Interactive Visualization Tools: Its Effects on the Mathematical Performance of Intermediate Pupils at Dangguinan Elementary School

.

ABSTRACT

|  |
| --- |
| This study aimed to investigate the effects of interactive visualization tools on the mathematical performance of intermediate pupils at Dangguinan Elementary School. The goal was to explore whether tools like 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 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. 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 improvement in performance. 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, affecting the learners' experiences. The study concludes that interactive visualization tools significantly enhance intermediate pupils' mathematical understanding and performance. However, addressing access and training issues is crucial for optimizing their effectiveness. Educational stakeholders are encouraged to integrate ICT in mathematics instruction and ensure that supporting infrastructure and training are provided. |

*Keywords:* *interactive visualization tools, mathematics education, GeoGebra, ICT integration, pupil performance, elementary school, rural education, mixed-methods research.*

1. INTRODUCTION

Mathematics has a real impact on pupils' abstract and problem-solving skills and is, therefore, a basic constituent of 21st-century education. In today's global knowledge economies, the skill of mathematics has become a primary single factor of education and national competitiveness, regrettably, such a situation is concurrent with the lowering of math performance on a global and local scale, mainly in developing countries such as the Philippines, even with the reforms. It has significantly changed in the last years and has been particularly marked by a movement to include Information and Communication Technology (ICT) to enhance learning. 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).

With the improvement of the world in numerous areas, the education sector remains one of the areas lacking the most. In the 2022 Program for International Student Assessment (PISA), a test to examine the learning levels of 16% of the Filipino students, the OECD countries had a 69% difference in Math Level 2 proficiency. In the 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 (Tan, 2020, David & Ariate, 2022)). 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. These results highlight the fact that students’ numeracy skills, especially in concepts related to mathematics, have not been consolidated, as well as that the students have problems in understanding numbers and interpreting data.

In response to these trends, research and educational policy worldwide increasingly advocate for the integration of digital and interactive tools in mathematics instruction. The number of studies is countless, in which it has been proved 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 (Hwang & Lai, 2017, Yáñez Gómez et al., 2021). Students who, in general, struggle with mathematics could learn much from visual materials. To be precise, Zbiek and Hollebrands (2023) (Zbiek & Hollebrands, 2023) 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 students’ memory. This view is also supported by the research of (Freeman et. al, 2014), where it is pointed out that academic achievements of students 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. Visual strategies and technological tools figured prominently among the most effective teaching techniques according to Hattie's meta-analysis (Hattie, 2009), too. rGeoGebra, 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). Moreover, 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 students’ 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. For instance, DepEd Order No. 67, s. 2023, also known as the Digital Rise Program, was introduced to enhance and facilitate the integration of new technology, digital literacy, and device accessibility in schools for basic education (Department of Education, 2023). 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 (2022) report that teachers in less developed areas are often unskilled and lack adequate ICT training and resources. Bautista (2022) makes similar observations, citing infrastructure and internet accessibility as major barriers. Subsequent policies, such as DepEd Order No. 21, s. 2019, have 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.

Furthermore, 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. This agenda emphasizes the need for studies that address region-specific challenges, such as integrating technology in 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 students’ success with modern mathematical resources is by equipping them with skills to navigate a fast-moving, socially complex world.

The Cordillera Administrative Region (CAR) faces these 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 students. A recommended response is for each school to conduct diagnostic pre-assessments to identify students' strengths and weaknesses. This would reveal learning gaps and unmastered skills, prompting necessary curriculum and strategy adjustments.

Considering persistent problems, such as low student 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 students' weakness in number sense, problem-solving, and spatial skills (Department of Education – CAR, 2024b).

Despite the implementation of the MATATAG Curriculum (Department of Education, 2022) 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, 2016).

Visualization tools such as GeoGebra, Desmos, and PhET Interactive Simulations have proven essential in making abstract math concepts visually and interactively comprehensible (Freeman et al., 2014). These tools help students retain information and boost engagement, particularly in rural areas. 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 students’ problem-solving and conceptual clarity (Niem et al., 2022).

