Limited access to ICT and interactive visualization tools and its impact on the math performance of intermediate pupils at Dangguinan Elementary School, Apayao

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ABSTRACT

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| This study forms a broader input on ICT and learner integration; it has specific scientific results that not only address access but also go beyond social and economic inequalities that communities face with limitations on social and economic activity that impact and scientific and academic growth of communities. This study aimed to investigate the effects of interactive visualization tools on the mathematical performance of intermediate pupils at Dangguinan Elementary School, Conner, Apayao, Philippines. The problem being studied centers on persistent difficulties in Mathematics performance, particularly learners' struggles in grasping abstract concepts and applying problem-solving skills effectively. Amongst the tools the study investigated included GeoGebra, simulations, and animated presentations could address persistent challenges in Mathematics performance. The research utilized a mixed-methods design, combining both quantitative and qualitative approaches to examine improvements in mathematics learning and explore implementation challenges. The study's mixed-methods approach offers a comprehensive understanding of both the quantitative impact on learning outcomes and the qualitative challenges encountered during implementation. Its findings are crucial for educational stakeholders in developing countries like the Philippines, as they highlight the potential of ICT integration in addressing persistent low math proficiency, while also underscoring the critical need to address infrastructure and digital literacy gaps for successful technology adoption in underserved areas. The study was conducted at Dangguinan Elementary School, Conner, Apayao, during the academic year 2024–2025. Forty-six pupils from Grades 4 to 6 participated in the study. The research applied the DepEd Likert Scale to group learners by their mathematics skills, instead of just using mean scores to assess them. Learners who had 15–17 points out of 20 (equivalent to 71%–85%) received the rating of "Proficient"—signifying they met the expected understanding and skills for their age. By using this method, educators could watch how each learner was improving and decide who might need more help. Rather than presenting average scores, the study used a thorough scale to better show how learning improved when interactive visualizations were used. A pre-test was administered to assess baseline mathematical proficiency. Following this, an instructional intervention was implemented using interactive visualization tools. After the intervention, a post-test was conducted to evaluate performance improvement. Additionally, interviews were carried out to understand the challenges encountered during the intervention. Quantitative results were analyzed using descriptive statistics and a paired sample t-test, while qualitative data were thematically analyzed. The pre-test mean score was 7.6, falling under the "Developing" performance level. Post-test scores improved significantly to a mean of 11.8, aligning with the "Approaching Proficiency" level. Statistical analysis revealed a significant difference between pre-test and post-test results (P = .000). Interviews revealed two major challenges: poor internet connectivity and insufficient orientation in using the tools, both of which affected the learners’ engagement with interactive visualization. To address this, alternative offline versions of instructional materials were provided, ensuring accessibility despite connectivity issues. Additionally, structured training sessions were introduced to familiarize learners with visualization tools before implementation, enhancing their confidence and ability to navigate digital learning environments effectively. The study concludes that interactive visualization tools significantly enhance intermediate pupils' mathematical understanding and performance. The research shows that using these interactive tools greatly improves how intermediate pupils understand and perform in mathematics. Still, overcoming problems with access and training is necessary to use them well. According to the study, upgrading the infrastructure and adding satellite technology for better connectivity, as well as apps that let learners work offline, would help make technology-aided math more effective. In addition, teachers should receive instruction, and learners should participate in orientation to help ICT become an important part of learning mathematics. Schools need support from educational stakeholders towards long-term digital change, helping them select and learn how to use the needed technology. |

*Keywords:* *interactive visualization tools, mathematics education, ICT integration, pupil performance, elementary school, rural education*

1. INTRODUCTION

The education systems globally, as outlined in a report by the organization for Economic Cooperation and Development (OECD) and United Nations Educational, Scientific and Cultural Organization (UNESCO), give a lot of importance to certain skills, such as critical thinking, problem-solving, and digital literacy, based on the latest international models for educational reform, which mark these skills as the 21st-century basics (OECD, 2018, UNESCO, 2017). Mathematics has a real impact on pupils' abstract and problem-solving skills and is, therefore, a basic constituent of 21st-century education (OECD, 2018; UNESCO, 2017In today's global knowledge economies, mathematics plays a crucial role in education and national competitiveness. However, despite ongoing reforms, math performance continues to decline both globally and locally, particularly in developing countries such as the Philippines (Marthur, n.d.). Over the past years, there has been a significant shift, notably characterized by the increasing integration of Information and Communication Technology (ICT) to enhance learning (Ghavifekr & Rosdy, 2015).

