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Use of Visual Representation on Student Mathematical Word Problem-Solving Skills: The Mediating Role of ICT Integration

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ABSTRACT

Low problem-solving skill is a concern in mathematics education. The mediating role of ICT integration on use of visual representation - student mathematical word problem-solving skills correlation was explored. Descriptive-correlational research design, stratified random sampling in selecting 296 Grade 10 students, survey approach, and mediation analysis were applied in the study. Results revealed that the predictor-criterion correlation was not significantly mediated. The Dual Coding Theory was denied. Further research may be explored testing other potential variables as mediators. Teachers may divert to other means of learning and redirect educational resources for alternative methods.

Keywords: Use of visual representation, mathematical word problem-solving skills, mediating role of ICT integration

INTRODUCTION

The Problem and Its Setting

Difficulty in solving mathematical word problems remains a global concern, as many students still demonstrate low performance and limited proficiency despite the growing emphasis on higher-order thinking and problem-solving skills in modern mathematics curricula (Säfström et al., 2023). Moreover, evidence from contemporary educational research indicates that difficulties in interpreting mathematical relationships and identifying unknown quantities persist among learners at different educational levels, demonstrating the ongoing global struggle with mathematical word problem solving (Wong et al., 2023).

Student difficulty in solving mathematical word problems is evident across countries, including the United States, where students with mathematics difficulties continue to perform poorly in tasks involving reasoning and mathematical representation. (Xin et al., 2023). In China, research showed that many early adolescent learners encounter persistent difficulties in understanding and solving arithmetic word problems, reflecting continuing concerns regarding mathematical comprehension and problem-solving performance (Zhang et al., 2023). Similarly, in Indonesia, investigations demonstrated that secondary school students still exhibit low ability to solve mathematical word problems and experience difficulties in applying mathematical reasoning to contextualized tasks (Hidayah & Prayitno, 2023).

In the Philippines, difficulty in solving mathematical word problems remains a major concern, as many Grade 8 students struggle with linear equation word problems and show weak performance in mathematical problem-solving activities (Tilos & Balila, 2023). Similarly, studies conducted among Filipino secondary students identified frequent errors and low proficiency in solving mathematical word problems, emphasizing the persistent nature of this issue in Philippine mathematics education (Verzosa & Mabansag, 2023).

Learners who consistently have difficulty in solving word problems may demonstrate low mathematics achievement and reduced confidence in engaging with complex mathematical tasks (Xin et al., 2023). Furthermore, persistent struggles in mathematical word problem solving may negatively affect students' academic preparedness for advanced mathematical learning and future career opportunities that require quantitative reasoning and problem-solving competencies (King & Powell, 2023). Hence, addressing student difficulty in solving mathematical word problems remains an important concern in improving mathematics education and learners' overall academic performance.

Significance of the Study

This study was significant because it may help address students' difficulty in solving mathematical word problems, thereby supporting the attainment of Sustainable Development Goal 4 (Quality Education) by promoting inclusive and equitable quality mathematics education and enhancing learners' problem-solving competencies. In the Philippine context, the findings of this study may support the Department of Education's goals of improving mathematics achievement, strengthening learners' critical thinking skills, and enhancing the overall quality of instruction through evidence-based educational practices. At the institutional level, the results may be valuable to Holy Cross of Davao College in strengthening faculty development, promoting teacher well-being, and sustaining a mission-driven academic community aligned with its commitment to excellence, service, and holistic formation, ultimately contributing to improved student learning outcomes and long-term educational sustainability.

Statement of the Problem

This study aimed to investigate the extent to which the use of visual representation affects student mathematical word problem-solving skills and to examine whether ICT integration mediates this relationship. Specifically, this study sought to address the following objectives.

