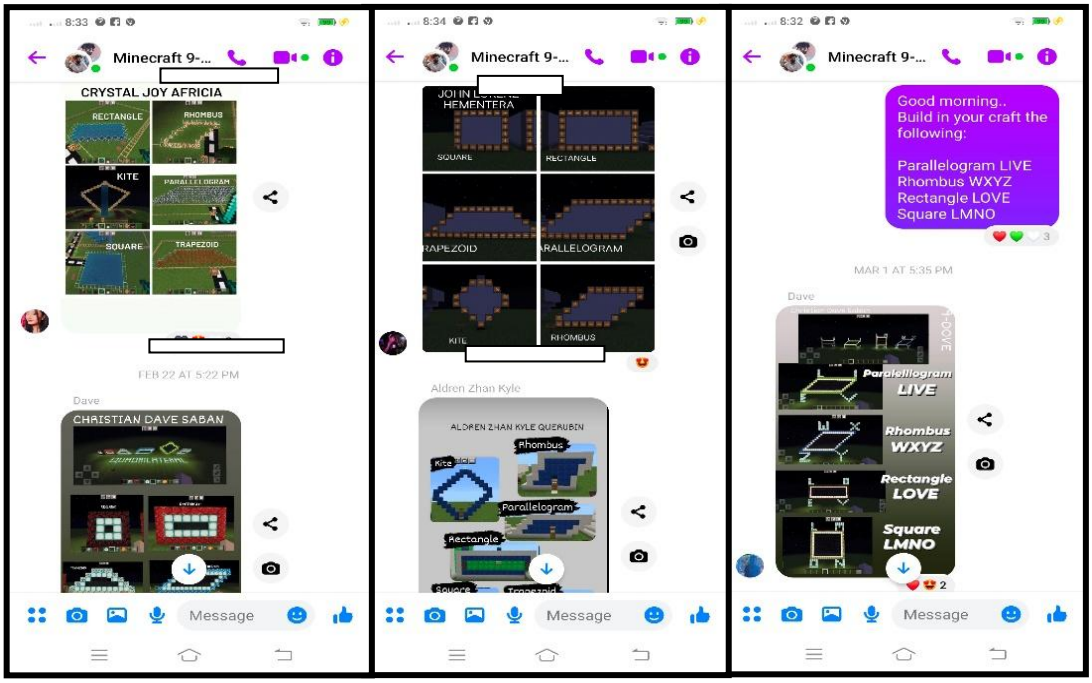

Figure 8: Group chat used as a channel for their outputs

During the first and second weeks of intervention, Student 16 was the only one who did not submit outputs. It was also observed that she did not participate in the class discussion. In the third week of intervention, it was found that she was not even playing Minecraft. Therefore, the researcher encouraged her to at least try playing the game. Student 16 tried to make her outputs in the third week of intervention, and after one hour of playing the game, she said

> *"naexcite ko maghampang Minecraft"* [Playing Minecraft is exciting].

Student 16 finished her output in the third week of intervention, up to the last week. It was also observed that Student 16 participated in the class discussion. In fact, 16 students said that she was excited and motivated in the class every day and was looking forward to playing Minecraft.

Figure 9: Student 16 doing Minecraft activities

3.2.3 Theme 3: Learners Developed Creativity

In spending time with learners and showing them the structures and environments they have created in Minecraft, it can be seen how beneficial it is for fostering creativity. Giving them a creative outlet allows them to explore new concepts and makes them feel as though they are contributing something worthwhile (Ontario Ministry of Education, 2016). Cipollone (2014) explained that the open-ended nature of the game allows players to experiment with different notions of characters and plot that are not restricted to actual materials, and Minecraft may be used to express creativity in ways that would ordinarily be far more expensive.

In a 6-week intervention, learners played Minecraft and completed the assigned task to develop and express their creativity. They used different tools and made a creative representation of the figures. They were given the chance to explore the digital game to create a better output from the available materials.

Student 11 said

> *"Ang pag-explore sang Minecraft wala sang katapusan,gani wala man sang katapusan ang pwedi mo mahimo diri"* [Exploring Minecraft is endless and so you can do endless activity in Minecraft].

Student 17 also added

> *"Using different materials in Minecraft I can make everything I imagined".*

Each learner created a different representation of a figure in their craft.

Figure 10: Creative outputs of Student 11 and Student 17

Building representations of figures in the world of Minecraft is a challenge among learners; in fact, " every time they were told to build something, many of them asked "how to do it" and "how to do that. In building a Rhombus, learners were a bit challenged, but as they continued exploring the game, they eventually discovered the technique, As Student 18 said

> *"Sang lumpias nabudlayan ako maghimo sang rhombus Pero sang darayon ko nag explore nakuha ko ang technique kung piano ubrahon"* [Building a rhombus is challenging for me at first but, as I continue exploring the game, I got some technique on how to do it].