The 2022 Programme for International Student Assessment (PISA) results revealed that only 16% of Filipino learners attained at least Level 2 proficiency in mathematics, significantly lower than the OECD average of 69%. This highlights a substantial gap in mathematical competency between learners in the Philippines and those in OECD countries (OECD, 2023). In the Programme for International Student Assessment (PISA) test, the Philippines was placed at number 75 among 81 countries in terms of their average math score, which was just 355, thus making a point on the big lag (OECD-PISA, 2023). The scholars mainly emphasize that the problem with the low productivity rates in the Philippines is the heavy reliance on rote learning, deliveries, and the lack of utilization of technology in the classroom as the reasons (Espinosa et al., 2023). Furthermore, it has been argued by Corpuz & Salandanan (2012) that the curriculum, though it has elements of competency, is limited by such a scope that it just develops up to the knowledge level of the hierarchy of learning. The above results by OECD highlight that learners’ numeracy skills, especially in concepts related to mathematics, have not been consolidated, as well as that the learners have problems in understanding numbers and interpreting data.

* 1. **Literature review**

In response to these trends, research and educational policy worldwide increasingly advocate for the integration of digital and interactive tools in mathematics instruction (McMahon et al., 2024). Studies conducted by Hwang and Lai (2017), Banu and Naveena (2024) has proven that technologies for interactive visualization, such as software for exploring math, virtual manipulatives, and animated PowerPoint presentations, are instrumental in presenting math contexts meaningfully, and they also boost learners’ motivation while learning, especially when they involve such complex topics as algebra, fractions, and geometry. Learners who, in general, struggle with mathematics could learn much from visual materials. To be precise, Shahmohammadi (2019) and Santos et al. (2008) showed that the use of dynamic tools will be useful in solving mathematical problems and developing an idea abstractly, and, in addition to this, these tools can enhance learners’ memory. This view is also supported by the research of (Freeman et. al, 2014), where it is pointed out that academic achievements of learners pursuing career paths in the fields of science, technology, engineering, and mathematics saw a major increase with the application of active learning strategies as well as the use of digital visualization compared to traditional methods. Given the increasing emphasis on technology-driven instruction, digital tools like EdPuzzle have emerged as valuable resources in mathematics education. Research by Cigario, Adora, Balanquit, & Nobis Jr. (2025) indicates that EdPuzzle fosters interactive learning, boosts engagement, and enhances assessment accuracy, addressing key learning challenges in mathematical instruction. Visual strategies and technological tools figured prominently among the most effective teaching techniques according to Hattie's meta-analysis (Hattie, 2009), too. GeoGebra, as a case in point, not only allows for the variation of the parameters but also provides the opportunity to obtain instant-changing views, which is a very important characteristic of abstract thinking (Hohenwarter & Preiner, 2007). As educational institutions seek innovative strategies to enhance mathematics instruction, AI-driven tools like chatbots are emerging as promising solutions. Research by Pala, Lagrimas, & Nobis (2025) highlights how chatbots improve problem-solving skills and conceptual understanding by offering instant feedback and adaptive learning pathways. Their accessibility enables students to engage with mathematics content in more flexible and interactive ways, though challenges such as dependency and accuracy must be carefully managed. Moreover, Physics Education Technology (PhET) simulations and Desmos, through their interactive nature, allow the user to explore algebraic relations and visual pattern recognition (PhET, Desmos Studio). The visual representations of numbers, the visualization of how the data is driven over the grid, drawing of shapes, and the mapping of relationships are facilitated by these tools, as it is possible to modify them, while it is impossible to treat them as static, when the learning is conducted only in textual mode (Keengwe & Onchwari, 2019). Additionally, these tools allow for the provision of individualized education to cater to diverse learners’ learning preferences and to foster their independence (Lin & Tsai, 2017).

In the context of the Philippines, the Philippine Department of Education (DepEd) has taken crucial steps to counteract flaws in the system through ICT-linked reforms (DepEd, Computerization program, 2018). On the other hand, DepEd Order No. 42, s. 2017 mandates the use of learner-centered pedagogies and relevant teaching resources supporting 21st-century skills (Department of Education, 2017). Nonetheless, there is a lack of consistency in implementation, particularly in rural schools.