1. To determine the levels of use of visual representation in terms of diagrams, and physical models; ICT integration in terms of readiness to integrate ICT tools, and the extent of ICT use; and student mathematical word problem-solving skills using the four steps in Polya's method.
2. To determine the significance of the correlation between the use of visual representation and student mathematical word problem-solving skills.
3. To determine the significance of the correlation between ICT integration and student mathematical word problem-solving skills.
4. To determine the significance of the direct effect of use of visual representation on student mathematical word problem-solving skills, controlling for ICT integration.
5. To determine the significance of the indirect effect of use of visual representation on student mathematical word problem-solving skills through ICT integration.
6. To determine the significance of the total effect of use of visual representation on student mathematical word problem-solving skills

Hypotheses

Ho_1: Use of visual representation does not significantly correlate with student mathematical word problem-solving skills.

Ho_2: ICT integration does not significantly correlate with student mathematical word problem-solving skills.

Ho_3: The direct effect of the use of visual representation on student mathematical word problem-solving skills, controlling for ICT integration, is not significant.

Ho_4: The indirect effect of the use of visual representation on student mathematical word problem-solving skills through ICT integration is not significant.

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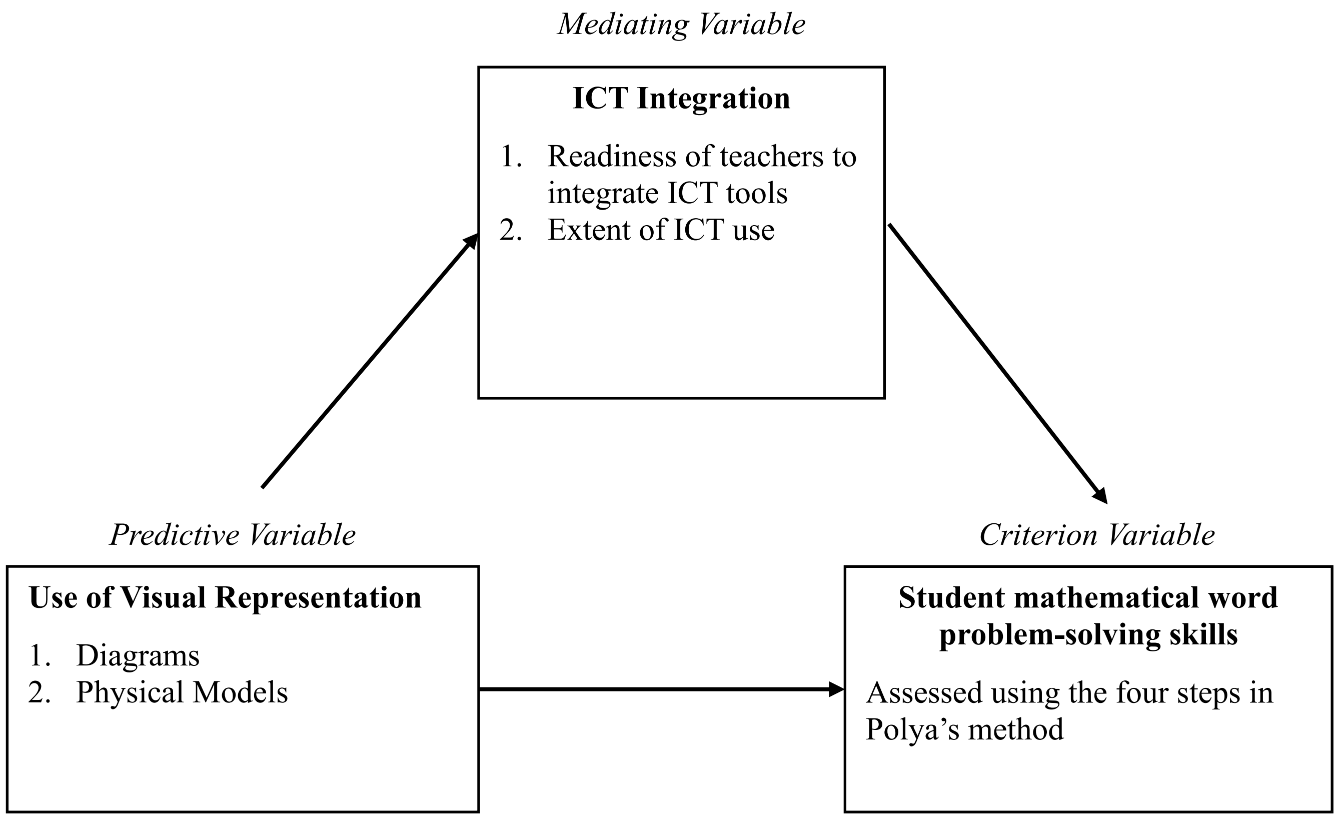
Ho_5: The total effect of the use of visual representation on student mathematical word problem-solving skills is not significant.