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 students 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

Generally, 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 students 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 students' 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 students' 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, students 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 students 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 students 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 students’ minimal effort and understanding, especially in mathematics (Ugalde et al., 2021). Additionally, when cognitive overload exists because of abstract or disorganized instruction, students 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 student-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 students' 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, 2021), it has been observed that students 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 students 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 students’ motivation and engagement, resulted in increased academic performance (Rahim & Said, 2019). While no students achieved the top bracket (scores 18–20), the emergence of a statistically significant number of “Proficient” pupils and the concomitant reduction in students 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** | **t correlation value** | **P-value** | **Interpretation** |
| Pre-test | 7.6 | 0.962 | 0.000 | Significant |
| Post-test | 11.8 |

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

Table 4 shows the statistical analysis of pre-test and post-test scores of intermediate pupils after the implementation of interactive visualization tools in mathematics instruction. The mean score increased from 7.6 (pre-test) to 11.8 (post-test). The t-correlation value of 0.962 with a p-value of 0.000 (p < 0.05). Therefore, there is a significant difference in the performance level of intermediate pupils in mathematics before and after using interactive visualization tools. This result strongly suggests that the intervention had a positive impact on pupils' mathematical performance.

The data point out that interactive visualization tools have had a positive impact on students' 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 students' procedural fluency and conceptual understanding in mathematics (Zhange et al., 2025).

Interactive visualization tools promote active learning, allowing students 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 students’ 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 student engagement (Kozan, 2020).

Some recent research (Rahim & Said, 2019) also finds that using interactive simulations and visual tools can help students 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. Students in remote and marginalized communities experience many barriers to technology, disrupting the quality of their education. The digital gap forces students to miss online lessons that involve interacting, thus affecting their school performance. Having a weak or non-existent internet connection is common for students in distant regions, and this makes involvement in online courses challenging (Baticulon et al., 2021; Cabual, 2023; Bolaños et al., 2022). In addition, when students do not have proper educational tools, they find it harder to improve their digital skills (Cabual, 2023; UNESCO, 2022). Weak or limited connectivity and digital services negatively influence a student’s academic achievements and enthusiasm for learning (Baticulon et al., 2021; Soriano, 2020).

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 (Morra et al., 2022; Ng et al., 2024; Muhajir et al., 2023; 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 students relying on mistakes, and this usually makes them doubtful and leads them to perform badly on tasks. It has been found that guiding students 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 Puentedura’s (2014) SAMR model that technology adoptions should always be supported by careful scaffolding. They are meant to build on what traditional teaching does, making the experience better or different. If students 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, adequate resources, and technical assistance with the tools. Removing these obstacles will foster more inclusive, stimulating, and efficient environments for learning.

Consent (where ever applicable)

I affirm that 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.

Ethical approval (where ever applicable)

The study was conducted in accordance with the ethical standards and guidelines set forth by the college. Formal ethical approval was not required, as 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.

References

Adoption of the basic education research agenda. (2020).

Baticulon, R. E., Alberto, N. R. I., Baron, M. B. C., Mabulay, R. E. C., Rizada, L. G. T., Sy, J. J., et al. (2021). Barriers to online learning in the time of COVID-19: A national survey of medical students in the Philippines. *Medical Science Educator, 31*(2), 615–626. <https://doi.org/10.1007/s40670-021-01231-z>

Bautista, M. (2022). ICT integration barriers in Philippine public schools. *Journal of Southeast Asian Education Studies, 10*(4), 112–120.

Bolaños, M., Carreon, M., & Ramos, R. (2022). The challenges of distance learning for geographically isolated public schools in the Philippines. *International Journal of Education and Development using ICT, 18*(2), 45–58. <https://ijedict.dec.uwi.edu/viewarticle.php?id=3070>

Bozkurt, A., & Sharma, R. C. (2020). Emergency remote teaching in a time of global crisis due to the coronavirus pandemic. *Asian Journal of Distance Education, 15*(1), 1–6.