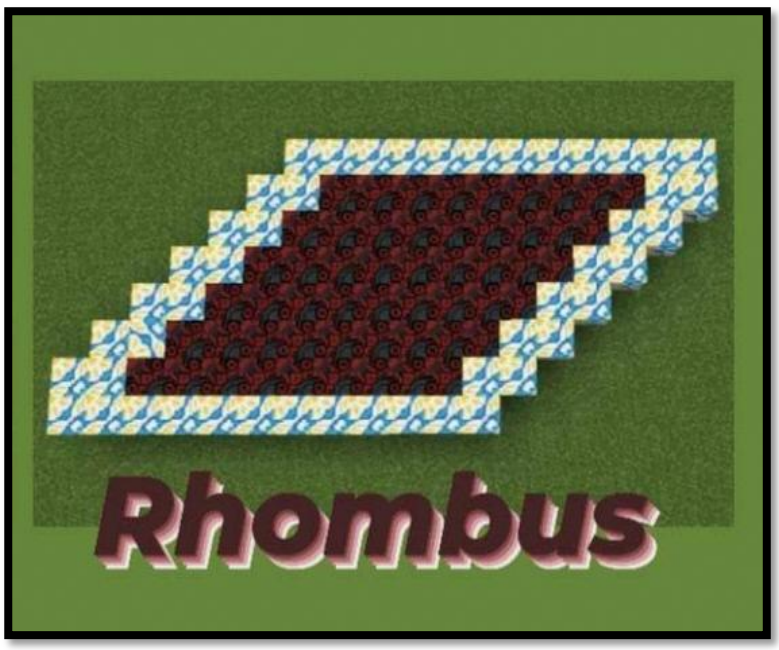

Figure 11: Student 18's output of rhombus

Every week, learners' creativity was developed in making different outputs in Minecraft. Each learner had a unique representation of a figure.
Student 6 explained that

> *"Sa Minecraft magamit ko ang akun abilidad para mapakita ang ara sa akun pinsar"* [Through Minecraft I can use my skills to show what's in my mind].

Student 18 added

> *"Ang Ginebra ko sa Minecraft ginapana-aw ko na nga daan"* [I can figure out things to be done in Minecraft].

Figure 12: Student 6 and Student 18's creative representation of figures

To give value for the creative skills of the learners in Minecraft in a 6-week intervention, the researchers organized a contest for "Most Creative Craft in Minecraft." Every learner made a creative craft with all the figures discussed (Parallelogram, Rectangle, Rhombus, Square, Trapezoid, and Triangle). They all created unique and creative crafts, and Student 22 won first place, Student 19 won second place, and Student 11 won third place.

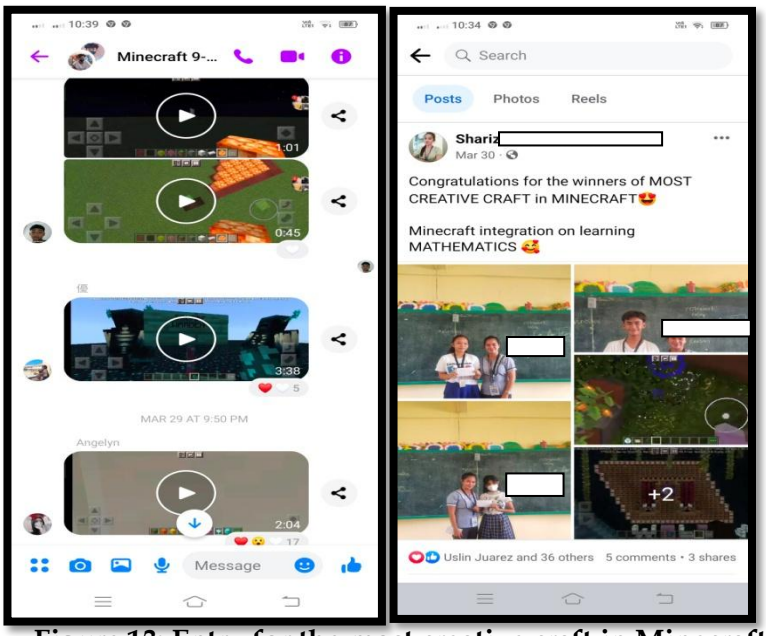

Figure 13: Entry for the most creative craft in Minecraft

3.2.4 Theme 4: Promoted Collaboration and Communication

According to Ciampa (2013), students who participated in cooperative learning groups got along better and worked more effectively with one another. The effects of mobile game-based learning on cooperation and communication have been well-documented (Chang & Hwang, 2018). A collaborative knowledge-construction technique was incorporated into a computer game to boost students' information sharing and organization while participating in game-based learning (Sung & Hwang, 2018).

By using common Minecraft languages, settings, tools, and artifacts, students were able to interact with one another and discuss what they had in common. As ideas, understandings, and linguistic abilities developed through collaboration and information searches, casual chat among Minecraft players also appeared to support informal learning processes. However, there are benefits to information gathering and dissemination that go beyond language learning; an additional catalyst for pupils' language acquisition in Minecraft was encouraging collaboration (Baek, 2020).