THEORETICAL FRAMEWORK AND CONCEPTUAL FRAMEWORK

This study was anchored in Allan Paivio's Dual Coding Theory, which posits that verbal information (e.g., words, texts, and numbers) and visual information (e.g., diagrams, images, and graphic organizers) are processed through two distinct yet interconnected cognitive channels in long-term memory. According to the theory, learning is enhanced when information is presented simultaneously in both verbal and visual modalities, as this dual presentation facilitates elaboration, strengthens mental connections, and promotes a deeper understanding of the material (Paivio, 1990).

In this study, the predictive variable was the use of visual representation indicated by Diagrams and Physical Models (Parame-Decin, 2023), reflecting the verbal and visual information emphasized in Paivio's Dual Coding Theory. The mediating variable was ICT integration, measured by teachers' readiness to integrate ICT tools (Arhin et al., 2024) and the extent of ICT use in mathematics instruction (Alcantara et al., 2020). ICT integration was proposed as a mediating variable since technology-based instructional tools can serve as a platform through which visual representations are created, enhanced, and delivered to learners. Consistent with Dual Coding Theory, ICT tools such as presentation software, dynamic mathematics applications, and interactive visualizations can simultaneously provide verbal explanations and visual representations, thereby strengthening students' cognitive processing of mathematical information. The criterion variable was the student mathematical word problem-solving skills, assessed using the four steps in Polya's method. Together, these variables served as basis of the conceptual framework.

Figure 1: The Conceptual Framework



METHODOLOGY

This chapter includes the research design, the study locale, the sample and sampling technique, the data-gathering technique, data analysis, and ethical considerations.

Research Design

This study employed a descriptive-correlational research design. It is a quantitative, non-experimental approach used to describe existing conditions and examine relationships among variables without manipulation, enabling efficient collection of large datasets and systematic variable description. (Miksza et al., 2023). Descriptive-correlational research design is applied when the researcher aims to examine whether significant associations exist among variables in a natural setting while simultaneously presenting an accurate description of the status of the phenomena being studied (Devi et al., 2023). Moreover, this study incorporated a mediation analysis. It is a statistical technique used to determine how or why an independent variable influences a dependent variable by examining whether the relationship occurs directly or indirectly through an intervening variable known as a mediator (Angriman et al., 2024).

Locale of the Study

This study was conducted in three public secondary schools in Cluster 6, Davao City. The Schools Division of Davao City, a divisional entity of the Department of Education, supervises these schools. These schools are chosen because they align with the study's objectives of focusing on a homogeneous group with consistent curriculum implementation and the necessary equipment to integrate ICT into the teaching and learning process.

Sample and Sampling Technique

The respondents in this study were 296 Grade 10 students enrolled in the school year 2025–2026 at three public secondary schools in Cluster 6, Davao City, for a total population of 1,272 students. These students were minors aged 15-16.

The study used stratified random sampling. It is a probability sampling technique in which the population was divided into homogeneous subgroups called strata, and random samples are selected from each group (Thomas, 2023). Stratified random sampling was used in the study to ensure that important subgroups of a population are adequately represented, especially when the population was diverse. Its advantages include greater accuracy, reduced sampling error, and better population representation than simple random sampling (Simkus, 2023). The required sample size was calculated using the Raosoft Sample Size Calculator. This freely available web-based tool computes the appropriate sample size for a given population, desired margin of error, confidence level, and response distribution.