Niem, Veriña, and Alcantara (2020) report that teachers in less developed areas are often unskilled and lack adequate ICT training and resources. Castillo (2017) makes similar observations, citing infrastructure and internet accessibility as major barriers. Subsequent policies, such as DepEd Order No. 21, s. 2019, has reinforced the importance of technology in the K–12 curriculum (Department of Education, 2019). However, the challenge lies in translating these policies into effective classroom practices, especially in regions with limited resources.

Through Regional Memorandum No. 242, s. 2024, the Department of Education–Cordillera Administrative Region (DepEd–CAR) encouraged schools in the region to utilize interactive visualization tools for competency-based mathematics teaching aligned with the Most Essential Learning Competencies (MELCs) (Department of Education – CAR, 2024a). The adoption of the Basic Education Research Agenda further underscores the region’s commitment to improving educational outcomes through localized research (DepEd, 2016). The Basic Education Research Agenda (BERA) emphasizes the need for studies that address region-specific challenges, such as integrating technology into classrooms often underserved by infrastructure and resources (Department of Education, 2020). This study aligns with that agenda, seeking to provide actionable insights that can inform educational policy and practice in the region.

Therefore, the purpose of this study is not only to examine the viability of technology integration in Philippine elementary mathematics but also to determine how visualization tools can offer alternatives to conventional learning and enhance understanding of mathematical principles. This research goes beyond technology to present a broader framework from which educators and policy implementers can design a relevant and effective mathematics curriculum. One way to ensure learners’ success with modern mathematical resources is by equipping them with skills to navigate a fast-moving, socially complex world.

The results by the Cordillera Administrative Region (CAR) on math performance have shown the following national challenges. In the 2024 Regional Achievement Test (RAT), Apayao Division, one of the lowest-performing, posted a Mathematics Mean Percentage Score (MPS) of just 38.93% (Department of Education – CAR, 2024b). Similarly, in the National Achievement Test (NAT), Apayao Division scored 48.43% MPS in Mathematics, falling under the “Low Proficient” category (Department of Education – CAR, 2024c).

Findings from various evaluation tests revealed mathematics as the lowest-performing subject, with MPS below 50%. These results reflect a critical situation for Apayao teachers and learners. A recommended response is for each school to conduct diagnostic pre-assessments to identify learners' strengths and weaknesses. This would reveal learning gaps and unmastered skills, prompting necessary curriculum and strategy adjustments (DepEd Order No. 55, s., 2016).

Considering persistent problems, such as low learner performance and mathematical misconceptions, in Grades 4 to 6, particularly in Apayao, integrating virtual interactive tools into instruction becomes essential. Major national exams, like NAT6, have repeatedly shown subpar results (Department of Education – CAR, 2024c). The NAT6 was particularly revealing, showing CAR learners' weakness in number sense, problem-solving, and spatial skills (Department of Education – CAR, 2024b).

Despite the implementation of the MATATAG Curriculum and DepEd’s Sulong EduKalidad initiative (Department of Education, 2019), many pupils still struggle with complex concepts due to indirect teaching methods. The K to 12 Mathematics Curriculum advocates a learner-centered, technology-enhanced approach for Grades 4 to 6, focusing on key competencies like comparing fractions, operations on mixed numbers, geometry, and measurement (Department of Education, K to 12 Mathematics Curriculum Guide, 2016).

Visualization tools such as GeoGebra, Desmos, and Physics Education Technology (PhET) Interactive Simulations have proven essential in making abstract math concepts visually and interactively comprehensible (Freeman et al., 2014; Gökçe & Güner, 2022). Gökçe and Güner (2022) examined the evolving role of GeoGebra in mathematics education, identifying key trends in its application for conceptual understanding and instructional strategies. These tools help learners retain information and boost engagement, particularly in rural areas. Visualization tools have been shown to enhance children's ability to analyze and reflect on their collaborative interactions (Celepkolu et al., 2021). For instance, GeoGebra enables real-time graphing and dynamic geometry, enhancing learners’ ability to visualize mathematical changes and measurements. These methods align with the Philippine Professional Standards for Teachers, which emphasize ICT integration. Evidence from Apayao shows that ICT-based visualization strategies significantly improved learners’ problem-solving and conceptual clarity (Niem et al., 2020).

To support DepEd’s ICT initiatives, this study focused on Grades 4 to 6 and the use of interactive visualization tools to improve math performance. These tools helped learners form mental images of abstract math concepts and recognize patterns and operations. This research tackled challenges faced in early education, such as understanding fractions, visualizing geometric shapes, and solving problems. By employing tools like GeoGebra, animated slides, and simulations, the study aimed to address conceptual misunderstandings and support differentiated learning, ultimately improving outcomes in underperforming areas like Apayao.