Learners' shared understanding of how to develop and construct a shared reality, as well as their ability to communicate in a "chat" environment, enabling them to cooperate successfully on a range of joint projects. In this approach, students sought out meaningful partnerships on their own. Collaborative learning settings in gaming communities can provide useful structures for studying how learners operate in informal learning contexts. Minecraft video artists are an amazing example of a collaborative learning community that works closely together to support one another in the learning process (Niemeyer & Gerber, 2015). One reason students appreciate Minecraft is that it allows them to collaborate; working in groups, learning from and contributing to others' learning, and using social media are all important aspects of cooperation in the 21st century.

According to Lane and Yi (2017), Minecraft is a naturally cooperative game in which teams can often accomplish more together than they could on their own. Students were familiar with Minecraft and had played with their friends locally, but this was an entirely new experience for them. Students met and worked with students from diverse cultures, and they were successful in collaborating. Their shared understanding of how to design and construct a shared reality, along with thorough coaching from teachers on communicating in a "chat only" environment, enabled them to work successfully on a range of joint projects.

In playing Minecraft, they could not only play a solo player but also in pairs or as multiple player, which promoted collaboration and communication. Student 20, Student 21 and Student 22 stated they played as a team to accomplish a task quickly and accurately through collaboration.

Jamila said

"Playing as a team makes the task accomplished quickly and accurately."

Student 20 also added that

"Playing in a multiple-player mode can accomplish more."

They played in one world but on separate mobile devices through "mobile hotspot."

Figure 14: Student 21, Student 20, and Student 22 playing Minecraft in a shared world

Sharing one Minecraft world and accomplishing a certain goal together promoted communication skills. A team cannot accomplish a task successfully without proper communication, and, in playing Minecraft as a team to build figures, as Student 22, Student 20, and Student 21 did during the "Minecraft activity" where tthey communicated in-game via "Chat and command" to discuss how to finish their task.

Student 21 stated that

"Communicating inside the game is necessary to have a better output."

Jamila added

> *"Collaboration and proper communication help the group accomplish the task successfully."*

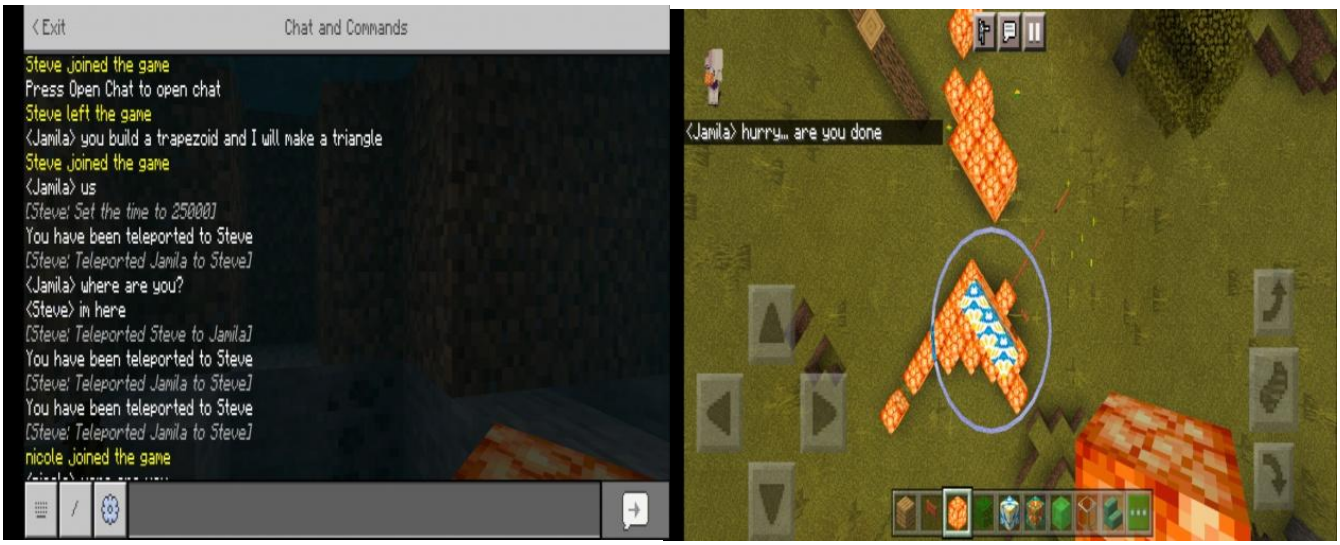

Figure 15: Students 21, 20, and 22 communicated within the game.

Student 23 stated,

> *"Mas nami gid maghampang Minecraft nga team kay makabuligay kamu kag pwedi kamu kaestorya sa chat man ukon sa personal"* [It's good to play Minecraft as a team because you can help each other and you can talk in chat or even personal].

Student 24 also supported by saying

> *"Pwedi nga tungaon ang ubra sa grupo para madasig ang ubra basta ginapartida lang sang insakto"* [You can divide the work in a team as long as you divide it equally].