Data Gathering Technique

This study used a survey technique to gather data. Survey technique is a method of collecting data by asking respondents a set of structured questions through questionnaires, interviews, or online forms (Goodfellow, 2023). Surveys are commonly used in educational and social research because they provide cost-effective and efficient access to participants (Mazikana, 2023).

In gathering the data, the study used three adapted and modified survey questionnaires. The first questionnaire measured the use of visual representation and was adapted from Parame-Decin (2023) with ten (10) statements evenly distributed in each indicator: Diagrams and Physical Models. This study used a four-point Likert scale to describe the utilization of visual representation of teachers as perceived by the respondents. The adapted instruments were pilot tested for reliability, yielding a Cronbach's alpha of 0.729.

The second instrument measured the ICT integration and was adapted from Arhin et al. (2024) and Alcantara et al. (2020). The section consisted of ten (10) statements divided into two indicators: Readiness of teachers to

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integrate ICT tools, and the Extent of ICT use. This questionnaire also used a four-point Likert scale to assess the extent of teachers' ICT integration as perceived by the respondents. Pilot testing revealed a Cronbach's alpha of 0.742

The third instrument was a written test consisting of two (2) word problems adapted from the Mathematics 10 Self-Learning Modules of the Department of Education–Davao City Division by Torollo and Dujali (2020). The items mainly focused on the Permutation topic, which was covered during the first week of Quarter 3 in the current school year. Student responses to the word problems were evaluated using a four-point scoring rubric based on Polya's four-step problem-solving method. Although pilot testing revealed a Cronbach's alpha of 0.608, its internal consistency was acceptable.

Data Analysis

In this study, the data analysis techniques used were descriptive, correlation, and mediation analysis. Descriptive analysis is essential in quantitative research, as it summarizes raw data into understandable forms that describe key characteristics of a dataset (Kotronoulas et al., 2023). Mean and standard deviation were used in this study. Moreover, correlation analysis indicates whether variables are related positively, negatively, or not related at all, helping researchers understand data patterns clearly (Bhandari, 2023). The Pearson Product-Moment correlation statistical tool was used. Lastly, mediation analysis allows researchers to understand intermediate processes or pathways through which an exposure affects an outcome, making it a key tool for identifying mechanisms in behavioral, educational, and health studies (Schuler et.al, 2024). The Beta estimate statistical tool was utilized to estimate the direct, indirect, and total effects of the determinant.

The matrix below presents the scale, descriptive levels, and corresponding interpretations assigned to each variable in the study.

Scale	Descriptive level	Use of Visual Representation	ICT Integration	Student Mathematical Word Problem-Solving Skills
3.26 - 4.00	Very High	Always	To a very great extent	Very Good
2.50 – 3.25	High	Sometimes	To a great extent	Good
1.75 -2.49	Low	Seldom	To a lesser extent	Poor
1.00 -1.74	Very Low	never utilized	Lack of use	Very poor

Standard Deviation Value Ranges and Interpretation

Range	Description	Interpretation
SD ≤ 0.50	Highly consistent responses	Strong and uniform perception
SD = 0.51 – 1.00	Moderate consistent responses	Acceptable consistency
SD = 1.01 – 1.50	Low consistent responses	Differing views or experiences
SD > 1.50	Very low consistent responses	High variability and lack of consensus

The r-value is interpreted using the scale below.

Computed r	Descriptive Interpretation
+/- 1.00	Perfect correlation
Between +/- 0.75 - +/- 0.99	High correlation
Between +/- 0.51 - +/- 0.74	Moderately high correlation
Between +/- 0.31 - +/- 0.50	Moderately low correlation

Between +/- 0.01 - +/- 0.30	Low correlation
0.00	No correlation

The standard measure for the interpretation of the strength of the mediation was as follows:

Proportion Mediated	Interpretation
< 0.20	Weak Mediation
0.20 – 0.50	Moderate Mediation
> 0.50	Strong Mediation