2. STATEMENT OF THE PROBLEM

This study aimed to investigate the effectiveness of interactive visualization tools on the mathematical performance of intermediate pupils at Dangguinan Elementary School. Specifically, it sought to answer the following questions:

1. What is the pre-test score/mathematical performance of the intermediate pupils before using the interactive visualization tools?
2. What is the post-test score/mathematical performance of the intermediate pupils after using the interactive visualization tools?
3. Is there a significant difference between the pre-test and post-test scores in the mathematical performance of the intermediate pupils before and after the utilization of interactive visualization tools?
4. What challenges were encountered during the process of utilizing interactive visualization tools?
   1. **Hypothesis**

There is no significant difference between the pre-test and post-test scores in the mathematical performance of intermediate pupils before and after using interactive visualization tools.

3. METHODOLOGY

3.1 Research Design

This study employed a mixed-method research design, integrating quantitative and qualitative approaches to comprehensively assess the effectiveness of interactive visualization tools in the mathematics education of grades 4 to 6 pupils at Dangguinan Elementary School. The quantitative phase involved administering a pre-test to evaluate learners’ initial proficiency and implementing the intervention using interactive visualization aids. A post-test was then conducted to measure any changes in the mathematical achievement of the intermediate learners. The qualitative component complemented this by exploring learners’ experiences and challenges when integrating these tools into classroom instruction through an interview.

**3.2 Locale of the Study**

The study was conducted at Dangguinan Elementary School (DES), a public elementary school in Purok 7, Calafug, Conner, Apayao, Southern Conner District. With a total of forty-six (46) learners, the school had one (1) section for each of Grades 4 through 6.

**3.3 Respondents of the Study**

The respondents of this study were the intermediate learners enrolled at Dangguinan Elementary School, comprising twenty-three (23) male and twenty-three (23) female pupils, for a total of forty-six (46) pupils enrolled for the 2024–2025 academic year. These pupils represented diverse levels of mathematical proficiency, as determined by their previous quarter grades. Total enumeration was used.

**3.4 Research Instrument**

The study used pre-tests and post-tests as the primary tools for measuring learners' mathematics performance before and after the intervention using interactive visualization tools. The research instrument consists of a 20-item multiple-choice test assessing mathematical proficiency. The items were aligned with competencies outlined in the DepEd Mathematics Curriculum Guide and are categorized into basic operations, problem-solving, and logical reasoning as adopted from the DepEd Project Standardized and Meaningful Assessment Result-Based Teaching (SMART). The pre-test established a baseline for learners' prior knowledge and proficiency, while the post-test measured any improvement attributable to the intervention.

And on the qualitative part, this study employed an interview as an instrument to systematically gather detailed insights from intermediate pupils regarding the challenges they had experienced with interactive visualization tools in mathematics instruction.

**3.5 Data Gathering Procedures**

Firstly, the researcher sought permission from the Public Schools District Supervisor (PSDS) of Southern Conner District and the school head who is concerned. After which, the necessary approvals were obtained, and the questionnaires were administered. An orientation session was held for the learners to explain the purpose of the study, their roles, and how the interactive visualization tools were utilized. To establish baseline data, a pre-test was administered to assess the learners' initial proficiency in Mathematics.Alongside this, the learners’ mathematics grades from the previous quarter were retrieved from school records to serve as secondary data, providing a measure of their prior performance. Following this, the integration of interactive visualization tools was implemented. The sessions covered essential topics such as basic operations, fractions, measurement, geometry, and problem-solving. After the intervention, a post-test was administered using the same format as the pre-test to measure the improvement in learners’ mathematical performance. Concurrently, for the qualitative component, an interview was conducted to gather in-depth insights into the challenges encountered by the pupils with the visualization tools.

With the observance of ethical standards and the Data Privacy Act of 2012, before data collection, consent was obtained from all participants. Consequently, the experiment objectives, procedures, potential risks, and benefits of the research were explained to the participants. Besides, the data collected was fully anonymized and kept in a secure place, being accessible only to authorized personnel. The researchers were guided by the principles of transparency, legitimate purpose, and proportionality in the collecting, retaining, and processing of personal information mandated by the Data Privacy Act. The data gathered were tabulated, consolidated, and analyzed by the researcher.