Bruner, J. S. (2020). *Actual minds, possible worlds*. Harvard University Press.

Cabual, R. A. (2023). Unequal access, unequal learning: The Philippine education system and the digital divide. *Journal of Public Administration and Governance, 13*(1), 123– 138. <https://www.macrothink.org/journal/index.php/jpag/article/view/22325>

Chang, C. C., & Yang, S. T. (2023). Interactive effects of scaffolding digital game-based learning and cognitive style on adult learners’ emotion, cognitive load and learning performance. *International Journal of Educational Technology in Higher Education, 20*, 16.

Corpuz, B. B., & Salandanan, G. C. (2012). *Principles of teaching 2* (2nd ed.). Lorimar Publishing.

David, C. C., & Ariate, J. M. (2022). Education crisis in the Philippines: Beyond access. *Policy Brief Series*. Ateneo Policy Center.

Department of Education. (2016). *K to 12 curriculum guide: Mathematics (Grades 1–10)*. Pasig City: DepEd.

Department of Education. (2017). *National adoption and implementation of the Philippine Professional Standards for Teachers (DepEd Order No. 42, s. 2017)*. Pasig City: DepEd.

Department of Education. (2019a). *DepEd Order No. 21, s. 2019: Policy guidelines on the K to 12 basic education program*. Pasig City: DepEd.

Department of Education. (2019b). *Sulong EduKalidad: National effort to improve the quality of basic education (DepEd Order No. 14, s. 2019)*. Pasig City: DepEd.

Department of Education. (2022). *Adoption of the MATATAG Curriculum (DepEd Order No. 13, s. 2022)*. Pasig City: DepEd.

Department of Education. (2023). *DepEd Order No. 67, s. 2023: Guidelines on the implementation of the Digital Rise Program*. Pasig City: DepEd.

Department of Education – Cordillera Administrative Region. (2024a). *Administration of the Rapid Math Assessment (RMA) and Comprehensive Literacy Assessment (CRLA) for Grades 1 to 3 and Philippine Informal Reading Inventory (Phil-IRI) for Grades 4 to 6 for the End-of-School-Year (SY 2023–2024) [Regional Memorandum No. 242, s. 2024]*. Baguio City: DepEd–CAR.

Department of Education – Cordillera Administrative Region. (2024b). *National Achievement Test (NAT) results, SY 2023–2024* [Unpublished data]. Baguio City: DepEd–CAR.

Department of Education – Cordillera Administrative Region. (2024c). *RM No. 609, s. 2024 – Results of the 2024 Regional Achievement Test (RAT)* [Internet]. Baguio City: DepEd–CAR.

Desmos Studio. (n.d.). *Desmos graphing calculator* [Internet]. <https://www.desmos.com/calculator>

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., et al. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States of America, 111*(23), 8410–8415.

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Routledge.

Hohenwarter, M., & Preiner, J. (2007). Dynamic mathematics with GeoGebra. *Journal of Online Mathematics and its Applications, 9*(1), 1–8.

Hwang, G. J., & Lai, C. L. (2017). Facilitating and bridging out-of-class and in-class learning: An interactive e-book-based flipped learning approach for math courses. *Journal of Educational Technology & Society, 20*(1), 184–197.

Keengwe, J., & Onchwari, G. (2019). Technology and early childhood education: A technology integration professional development model for practicing teachers. *Early Childhood Education Journal, 47*(4), 431–438.

Kozan, K. (2020). Cognitive load theory in the digital age: Instructional implications of interactive learning environments. *Computers & Education, 149*, 103835.

Lin, T.-J., & Tsai, C.-C. (2017). A multi-dimensional instrument for evaluating web-based learning environments in Taiwan. *Innovations in Education and Teaching International, 54*(1), 80–91.

Mayer, R. E. (2021). *Multimedia learning* (3rd ed.). Cambridge University Press.

Morra, D., Huang, A., Jacobs, A., Leung, F. H., Shrichand, A., Tran, A., et al. (2022). The impact of digital facilitation training on student engagement and learning outcomes during remote education. *MedEdPORTAL, 18*, 11245.

