

DIGITAL LITERACY AND AI-SUPPORTED MATHEMATICAL PROBLEM-SOLVING AMONG SECONDARY SCHOOL STUDENTS: AN EXPLANATORY MIXED-METHODS STUDY

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Abstract

This study investigated the level of digital literacy and generative AI-supported mathematical problem-solving among secondary school students. The study employed an explanatory mixed-method design. 62 students were used for the study and 8 of them were interviewed. Digital Literacy and Competence in Mathematics Questionnaire” (DLCMQ) for students, and Semi-structured interview guide for students were the instrument used for the study. The instruments were validated and trial tested with DLCMQ yielding a reliability coefficient of 0.77. The findings of this study indicated a high rate of digital literacy (Mean=2.64; SD=0.48); a low rate of gen.AI competence (Mean=2.39; SD= 0.47); a high rate of generative AI usage (Mean=2.60; SD=0.49); a low rate of generated AI verification; and a very high rate of challenges (Mean=3.51; SD= 0.56). It was recommended among others that mathematics teachers should endeavor to educate students about the need to use generative AI-support tools in personalized learning.

Keywords: Digital literacy, Generative AI, Mathematics learning, Mixed-method, Problem-solving.

Introduction

The rapid development of digital technologies and artificial intelligence (AI) is transforming teaching and learning across STEM disciplines. Mathematics being the cornerstone of STEM occupies a central position in school curricula worldwide because of its importance in scientific reasoning, technological development, and everyday problem solving (Ukwueze & Egbuniwe, 2026). Despite this importance, many students experience challenges while studying mathematics leading to their low academic achievement (Ukwueze, 2024). This low achievement was evidenced in the WAEC chief examiners’ reports of the year (2022-2025). The cause of this could be none usage of generative AI

tools by individual student for mathematics learning, hence, the need for this study which focused on ascertaining the level of digital literacy knowledge and competences in using AI-supported mathematical problem-solving among secondary school students using an explanatory mixed-methods approach.

Previous studies have shown that improving students' mathematics performance requires a multifaceted approach (Ukwueze et al., 2024; Egara & Mosimege, 2024; Ukwueze, 2026). This includes students' use of AI-ChatGPT-powered personalized instruction (Abedi, 2023; Mhlongo et al., 2023; Ukwueze & Egbuniwe, 2026). Despite these approaches, students continue to struggle with the learning of mathematics as reflected by the WAEC chief examiners' report of year (2025). This state of art has been attributed to many factors such as ineffective teaching methods, lack of student interest, inadequate study habits (Gloria-Ibemenji et al., 2019; Ukwueze et al., 2022). Ineffective teaching techniques (Salami, 2024). A lack of personalized support to accommodate varying learning paces and styles (Ukwueze, 2024). Moreover, research has hinted that classroom teaching and learning were better with the usage of guided open AI apps in classroom instructions (Ukwueze & Egbuniwe, 2026).

The above assertions pointed the fact that teaching and learning of mathematics in this era should be geared towards building students' confidence to learn using digital tools. This brought the need for this present study which aimed at investigating the level of digital literacy and competence in using AI-supported mathematical problem-solving among secondary school students using an explanatory mixed-methods approach.

Empirical literatures have noted that artificial intelligence tools such as intelligent tutoring systems, adaptive learning platforms, and online learning environments have been used to support differentiated instruction (Nja, et al., 2024). More recently, the emergence of Artificial Intelligence (AI) has further expanded the potential of educational technology to provide real-time, individualized learning support (Garcia-Martinez, 2023; Owan et al., 2023). This can effectively be so if students' levels of digital literacy knowledge and competence in using generative AI-supported mathematics problem-solving is commensurate.

In mathematics education, generative AI tools can provide explanations, worked examples, alternative solution strategies, feedback, and opportunities for students to engage with mathematical problems interactively when well used (UNESCO, 2023). However, access to such technologies does not necessarily mean that students can use them effectively for learning thereby hinting back on their level of digital literacy and competences in utilizing generative AI-tools in mathematics problem-solving exercises.