**3.6 Statistical Analysis**

The learners' performance level was calculated based on the Descriptive Statistics concepts to illustrate frequency, percentage, and standard deviation in the pre-test and post-test stages. A summary of the scores was decoded using the DepEd Likert Scale to establish the level of proficiency, and the pupils' performances were distributed among the four categories: Beginning, Developing, Approaching Proficiency, and Proficient. In this way, it was easy to monitor the learners' progress in their math skills without using the mean score as a measure of the central tendency. It also gave a clear picture of the fluctuation of the learners' math performance before and after using interactive visualization tools.

**Table 1: DepEd Likert Scale**

|  |  |  |  |
| --- | --- | --- | --- |
| **Score Range (Out of 20 Items)** | **Percentage Range** | **Performance Level** | **Interpretation** |
| 1 – 4 | 1% – 20% | Beginning | Struggles to understand key concepts; needs improvement. |
| 5 – 8 | 21% – 40% | Developing | Shows partial understanding; needs further support. |
| 9 – 14 | 41% – 70% | Approaching Proficiency | Nearly meets expectations; some gaps remain. |
| 15 – 17 | 71% – 85% | Proficient | Meets the expected level of understanding and skills. |
| 18 – 20 | 86% – 100% | Advanced | Exceeds expectations; demonstrates in-depth understanding. |

Descriptive statistics such as frequency, percentage, and standard deviation were used to summarize the performance levels of the pupils. To test the hypothesis, “there is no significant difference between the pre-test and post-test scores in the mathematical performance of intermediate pupils before and after using interactive visualization tools,” a Paired Sample t-Test was computed.

To support the findings generated from numbers and gain more profound knowledge about learners’ experiences, learners were interviewed on specific questions. The purpose of the discussion was to inquire into the problems and difficulties addressed by pupils while undergoing their math lessons with visual instructional technology.

The collected data were turned into transcripts, which were analyzed thematically. Major themes were determined, given codes, and then represented by categories such as teacher support and instruction, tool effectiveness, ease of use, engagement and motivation, technical issues, conceptual understanding, emotional and cognitive factors, time management, accessibility, and peer support

Through this method of analysis, the learners’ voices were made part of the discussion of the hindrances to effective tool usage, thus giving a more in-depth understanding of the problems. Overall, the combination of Paired Sample T-Test for the quantitative data and descriptive thematic analysis for the qualitative responses provided a comprehensive evaluation of both the effectiveness of interactive visualization tools in improving pupils' mathematical performance and the implementation challenges faced during their integration into mathematics instruction.

**4. RESULTS AND DISCUSSION**

**4.1 The pre-test score of the intermediate learners before the use of the interactive visualization tool**

**Table 2. Mean, Frequency, and DepEd Likert Scale distribution according to the performance level of the intermediate pupils in Mathematics pre-test, before the use of interactive visualization tools**

|  |  |  |  |
| --- | --- | --- | --- |
| **Score Range (out of 20 items)** | **Frequency** | **Performance Level** | **Interpretation** |
| 1 – 4 | 4 | Beginning | Struggles to understand key concepts; needs improvement. |
| 5 – 8 | 27 | Developing | Shows partial understanding; needs further support. |
| 9 – 14 | 15 | Approaching Proficiency | Nearly meets expectations; some gaps remain. |
| 15 – 17 | - | — | — |
| 18 – 20 | - | — | — |
| Mean Score | 7.6 | Developing | Shows partial understanding; needs further support. |

Table 2 illustrates the preliminary results from the mathematics assessment of the intermediate pupils before the use of interactive visualization tools in teaching the subject. The data shows the average score was 7.6, which puts it on the “Developing” level of performance according to the Department of Education (DepEd) Likert scale. This classification shows that most pupils demonstrated only a partial grasp of mathematical concepts and appreciated instructional guidance. The data reveal a concentration of learners within the lower two categories of the performance scale: 4 pupils (8%) in the “Beginning,” 27 pupils (59%) in the “Developing,” 15 (33%) in “Approaching Proficiency.” None were at a “Proficient” or “Advanced.” This pattern of distribution highlights the lack of conceptual understanding and skill proficiency of many learners before the instructional intervention.

These findings agree with research indicating that the teaching practices most commonly in use—especially those that emphasize reliance on words and numbers in their most abstract forms—tend to impede learners in mathematics, which requires a great deal of abstract reasoning. In the absence of visual aids and context, a substantial number of learners fail to construct adequate mental images of mathematics concepts, resulting in misconceptions and superficial understanding (Skulmowski et al., 2022; Zhang et al., 2025).