Muhajir, M., Lestari, R., & Sari, D. I. (2023). The impact of digital tool orientation on students' engagement and academic performance: A case study at Makassar State University. *EduLine: Journal of Education and Learning Innovation, 3*(2), 45–56.

Ng, F., Hasegawa, H., & Du Plessis, A. (2024). Enhancing digital competence among academics: The role of professional development and institutional support. *Education + Training, 66*(1), 89–104.

Niem, M. M., Veriña, R. U., & Alcantara, E. C. (2022). Teaching and learning with technology: ICT integration in mathematics education. *Southeast Asian Mathematics Education Journal, 12*(1), 56–72.

OECD. (2020). *Future of education and skills 2030: Conceptual learning framework*. Paris: OECD.

OECD. (2023). *PISA 2022 results (Volume I & II): What students know and can do*. Paris: OECD Publishing.

Puentedura, R. (2014). SAMR: A model for integrating technology into teaching and learning. *Hippasus Blog*.

Rafiq, M., & Iqbal, K. (2024). The impact of digital tools and online learning platforms on higher education learning outcomes: A case for structured training. *International Journal of Educational Research Open, 5*, 100217.

Rahim, N. F. A., & Said, N. M. (2019). Effectiveness of simulation-based learning tools on mathematics achievement. *International Journal of Emerging Technologies in Learning, 14*(24), 132–145.

Romrell, D., Kidder, L., & Wood, E. (2014). The SAMR model as a framework for evaluating mLearning. *Online Learning, 18*(2), 1–15.

Saat, N. A., Alias, A. F., & Saat, M. Z. (2024). Digital technology approach in mathematics education: A systematic review. *International Journal of Academic Research in Progressive Education and Development, 13*(4).

Serin, H. (2023, June 1). The integration of technological devices in mathematics education: A literature review. *ProQuest*, 54–59.

Skulmowski, A., Xu, K., & Han, J. (2022). Understanding cognitive load in digital and online learning: A new perspective on extraneous cognitive load. *Educational Psychology Review, 34*, 171–196.

Soriano, C. R. R. (2020). Remote education during COVID-19: Lessons from the Philippines. In J. Saavedra (Ed.), *Education in crisis* (pp. 32–35). Brookings Institution.

Tan, M. L. (2020). Rote learning in Philippine classrooms: Tradition vs. transformation. *Philippine Journal of Education, 99*(3), 45–57.

Ugalde, L., Santiago-Garabieta, M., Villarejo-Carballido, B., & Puigvert, L. (2021). Impact of interactive learning environments on learning and cognitive development of children with special educational needs: A literature review. *Frontiers in Psychology, 12*, 674033.

UNESCO. (2017). *Education for sustainable development goals: Learning objectives*. Paris: UNESCO.

UNESCO. (2022). *Education and digital inequality: Realities and solutions*. Paris: UNESCO. <https://unesdoc.unesco.org/ark:/48223/pf0000381045>

University of Colorado Boulder. (n.d.). *PhET Interactive Simulations* [Internet]. <https://phet.colorado.edu>

Villaseñor, R. A. (2024). Challenges and dilemmas of digitalization in Philippine education: A grassroots perspective. *Journal of Public Administration and Governance, 14*(2), 232.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Yáñez Gómez, R. M., Cano, M. B., & Montero, F. (2021). Enhancing mathematical learning with visualization tools: A study on GeoGebra use in primary education. *International Journal of Mathematical Education in Science and Technology, 52*(2), 263–278.

Zbiek, R. M., & Hollebrands, K. F. (2023). A research synthesis of technology in secondary school mathematics. In *Second handbook of research on mathematics teaching and learning* (pp. 997–1021). Information Age Publishing.

Zhang, Y., Wang, P., Jia, W., Zhang, A., & Chen, G. (2025). Dynamic visualization by GeoGebra for mathematics learning: A meta-analysis of 20 years of research. *Journal of Research on Technology in Education, 57*(2), 437–458.