Figure 16: Student 23 and Student 24 playing in a multiple player mode

3.2.5 Theme 5: Challenging and Engaging Environment

Minecraft has been recognized as an engaging platform that naturally draws learners into exploring virtual environments. Its creative mode, in particular, supports the generation and development of gameplay ideas. However, facilitating learners' engagement with more abstract or conceptual learning tasks within the game can present challenges. In this regard, the use of modifications (mods) becomes a valuable approach, as it allows educators to design experiences that better align with specific learning objectives.

Baek et al. (2020) emphasized that the initial and intended goal of Minecraft was to encourage building, and this type of application allowed pupils to be independent and participate in creating, and students can be engaged by Minecraft-based activities in unexpected ways. Playing Minecraft with specific goals created a demanding and engaging atmosphere for students. They created a wide range of shapes, including quadrilaterals, parallelograms, rhombuses, squares, rectangles, trapezoids, and triangles. They were involved in an environment where they could individually create a figure using their favorite materials while building different representations of the figure.

Using Minecraft as a tool for building mathematical figures to be used in the discussion keeps students engaged in a challenging environment, but after engaging in an activity and accomplishing a goal, learners experience satisfaction and fulfillment, as seen in Student 25 and Student 26. Student 25 said

> "*Putting names (label) on the figures challenged me, but it's satisfying after exploring and finally finding a strategy on how to do it*."

Student 26 also added

> "*Sang lumpias kabudlay mag-butang sang letters Kada vertex pero dapat Gali dakuon mo nga figure para malatang ka letters*" [At first, I struggled with putting letters in every vertex, but you just have to make the figure bigger to put letters in it].

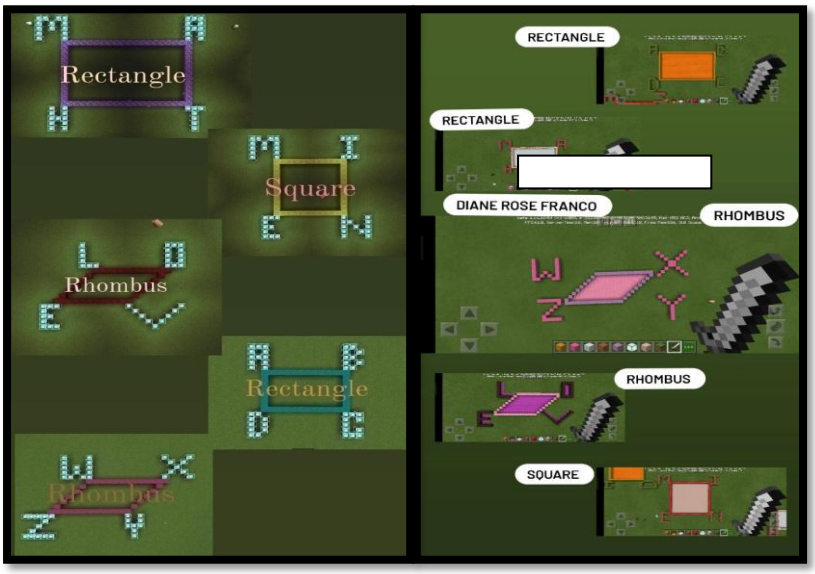

Figure 17: Student 25 and Student 26 output

In the lesson on proving the midline theorem, Student 27 said that

> *"Proving the midline theorem of a triangle in Minecraft is quite challenging yet fulfilling after doing it perfectly."*

Student 28 added

> *"Kauti mag-isip isip sang blocks para makita ang midpoint kag makaubra sang midline, dapat gali isipon mo nga daad samtang nagabutang ka pa lang"* [It is difficult to count the blocks to locate the midpoint in order to build a midline. You should count it as you put it together].

Student 29 also said

> *"Sakit as mata mag-prove sang midline theorem sang triangle keg trapezoid, mapili ka dap at sang blocks nga kitaon mag-isip"* [Proving the midline theorem of triangle and trapezoid is painful in the eyes, you must choose the blocks that to visible to count].