The poor results in the pre-test may also arise from a lack of dynamic teaching materials that are key to building mental models as well as memory retention. Based on Bruner’s stages of representation, learners, especially mid-graders, appreciate moving through enactive (doing), iconic (seeing), and symbolic (thinking) levels of understanding. Failure to provide visuals during the teaching process might have stunted (Bruner, 2020).

From a constructivist standpoint, learning takes place when learners are involved in the process of constructing knowledge. Involving a passive learning approach, as was likely the case during the pre-test stage, tends to lead to learners’ minimal effort and understanding, especially in mathematics (Ugalde et al., 2021). Additionally, when cognitive overload exists because of abstract or disorganized instruction, learners may end up becoming apathetic or lost, which only fuels their inadequate performance (Chang & Yang, 2023).

In this sense, the results of the pre-test have shown a great need for innovative and learner-centered learning approaches, particularly the tools of interactive visualization, which, in theory, have the potential of overcoming the mentioned instructional shortcomings by promoting not only active engagement but also abstract thinking, and leading to a better understanding of mathematical concepts at the same time.

**4.2 The post-test score of the intermediate pupils after using the interactive visualization tools**

**Table 3. Frequency and DepEd Likert Scale distribution according to the performance level of the intermediate pupils in Mathematics post-test, after the use of interactive visualization tools**

|  |  |  |  |
| --- | --- | --- | --- |
| **Score Range (out of 20 items)** | **Frequency** | **Performance Level** | **Interpretation** |
| 1 – 4 | - | — | — |
| 5 – 8 | 9 | Developing | Shows partial understanding; needs further support. |
| 9 – 14 | 24 | Approaching Proficiency | Nearly meets expectations; some gaps remain. |
| 15 – 17 | 13 | Proficient | Meets the expected level of understanding and skills. |
| 18 – 20 | - | — | — |
| Mean Score | 11.8 | Approaching Proficiency | Nearly meets expectations; some gaps remain. |

Table 3 presents a substantial improvement in the mathematical performance of intermediate pupils following the integration of interactive visualization tools in the learning process. The mean score increased to 11.8, shifting the average performance level from “Developing” in the pre-test to “Approaching Proficiency” after the intervention.

The change in performance level of the pupils serves as an indication of the efficacy of interactive visualization tools on learners' overall understanding of concepts and competence acquisition. Besides, the group of 13 pupils (28%) demonstrated a significant “Proficient” level, which was an increase from zero, whereas the score of pupils in the “Developing” group decreased from 52% (24 pupils) to 20% (9 pupils), respectively, indicating this growth further.

As per Mayer’s Cognitive Theory of Multimedia Learning (Mayer, 2020), it has been observed that learners can grasp information more efficiently through both auditory and visual channels as compared to the use of the auditory channel only. The interactive data visualization instruments utilized in the research reflect this concept, as these instruments showed the deep meaning of abstract mathematical content using a dynamic picture, and hence, this likely was the cause of the better retention and comprehension that were observed.

The results of the study are also in line with Vygotsky’s Social Constructivist Theory, which advocates the viewpoint that learners are active in shaping their knowledge through interaction and scaffolding (Vygotsky, 1978). The interactive tools are what lead to this interaction since they give learners the possibility of discussing the visual symbols, doing the dynamic stimulations, and getting immediate feedback; hence, they agree with constructivist learning environments, and the increase in the results of the test is also easily explained.

Additionally, cognitive engagement is a critical factor of academic success. Research indicates that learners actively interpreting and interacting with visuals tend to be more motivated and grasp concepts more deeply (Skulmowski et al., 2022; Zhang et al., 2025). Findings from this study confirm that these interactions, as the visualizations likely enhanced the learners’ motivation and engagement, resulted in increased academic performance (Talan, 2021). While no learners achieved the top bracket (scores 18–20), the emergence of a statistically significant number of “Proficient” pupils and the concomitant reduction in learners needing additional support suggests that the interactive visualization tools fostered differentiated learning. This is especially pertinent in diverse classrooms with varying learning and ability levels.