Digital literacy is therefore increasingly important in the learning of mathematics and other STEM discipline. A digital literate mathematics learner needs more than the ability to operate a digital device (Long & Magerko, 2020). The learner must be able to formulate appropriate prompts, evaluate AI-generated mathematical responses, identify errors, verify solutions using mathematical reasoning, and use AI responsibly as a learning support rather than simply copying answers (Long & Magerko, 2020; Vuorikari et al., 2022; OECD, 2023). The authors stand above created an important issue for mathematics education discourse thus: Does students' level of digital literacy influence how competently they use generative AI for mathematical problem-solving? For this study, students' digital literacy and competence in using generative AI-supported tools for mathematics problem-solving was the onus to be eschewed. Study has noted that the capacity to provide individualized real-time responses to mathematics learner presents new possibilities for improving the learning knowing that the subject is often associated with low anxiety, low achievement, and low engagement among students (Wardat et al., 2023).

Despite this, digital literacy and competence in employing generative AI-supported tools for mathematics problem-solving is greatly alarming. The study can therefore move beyond simply asking whether students' use ChatGPT or other generative-AI tools to investigate how competently students use these technologies and whether generated AI are verified and evaluated by students in their mathematical problem-solving.

Study has suggested that AI-ChatGPT could enhance mathematics instruction by promoting learner-centered and interactive learning experiences (Wardat et al., 2023; Tlili et al., 2023). In mathematics classrooms, ChatGPT has the potential to function as a virtual tutor that supports students outside and within the classroom by offering personalized instructions tailored to their level of

understanding. In spite of these promising possibilities, the actual impact of generative AI tools on mathematics learning outcomes and classroom practices remains largely under-researched in Enugu State, Nigeria. Questions remain regarding whether the students really possess the competence needed to verify and evaluate generated AI answers? Furthermore, successful integration of any new technology depends not only on its instructional potentials but also on level of digital literacy knowledge of the users.

Moreover, given the novelty of generative AI-supported learning and the complexity of classroom environments, existing studies on the AI-tools in education often rely solely on quantitatively analyzed data or qualitatively analyzed data. A mixed method approach is necessary to quantitatively measure the levels in both possessions of technological literacy and competence needed in its usage, qualitatively explore students' experiences and challenges encountered during learning. Also, empirical evidence on generative AI-tools for mathematics learning is still limited, particularly in developing educational contexts like Igbo-Eze North LGA of Enugu State, Nigeria. In the same lane, there is insufficient research on: whether the learner can formulate appropriate prompts, evaluate AI-generated mathematical responses, identify errors, verify solutions using mathematical reasoning, and use AI responsibly as a learning support rather than simply copying answers? Also, does students' level of digital literacy influence how competently they use generative AI for mathematical problem-solving? The anticipated answers create a lacuna in the literature of which, without such evidence, educators and policymakers cannot make informed decisions about generative AI tools in mathematics instruction. This study will therefore investigate the students' level of digital literacy and their competence in using generative AI for mathematical problem-solving, while also exploring students' experiences and challenges when using AI-supported mathematics learning in Igbo-Eze North LGA.

The study was guided by the following research questions: what is the level of students' digital literacy for mathematics learning? what is the level of students' competence in using generative AI for mathematics problem-solving? how do students use generative AI when solving mathematical problems? how do students evaluate and verify mathematical solutions generated by AI? what challenges do students experience when using generative AI for mathematics learning?