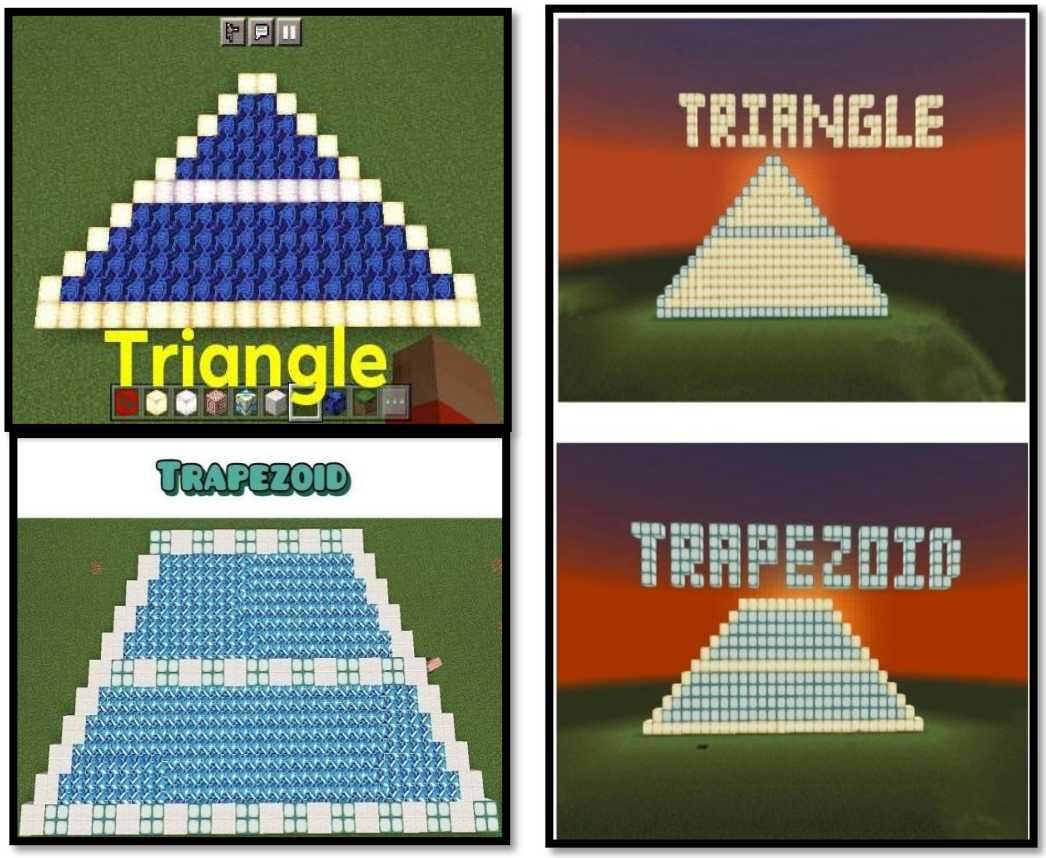

Figure 18: Outputs of Student 27, Student 28, and Student 29 on proving the midline theorem of the triangle and the trapezoid

3.2.6 Theme 6: Enabled Learners' Critical Thinking

Minecraft can be used to build experiences that are difficult to design otherwise and should address real-world problems that may not always have simple solutions (Drake, 2014). Higher-order thinking abilities, such as "the capacity to think logically and to solve ill-defined problems" and "the ability to formulate

creative solutions and take action," are required by digital tools like Minecraft (Ontario Ministry of Education, 2016).

Building figures such as quadrilaterals and triangles using various materials enabled learners to engage in critical thinking. They build figures with measurements based on the number of materials (blocks, mobs, etc.). Being able to accurately represent a figure enables learners to think critically, as Student 30 said,

> *"To be able to make a correct representation of a figure, I have to give focus and understand the lesson well."*

Student 28 added that

> *"Building quadrilaterals based on its characteristics is hard for me, but I made it because I focused on making it."*

Figure 19: Student 30 and Student 28's representation of quadrilaterals

Building figures that prove theorems challenges them and improves their critical thinking. Student 31 said,

> *"Proving theorems through Minecraft enables me to think critically just to make a correct representation."*

Student 32 also noted that

> *"Minecraft is helpful in the discussion since it helped me understand the topic well, especially the proving part that made me think deeply."*