**4.3 Significant difference in the pre-test and post-test scores of the learners before and after the use of the interactive visualization tool**

**Table 4. Test of significant difference in the performance level of intermediate pupils in mathematics before and after using interactive visualization tools**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable** | **Mean** | **SD** | **t correlation value** | **P-value** | **Interpretation** |
| Pre-test | 7.6 | 2.10 | 0.962 | 0.000 | Significant |
| Post-test | 11.8 | 3.39 |  |  |  |

***\*tested at 0.05 level of significance***

Table 4 presents the inferential statistics comparing the mathematics performance of intermediate pupils before and after the use of interactive visualization tools. The mean pre-test score was 7.6 with a standard deviation (SD) of 2.10, while the mean post-test score increased to 11.8 with a higher SD of 3.39, indicating greater variability in post-intervention performance. The computed t-correlation value was 0.962 with a p-value of 0.000, which is less than the 0.05 significance level. This confirms that there is a statistically significant difference between the pre-test and post-test scores. The findings suggest that the use of interactive visualization tools led to a measurable and meaningful improvement in pupils’ mathematical performance.

Although a paired sample t-test was used to assess the significance of the difference between pre-test and post-test scores, the study did not report conducting a normality test (e.g., Shapiro-Wilk) to formally verify the assumption of normality. However, given the sample size of 46 pupils, the Central Limit Theorem suggests that the sampling distribution of the mean differences can be approximated as normal. Future studies are encouraged to conduct and report formal normality testing to strengthen the validity of parametric test results.

The data point out that interactive visualization tools have had a positive impact on learners' knowledge of mathematical concepts. This introduction is based on previous studies that also indicate that using the modern technology of educational resources will improve both learners' procedural fluency and conceptual understanding in mathematics (Zhang et al., 2025).

Interactive visualization tools promote active learning, allowing learners to manipulate representations, engage in simulations, and receive immediate feedback, which enhances comprehension and retention. This approach is aligned with current pedagogical trends that advocate for constructivist and learner-centered strategies in the digital age (Saat et al., 2024).

Also, an increasing number of data shows that representation-based interfaces are a great aid to learners’ mathematical thinking by making it more conceivable, especially for those people who lack abstract reasoning skills (Skulmowski et al., 2022). These instruments present multiple modes of information, which are based on Mayer’s updated cognitive theory of learning from multimedia by emphasizing the reduced cognitive load and increased learner engagement (Mayer, 2024).

Some recent research (Lagmay et al., 2024) also finds that using interactive simulations and visual tools can help learners achieve significantly better test scores than those who adopt traditional methods, thus verifying the current study's results.

**4.4. Challenges encountered during the process of utilizing interactive visualization tools**

To gain deeper insight into the learners' experiences with interactive visualization tools in Mathematics, qualitative data were collected through semi-structured interviews. The responses were analyzed thematically and quantified according to the number of times each specific issue was raised. Thematic categories emerged from the responses. The main interview question asked was "Ano ang mga hamon na iyong naranasan sa paggamit ng mga interactive na visual tools sa araling Matematika?"

*("What are the challenges you faced in using interactive visualization tools in Mathematics?")*

**Theme 1. Restricted internet connections due to geographical limitations**

Learners have limited access to stable and reliable internet services, primarily because of the remote location of their community and school. This connectivity issue restricts their ability to access online resources, including the effective use of interactive visualization tools.

The learners experienced this as manifested in their responses:

*“Nu aggumissan e madi nga makatallung ki mobra nga aktibidad ta awan signal ki balay mi.”*

*(Sometimes I can't join the activity because there's no signal at our house.)*

*“Magim immang ya lesson ta kaddag mawawan ya signal.”*

*(The lesson gets interrupted because the internet suddenly cuts off.)*

These statements illustrate the ongoing challenge of the digital divide in rural or underdeveloped regions, which have limited or no access to reliable internet. This is in alignment with the work of Villaseñor (2024), who pointed out that educational institutions within remote geographic locations suffer from severe infrastructural limitations for the use of educational technology interventions such as ICT support and reliable internet connectivity. The Department of Education (DepEd) likewise reported that nearly 30% of rural schools experience severe connectivity problems, which impede the effective delivery of digital education. learners in remote and marginalized communities experience many barriers to technology, disrupting the quality of their education. The digital gap forces learners to miss online lessons that involve interacting, thus affecting their school performance. A weak or non-existent internet connection is common for learners in distant regions, making involvement in online courses challenging (Baticulon et al., 2021; Villaseñor, 2024). In addition, when learners do not have proper educational tools, they find it harder to improve their digital skills (Villaseñor, 2024; UNESCO, 2022). Weak or limited connectivity and digital services negatively influence a learner’s academic achievements and enthusiasm for learning (Baticulon et al., 2021; Bondoc et al., 2022).