Ethical Considerations

In this study, ethical standards in conducting research involving grade 10 students were strictly observed. Prior to the data collection, the researcher provided informed consent to parents using a detailed document that explained the purpose of the study, procedures, risks, benefits, confidentiality, and voluntary participation. They reviewed and signed the document, formally granting permission for their child's involvement. Likewise, simplified and age-appropriate informed assent was obtained from the respondents informing them of the study information and ensuring their full awareness of their rights and the freedom to withdraw at any time without penalty. Permission from the Department of Education – Schools Division of Davao City was formally secured to conduct the study within public schools under its jurisdiction. Moreover, the research proposal was reviewed and approved by the Society for Moral Integrity and Legal Ethics (SMILE) to ensure adherence to ethical, legal, and moral research principles.

RESULTS

This chapter displays the tabular findings of the descriptive, correlation, and mediation analyses, along with their interpretations. It concludes with a summary of the study's key findings.

Descriptive Results

The study's descriptive results are shown in Table 1. It summarizes the key variables, use of visual representation, ICT integration, and student mathematical word problem-solving skills, along with their corresponding indicators, sample size, mean, standard deviation, and descriptive interpretations.

Table 1. Descriptive Analysis.

Variables	N	SD	Mean	Descriptive Level
Use of Visual Representation	**296**	**0.48**	**3.01**	**High**
Diagrams	296	0.53	3.01	High
Physical Model	296	0.58	3.01	High
ICT Integration	**296**	**0.45**	**3.01**	**High**
Readiness of teachers to integrate ICT tools	296	0.58	2.93	High
Extent of ICT use	296	0.55	3.10	High
Student mathematical word problem-solving skills	**296**	**0.88**	**2.51**	**High**
Very High - (3.26 – 4.00); High - (2.50 – 3.25); Low – (1.75 – 2.49); Very Low – (1.00 – 1.74)				

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It is shown that the use of visual representation variable had a mean of 3.01, indicating a high level of use and suggesting that their teachers sometimes utilize visual representation. All indicators obtained a high level, suggesting that they are sometimes utilized in the delivery of their lessons. The corresponding standard deviation of 0.48 is considered high, indicating a strong and uniform perception among the respondents. Moreover, the ICT integration variable had a mean of 3.01, indicating a high level of integration, suggesting that teachers integrate ICT into their lessons to a great extent. It is supported by its indicators, which are all at a high level, implying that teachers are ready to integrate and use ICT tools in their teaching. The standard deviation of 0.45 indicates high consistency in responses, suggesting a strong and uniform perception. Furthermore, the variable of student mathematical word problem-solving skills had a mean of 2.51, indicating a high level and suggesting that their skills are good, reflecting strong analytical and critical thinking. The standard deviation of 0.88, which is considered moderately consistent, suggests that responses are acceptable in terms of consistency.

Use of visual representation and ICT integration are similarly high, reflecting consistent and frequent application in instruction, while student mathematical word problem-solving skills are also at a high level but show slightly less consistency in responses. Overall, all variables demonstrate positive levels, with instructional practices showing stronger uniformity than students' performance.

Correlation Results

Table 2 is correlational table. It presents the predictive, mediating, and criterion variables. It shows the r-value, p-value, decision on null hypothesis, and the corresponding interpretation.

Table 2. Correlation Analysis.

Variables	Student mathematical word problem-solving skills				
	N	r	p-value	Decision on H_o	Interpretation
Use of Visual Representation	296	0.039	0.502	Failed to reject H_o	Low positive correlation, Not Significant
ICT Integration	296	-0.036	0.535	Failed to reject H_o	Low negative correlation, Not Significant
Level of Significance: 0.05 Decision Rule: Reject H_0 if $p < 0.05$					

Results show that the correlation between the use of visual representation and student mathematical word problem-solving skills variables obtained a p-value of 0.502. Such a value is greater than 0.05 level of significance, indicating that the correlation is not significant; hence, the null hypothesis is not rejected. The corresponding r-value is 0.039, suggesting a low positive correlation. This implies that every change in the use of visual representation is not accompanied by a corresponding change in student mathematical word problem-solving skills. On the other hand, the correlation between ICT integration and student mathematical word problem-solving skills variables obtained a p-value of 0.535 which is above the 0.05 level of significance. This indicates that the correlation is not significant, so the null hypothesis is not rejected. The corresponding r-value obtained between the two variables is -0.036, indicating a low negative correlation. This implies that every change in ICT integration is not accompanied by a corresponding change in student mathematical word problem-solving skills.