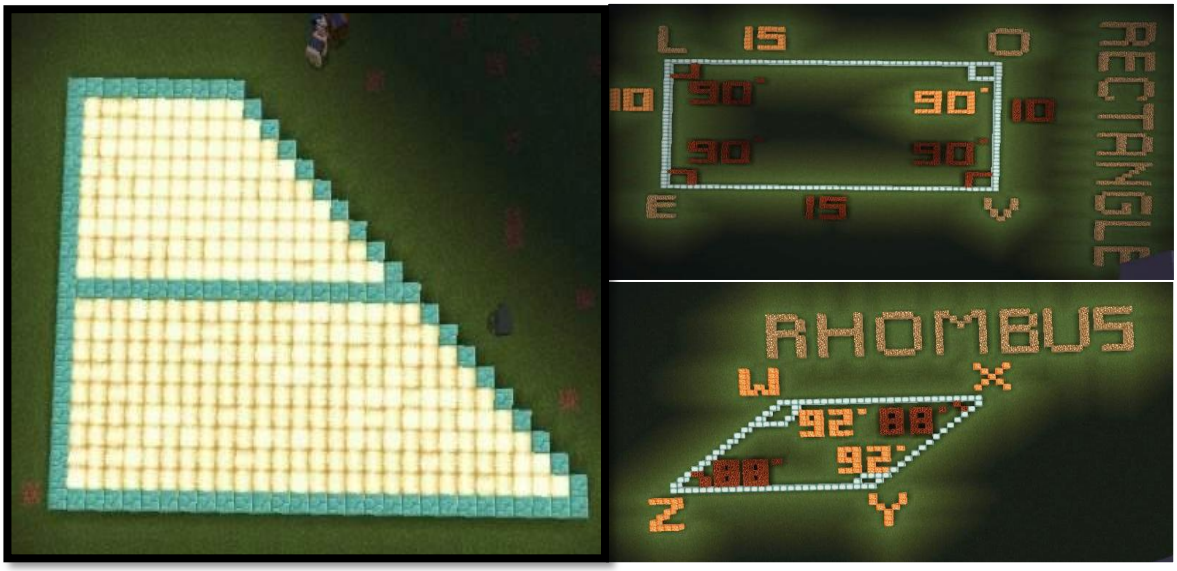

Figure 20: Student 31 and Student 32's representation in proving

3.3 Integration of Quantitative and Qualitative Findings

The quantitative and qualitative findings demonstrate that non-game-based instruction is less effective than game-based instruction, with a clear convergence of results. Quantitative data revealed that while both instructional approaches led to significant improvements, learners exposed to Minecraft-based digital game learning achieved significantly higher scores. This pattern is strongly supported by qualitative evidence showing that learners in the experimental group experienced increased motivation, engagement, and enjoyment—factors known to enhance learning outcomes.

Moreover, the development of creativity, collaboration, and critical thinking skills within the game-based environment provides a plausible explanation for the observed differences in achievement. The alignment between improved performance and enriched learning experiences suggests that the effectiveness of Minecraft-based instruction lies not only in content delivery but also in its ability to create an interactive, student-centered learning environment. Thus, the findings indicate complementarity between the two data strands, with qualitative insights explaining and strengthening the quantitative results, leading to a more comprehensive understanding of the impact of digital game-based learning on geometry achievement.

Table 4: Joint Display of Quantitative and Qualitative Findings

Quantitative Findings	Qualitative Findings	Integrated Interpretation
No significant difference in pre-test between groups	Learners initially experienced difficulty in constructing and understanding geometric concepts	Both groups started at a comparable level, supporting fair comparison of instructional effects
Both groups showed significant improvement	Learners reported increased understanding through active engagement in tasks	Improvement in both groups reflects the effectiveness of structured instruction
Experimental group showed significantly higher post-test scores	Learners expressed enjoyment, motivation, and engagement in Minecraft-based learning	Increased engagement and motivation contributed to higher achievement gains
Large effect size favoring Minecraft group	Learners developed creativity, collaboration, and communication	Interactive and social learning processes enhanced conceptual understanding
Strong improvement in problem-solving performance	Learners demonstrated critical thinking and reasoning while constructing figures	Higher-order thinking skills explain improved mathematical performance

4. Discussion

The results showed that students had low achievement in geometry at the start of the study, suggesting little prior knowledge and a struggle with abstract constructs; this has always been a quintessential challenge in mathematics education, particularly in geometry, as students often falter in spatial reasoning (Laborde, 2015; Sinclair et al., 2016). This result was supported by the qualitative findings, as learners initially reported difficulties in constructing geometric figures, identifying their relationships, and applying them appropriately.

After the intervention, learners' performance on mathematics achievement significantly improved compared to pre-intervention, and students exposed to digital game-based learning in Minecraft made larger gains than the other group. The results confirm previous literature suggesting that game-playing environments can be effective in increasing students' academic performance by creating more interactive, engaging, and meaningful learning experiences (Plass et al., 2015; Qian & Clark, 2016). By using Minecraft, learners were able to visualize geometric concepts, build representations, and investigate mathematical relationships in an interactive environment, which facilitated deeper conceptual understanding.

Qualitative findings provide additional insights into how learning through Minecraft led to increased achievement. A core theme that emerged was that learners were enjoying mathematics learning. Students wrote that the activities were fun and engaging, which lowered anxiety and made learning easier. This reinforces the general finding that having fun improves student engagement and

learning outcomes. When users see activities as enjoyable, they are more likely to engage and continue completing tasks (Plass et al., 2015).

The other significant insight was the increase in motivation and engagement among learners. This made students more engaged in attending class and in getting creative with their other Minecraft-inspired projects. This intense level of motivation was probably a major factor in their persistent effort and better performance. According to research, digital game-based learning environments facilitate intrinsic motivation through interactivity, challenge, and feedback (Qian & Clark, 2016; Sung & Hwang, 2018). Improved motivation is the key to students' achievement, especially in difficult subjects like mathematics.

The study found that creativity was also promoted. Learners were free to create geometric shapes with any materials and using as many different methods as they chose, in ways that represented their own understanding of how the figure looks. This process of creation, layered over many representations of mathematical concepts, is known to promote in-depth learning. Confirming previous studies about digital spaces like Minecraft support creativity through enabling learners to build and manipulate virtual objects (Baek et al., 2020; Cipollone et al., 2014).

Collaboration and communication also surfaced as major components of learners' experiences. Inside the Minecraft environment, learners worked together in groups, exchanged ideas, and solved problems. These conversations facilitated knowledge sharing and enabled collaborative problem-solving. This finding aligns with research indicating that students' conceptual understanding and social skills improve in collaborative learning environments (Johnson et al., 2014; Niemeyer & Gerber, 2015).