This challenge has significant implications. When internet access is disrupted, learners are unable to engage fully with interactive visual tools, resulting in missed learning opportunities, incomplete tasks, and increased frustration. These findings align with Bozkurt and Sharma’s (2020) argument that remote learning is only effective when infrastructure is accessible to all learners.

**Theme 2. Lack of orientation on tool usage and features**

In addition to internet-related issues, learners encountered challenges in navigating the interactive tools provided to them. Their difficulties were not with the content per se, but with understanding how to operate the platforms effectively.

Learner responses included:

*“Madih ammo no wajan na ya pindutan ko.”*

*(I don't know which one to click.)*

*“Nadigas nga unudan ta madih mi pakam kabisadu ya tool.”*

*(It's hard to follow because we're not yet familiar with the tool.)*

*“Makuriru nga kebalat ta napakadu ya pappilyan entre madih ammo no nagan para na.”*

*(I feel confused because there are so many options and I don't know what they're for.)*

These statements reflect a gap in digital literacy, specifically in tool orientation and user support. This is backed up by different studies (Choudhary & Bansal, 2022; Limniou, 2021; Rafiq & Iqbal, 2024), which state that providing both structured guidance and training with a digital tool helps learners to be more engaged and successful. Absence of appropriate preparation has learners relying on mistakes, and this usually makes them doubtful and leads them to perform badly on tasks. It has been found that guiding learners before they start using educational technology helps them feel confident and successful, leads to better grades, and makes engaging online activities less upsetting. When training is not enough, people are less likely to take part, use all the features, and achieve better results (Ng et al., 2024; Rafiq & Iqbal, 2024).

It is pointed out by Romrell et al. (2014) SAMR model that technology adoption should always be supported by careful scaffolding. They are meant to build on what traditional teaching does, making the experience better or different. If learners are left on their own, they tend to use technology only at the basic levels of substitution and augmentation (Romrell et al., 2014). This demonstrates how technical unfamiliarity can lead to anxiety and avoidance behavior.

5. CONCLUSION

Based on the findings derived from this study, it is concluded that the use of interactive visualization tools significantly improved the mathematical performance of intermediate pupils at Dangguinan Elementary School. There was a notable difference in the performance of the intermediate pupils before and after the intervention. Nonetheless, as the tools aided in learning outcomes, their application had several challenges.

Even with the positive results, learners experienced two main difficulties while implementing the intervention. A lack of good internet connections in far-away schools and community sites reduced the availability of digital content consistently. Secondly, the fact that participants did not understand the tools made it difficult for them to explore their functions. It underlines the importance of dealing with infrastructure-related barriers and providing structured guidance and training before the integration of digital tools in the classroom.

To conclude, interactive visualization tools are an effective Mathematics instructional aid that enhances conceptual understanding and performance. However, such tools can only be utilized optimally if schools provide equitable access to technology, adequate user preparation, sufficient resources, and technical assistance with the tools. Removing these obstacles will foster more inclusive, stimulating, and efficient environments for learning. Future research could further build upon these findings by exploring specific, localized interventions to address persistent challenges such as poor internet connectivity and insufficient orientation for technology tool usage, particularly in rural Philippine schools. Longitudinal studies could assess the sustained impact of interactive visualization tools on mathematical performance and track how digital literacy develops over time among pupils in similar underserved contexts. Additionally, investigating the effectiveness of various scaffolding strategies to prepare students for independent use of digital tools, especially through the lens of the SAMR model, could offer valuable insights into how schools can ensure deeper, more transformative integration of technology in mathematics education across the country.

**ETHICAL APPROVAL:**

The researcher sought permission from the Public Schools District Supervisor (PSDS) of Southern Conner District and the school head who is concerned. After which, the necessary approvals were obtained. The study was conducted in accordance with the ethical standards and guidelines set forth by the college. The research complied with all applicable ethical principles. The study ensured the voluntary participation of respondents and maintained strict confidentiality and respect for their privacy throughout the research process.

Consent:

Before data collection, consent was obtained from all participants and the respondents voluntarily agreed to participate after being fully informed about the purpose, nature, and potential implications of the study. Their responses have been treated with strict confidentiality and used solely for academic and research purposes, in accordance with ethical research standards.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

I acknowledge that the content of this document is my original work. I have used Quillbot solely for the purpose of refining certain sections for clarity and coherence. No substantial portion of the content was generated by artificial intelligence, and all ideas, analyses, and conclusions are my own.

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