The results show that none of the relationships is significant, with the use of visual representation and student mathematical word problem-solving skills variables exhibiting a weak positive association. In contrast, ICT integration and student mathematical word problem-solving skills variables show a weak negative association, indicating that all relationships are minimal and inconsistent.

Mediation Results

Table 3 is a mediation table. It contains the path/effect, the estimate of Beta, the standard error, the z-value, the p-value, the decision on null hypothesis and the corresponding interpretation.

Table 3. Mediation Analysis

Label	Path/ Effect	Estimate (B)	SE	z-value	p-value	Decision on H_o	Interpretation
a	Use of Visual Representation → ICT Integration	0.45	0.05	8.58	0.000	Reject H_o	Significant
b	ICT Integration → Student Mathematical Word Problem-Solving Skills	-0.14	0.11	-1.22	0.221	Failed to reject H_o	Not significant
c’	Use of Visual Representation → Student Mathematical Word Problem-Solving Skills (Direct Effect)	0.13	0.11	1.20	0.232	Failed to reject H_o	Not significant
a × b	Indirect Effect (Mediation)	-0.06	0.05	-1.20	0.229	Failed to reject H_o	Not significant
(a × b) +c	Use of Visual Representation → Student Mathematical Word Problem-Solving Skills (Total Effect)	0.07	0.10	0.70	0.486	Failed to reject H_o	Not significant
Level of Significance: 0.05 Decision Rule: Reject H_0 if $p < 0.05$ Proportion Mediated: indirect effect/ total effect = NO MEDIATION							

As shown in the result, the direct effect of the use of visual representation on student mathematical word problem-solving skills, controlling for ICT integration, yielded an estimated Beta of 0.13, with a corresponding p-value of 0.232, which is greater than the 0.05 level of significance; thus, failing to reject the null hypothesis. This indicates that the direct effect of the use of visual representation on student mathematical word problem-solving skills, controlling for ICT integration, is not significant. Similarly, the indirect effect of the use of visual representation on student mathematical word problem-solving skills through ICT integration obtained an estimated Beta of -0.06, with a p-value of 0.229, which is greater than the 0.05 level of significance. Hence, null hypothesis was not rejected. This indicates that the indirect effect of the use of visual representation on the criterion through the mediator is not significant. Lastly, the total effect of the use of visual representation on student mathematical word problem-solving skills resulted in an estimated Beta of 0.07. The corresponding p-value of 0.486, which is above the 0.05 level of significance, fails to reject the null hypothesis. This indicates that the total effect of the use of visual representation on the criterion is not significant.

The results reveal that the use of visual representation does not have a significant direct effect on student mathematical word problem-solving skills when ICT integration is controlled. Likewise, both the indirect effect through ICT integration and the overall total effect are not significant, indicating that no mediation has occurred.

However, these null findings may be influenced by limitations in the measurement of the variables. The assessment of mathematical word problem-solving skills was based on a limited number of items and specific mathematical domain which may not have fully captured the complexity of students' problem-solving abilities.

In particular, the narrow operationalization of problem-solving skills may have restricted the detection of meaningful relationships among the variables.

SUMMARY OF FINDINGS

Based on the statistical results, it was found that:

1. The use of visual representation did not significantly correlate with student mathematical word problem-solving skills.
2. ICT integration did not significantly correlate with student mathematical word problem-solving skills.
3. The direct effect of the use of visual representation on student mathematical word problem-solving skills, controlling for ICT integration, was not significant.
4. The indirect effect of the use of visual representation on student mathematical word problem-solving skills through ICT integration was not significant.
5. The total effect of the use of visual representation on student mathematical word problem-solving skills was not significant.