Minecraft provides an avenue for developing critical thinking skills. Learners indicated that building geometric figures required them to explore relationships, examine strategies, and use mathematical reasoning. These are higher-order thinking processes required to comprehend and apply mathematical concepts. These results align with the existing literature, which suggests that game-based learning contexts foster critical thinking by immersing learners in problem-solving and decision-making activities (Qian & Clark, 2016; Sung & Hwang, 2018).

Further, this study showed that learners experienced a stimulating learning environment. One challenge was that students were not used to working independently; however, over time, they learned to strategize and complete the tasks successfully. This is a clear reflection of the need to provide engaging, cognitively stimulating learning opportunities; more challenging tasks tend to promote deeper and more persistent thinking, both of which are important for learning (Plass et al., 2015).

5. Conclusion

Using a convergent parallel mixed-methods design, this study investigated the effectiveness of Minecraft-based digital game learning in improving geometry achievement among Grade 9 learners. The findings of this study indicate that

learners in both groups demonstrated comparable levels of prior knowledge in geometry before the intervention, as evidenced by the absence of a significant difference in pre-test scores. Significantly better conceptual understanding was shown by learners exposed to the Minecraft-based learning following this intervention phase, where both instructional approaches showed improvement, but interactive and technology-enhanced instruction mediated substantial improvement. These results were supported by qualitative findings indicating positive experiences in learning, such as increased enjoyment, motivation, and engagement that underpinned active participation in learning tasks.

Moreover, learning through Minecraft developed creativity, collaboration, and communication as it allowed learners to create meaningful representations of geometric concepts. There was also evidence of critical thinking through the analysis of relationships and the development of solutions in an active digital environment. While both quantitative and qualitative results point to similar conclusions, they indicate that digital game learning offers an interactive, motivating, and meaningful, contextually relevant environment that combines cognitive activities and social interaction to improve engagement. Although effective, the study had limitations, including sample size and context, which have challenged its findings, calling for more research within various settings and conducted over longer periods of time.

Overall, however, the results confirm that the incorporation of digital game-based learning into mathematics instruction is a potential way to enhance students' geometry achievement and learning experiences.

Conflict of Interest
The authors declare that there is no conflict of interest regarding the publication of this study.

6. Acknowledgments

The authors would like to express their sincere gratitude to all individuals and institutions who contributed to the successful completion of this study. First and foremost, heartfelt appreciation is extended to the Grade 9 learners who participated in this research for their active involvement, cooperation, and enthusiasm throughout the study. The authors also gratefully acknowledge the parents and guardians of the learners for granting permission and support, which ensured the smooth conduct of the research activities. Special thanks are extended to the school administrators and teachers of Sara National High School for their support, accommodation, and assistance during the study's implementation.

The authors likewise acknowledge the use of ChatGPT (OpenAI) in the preparation of this manuscript. The tool was used to improve the clarity, organization, and grammatical structure of the paper. However, the content remains an accurate representation of the authors' original work and intellectual contributions.

7. References

Al-Azawi, R., Al-Faliti, F., & Al-Blushi, M. (2016). Educational gamification vs. game-based learning: A comparative study. *International Journal of Innovation, Management and Technology, 7*(4), 131–136. https://doi.org/10.18178/ijimt.2016.7.4.659

Andersen, R., & Rustad, M. (2022). Using Minecraft as an educational tool for supporting collaboration as a 21st-century skill. *Computers & Education Open, 3*, 100094. https://doi.org/10.1016/j.caeo.2022.100094

Baek, Y., Min, E., & Yun, S. (2020). Mining educational implications of Minecraft. *Computers in the Schools, 37*(1), 1–16. https://doi.org/10.1080/07380569.2020.1719802

Bos, B., Wilder, L., Cook, M., & O'Donnell, R. (2014). Learning mathematics through Minecraft. *Teaching Children Mathematics, 21*(1), 56–59. https://doi.org/10.5951/teacchilmath.21.1.0056

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: Brain, mind, experience, and school*. National Academy Press.

Capate, R. N. A., & Lapinid, M. R. C. (2015, March 2–4). *Assessing the mathematics performance of Grade 8 students as basis for enhancing instruction and aligning with K to 12 curriculums*. In *Proceedings of the DLSU Research Congress 2015* (Vol. 3). De La Salle University, Manila, Philippines. https://www.dlsu.edu.ph/wp-content/uploads/pdf/conferences/research-congress-proceedings/2015/LLI/020LLI_Capate_RN.pdf

Chang, S. C., & Hwang, G. J. (2018). Impacts of an augmented reality-based flipped learning guiding approach on students' scientific project performance and perceptions. *Computers & Education, 125*, 226–239. https://doi.org/10.1016/j.compedu.2018.06.007

Ciampa, K., & Gallagher, T. L. (2013). Getting in touch: Use of mobile devices in the elementary classroom. *Computers in the Schools, 30*(4), 309–328. https://doi.org/10.1080/07380569.2013.846716

Cipollone, M., Schifter, C. C., & Moffat, R. A. (2014). Minecraft as a creative tool: A case study. *International Journal of Game-Based Learning, 4*(2), 1–14. https://doi.org/10.4018/ijgbl.2014040101

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approach* (4th ed.). SAGE Publications.