DISCUSSIONS

This chapter discusses the findings, conclusions, and recommendations.

Use of visual representation on student mathematical word problem-solving skills correlation

The findings indicate that the use of visual representation has no significant correlation with student mathematical word problem-solving skills, suggesting that visual representation do not significantly improve the mathematical word problem-solving skills of students. This result affirms Wei et al. (2023), who found that visual cueing had a limited influence on improving students' performance in solving arithmetic word problems, particularly among learners with mathematical learning difficulties, despite helping sustain attention during tasks. Similarly, the finding supports the systematic review by Vessonen et al. (2026), which highlights that representational pictures were not consistently associated with better performance, particularly in mathematically and linguistically complex word problems. It emphasized that when tasks involve higher cognitive demands, visual representations tend to show no effects.

However, the present finding contradicts the study by Purcar et al. (2024), which indicated that students who solved mathematical word problems using visual contexts and representations demonstrated significantly better problem-solving performance than those who solved problems in a normal text-only context. The study emphasized that visual representations enhanced learners' comprehension and supported accurate interpretation of mathematical situations, leading to improved solutions in word problems.

ICT integration and student mathematical word problem-solving skills correlation

The finding that ICT integration does not significantly correlate with student mathematical word problem-solving skills suggests that the use of technology in instruction is insufficient to improve students' problem-solving skills. This result affirms the findings of Pastor and Pedro (2023), who found no strong direct relationship between teachers' ICT use and students' problem-solving skills, despite teachers demonstrating high competence and positive attitudes toward ICT. This suggests that effective integration requires more than technical proficiency and must be meaningfully aligned with instructional goals and student needs. Similarly, the finding supports Suarez and Tado (2025), who reported that technology integration did not significantly relate to students' problem-solving skills in Mathematics, emphasizing that other cognitive and instructional factors may contribute more strongly to problem-solving development than ICT use itself.

On the other hand, this finding contradicts the study of Susilowaty (2023), revealing that ICT-assisted learning significantly improved students' mathematical understanding and problem-solving ability. The study argued that properly designed ICT-supported instruction can enhance students' engagement and analytical thinking, thereby strengthening their performance in mathematical problem-solving.

Mediating effect of ICT integration

The mediation result shows that ICT integration does not mediate the relationship between the use of visual representation and student mathematical word problem-solving skills. This affirms Courtney et al. (2022), who stated that ICT use in education has an inconsistent and often insignificant relationship with students' mathematics achievement. It asserts that mere exposure to technology does not guarantee improved learning outcomes, particularly when ICT is not pedagogically aligned with instructional goals. Moreover, the present finding supports Refvik and Opsal (2023), who found that participation in programming and computational thinking activities did not significantly improve students' mathematical problem-solving abilities, suggesting that integrating technological approaches may not necessarily strengthen students' problem-solving performance when instructional connections are weak.

However, a study of Liang and She (2021) contradicts the finding. They investigated the use of multiple representational scaffolds in an online (ICT-supported) environment. They found that students who were exposed to multiple representations (e.g., diagrams, symbols, and interactive supports) demonstrated significantly better mathematical problem-solving performance compared to those using a single representation.

CONCLUSION

Based on the findings, it is concluded that the student mathematical word problem-solving skills and use of visual representation correlation are not significantly mediated by ICT integration. This result opposes the assumption of Dual Coding Theory, which holds that learning is enhanced when information is presented simultaneously in both verbal and visual modalities.

RECOMMENDATION

Based on the conclusion, the following are recommended:

1. Further research may be explored testing other potential variables as mediators. Moreover, the use of a more comprehensive word problem-solving assessment is recommended to enhance the validity and reliability of the measurement of student mathematical problem-solving skills.

2. Teachers may divert to other means of learning and redirect educational resources for alternative methods.

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