Creswell, J. W., & Plano Clark, V. L. (2017). *Designing and conducting mixed methods research* (3rd ed.). SAGE Publications.

Drake, S. M., Reid, J. L., & Kolohon, W. (2014). *Interweaving curriculum and classroom assessment: Engaging the 21st century learner*. Oxford University Press.

Fraenkel, J. R., & Wallen, N. E. (1990). *How to design and evaluate research in education*. McGraw-Hill.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education* (8th ed.). McGraw-Hill.

Hartt, M., Hosseini, H., & Mostafapour, M. (2020). Game on: Exploring the effectiveness of game-based learning. *Planning Practice & Research, 35*(5), 589–604. https://doi.org/10.1080/02697459.2020.1778859

Hiebert, J., & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. In F. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 371–404). Information Age Publishing.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2014). Cooperative learning: Improving university instruction. *Journal on Excellence in College Teaching, 25*(3–4), 85–118.

Karsenti, T., & Bugmann, J. (2018). The educational impact of Minecraft on elementary school students. In P. Anastasiades & N. Zaranis (Eds.), Research *on e-learning and*

ICT in education (pp. 197–212). Springer. https://doi.org/10.1007/978-3-319-95059-4_12

Kopecký, K., Fernández-Martín, F.-D., Szotkowski, R., Gómez-García, G., & Mikulcová, K. (2021). Behaviour of children and adolescents and the use of mobile phones in primary schools in the Czech Republic. *International Journal of Environmental Research and Public Health*, *18*(16), 8352. https://doi.org/10.3390/ijerph18168352

Laborde, C. (2015). Teaching and learning geometry. In S. J. Cho (Ed.), *The proceedings of the 12th International Congress on Mathematical Education* (pp. 431–436). Springer. https://doi.org/10.1007/978-3-319-12688-3_35

Lane, H. C., & Yi, S. (2017). Playing with virtual blocks: Minecraft as a learning environment for practice and research. In F. C. Blumberg & P. J. Brooks (Eds.), *Cognitive development in digital contexts* (pp. 145–166). Academic Press. https://doi.org/10.1016/B978-0-12-809481-5.00007-9

Lipnevich, A. A., Maccann, C., Krumm, S., Burrus, J., & Roberts, R. D. (2011). Mathematics attitudes and mathematics outcomes of U.S. and Belarusian middle school students. *Journal of Educational Psychology, 103*(1), 105–118. https://doi.org/10.1037/a0021949

Niemeyer, D. J., & Gerber, H. R. (2015). Maker culture and Minecraft: Implications for the future of learning. *Educational Media International, 52*(3), 216–226. https://doi.org/10.1080/09523987.2015.1075103

Ontario Ministry of Education. (2016). *21st-century competencies: Foundation document for discussion*. Ontario Public Service. http://www.edugains.ca/resources21CL/About21stCentury/21CL_21stCenturyCompetencies.pdf

Organisation for Economic Co-operation and Development. (2019). *PISA 2018 results (Volume I): What students know and can do*. OECD Publishing. https://doi.org/10.1787/5f07c754-en

Pandey, B. (2017). A study of mathematical achievement of secondary school students. *International Journal of Advanced Research, 5*(7), 1–6. https://doi.org/10.21474/IJAR01/6165

Pho, A., & Dinscore, A. (2015). *Game-based learning*. *Tips and Trends* (Spring 2015). Association of College & Research Libraries, Instructional Technologies Committee. https://acrl.ala.org/IS/wp-content/uploads/2014/05/spring2015.pdf

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. *Educational Psychologist, 50*(4), 258–283. https://doi.org/10.1080/00461520.2015.1122533

Qian, M., & Clark, K. R. (2016). Game-based learning and 21st-century skills: A review of recent research. *Computers in Human Behavior, 63*, 50–58. https://doi.org/10.1016/j.chb.2016.05.023

Sinclair, N., Bartolini Bussi, M. G., de Villiers, M., Jones, K., Kortenkamp, U., Leung, A., & Owens, K. (2016). Recent research on geometry education. *ZDM Mathematics Education, 48*(5), 691–719. https://doi.org/10.1007/s11858-016-0796-6

Sung, H. Y., & Hwang, G. J. (2018). Facilitating effective digital game-based learning behaviors and learning performances. *Interactive Learning Environments, 26*(1), 118–134. https://doi.org/10.1080/10494820.2017.1283334

Trybus, J. (2015). *Game-based learning: What it is, why it works, and where it's going*. New Media Institute. http://www.newmedia.org/game-based-learning--what-it-is-why-it-works-and-where-its-going.html