In order to provide answers to the above questions, the study was guided by three underpinning theoretical frameworks thus: digital literacy theory, AI literacy perspective and mathematical problem-solving framework

The central theoretical foundation of the study is digital literacy theory (Eshet-Alkalai, 2004; Vuorikari et al., 2022; OECD, 2023). The theory conceptualizes digital literacy as more than the technical ability to operate computers or digital devices. It encompasses the ability to access, understand, evaluate, create and communicate information through digital technologies (OECD, 2023). Digital literacy is a form of critical engagement with information rather than simply a technical skill. It incorporates information processing, communication, content creation, safety and problem solving (Eshet-Alkalai, 2004). Also, the European Digital Competence Framework (DigComp) provides a particularly useful operationalization. The framework identifies five major competence areas: Information and data literacy, communication and collaboration, digital content creation, safety and problem solving (Vuorikari et al., 2022). These dimensions are highly relevant to mathematics education because students increasingly encounter mathematical information, representations, explanations, and problem-solving resources through digital environments. In the context of the present study, digital literacy is conceptualized as students' ability to access digital resources, formulate appropriate requests, evaluate digital information, interact critically with digital technologies, identify inaccuracies and use digital tools to solve mathematical problem responsibly. This perspective is particularly important with generative AI. A student who simply accepts an AI-generated mathematics answer demonstrates technology use, but not necessarily digital literacy. A digital literate student should be able to question the response, inspect the reasoning, identify possible errors, compare the response with mathematical principles and independently verify the result. Thus, the study assumes that higher levels of digital literacy should be associated with more effective and critical use of generative AI for mathematics learning.

AI Literacy Perspective (Long & Magerko, 2020; Ng et al., 2021). This perspective is an extension of conventional digital literacy because AI systems differ from ordinary digital tools. Students need to understand not only how to use AI but also its capabilities, limitations, probabilistic nature and potential to produce inaccurate information. Ng et al. (2021) conceptualize AI literacy as the competencies required to appropriately understand, evaluate, interact with

and use AI systems. Their framework emphasizes competencies such as recognizing AI, understanding its limitations, interpreting AI outputs, evaluating AI systems and using AI appropriately. This perspective is directly relevant to mathematics education. Generative AI can produce mathematically convincing but incorrect solutions. Consequently, students need AI literacy to distinguish between an apparently plausible answer and a mathematically valid answer. For this study, AI literacy is therefore, viewed through five interconnected competencies: understanding AI: knowing what generative AI can and cannot do; interacting with AI: communicating mathematical problems effectively through prompts; evaluating AI outputs: critically examining generated explanations and solutions; verifying AI-generated mathematics: using mathematical reasoning and alternative procedures to establish correctness; and responsible AI use: using AI as a learning support rather than simply copying generated answers. The AI-literacy perspective therefore provides the bridge between general digital literacy and actual competence in AI-supported mathematics learning.

The third theoretical component is the theory of mathematical problem-solving framework (Polya, 1945). Polya (1945) conceptualized mathematical problem-solving as a process involving four major stages: understanding the problem; devising a plan; carrying out the plan; and looking back. These stages provide an appropriate framework by examining how students use generative AI in mathematical problem-solving. For example, when confronted with a mathematical problem, a digitally and AI-literate students should first understand the problem rather than immediately asking AI for answer. The student may then use AI to explore possible strategies, compare alternative approaches and obtain explanations. However, the student should still carry out or reconstruct the mathematical reasoning and finally look back by checking whether the AI-generated answer is mathematically reasonable. This final stage is particularly important in the age of generative AI. AI can support problem-solving, but students must retain mathematical agency and responsibility for determining whether a solution is correct. This framework provides the mathematics-specific dimension of the study, while digital literacy and AI literacy explain the technological dimension.

An important critical position of this study is that AI access as result of digital literacy knowledge should not be equated with AI competence. A student may have frequent access to ChatGPT or another generative-AI system but still

have weak digital literacy. Such a student may accept generated solutions without questioning their validity. Conversely, a student with stronger digital and mathematical literacy may use AI dialogically asking for explanations, requesting alternative strategies, checking assumptions and identifying errors. Consequently, the study does not conceptualize generative AI as a replacement for mathematical thinking. Rather, it conceptualizes AI as a mediating digital tool whose educational value depends partly on the learner's digital literacy and mathematical competencies. This distinction gives the study a strong critical dimension. It shifts the question from: "Do students use generative AI to solve mathematics problems?" to: "What competencies enable students to use generative AI critically, responsibly and productively?" This is particularly important for STEM education because digital transformation can potentially widen rather than reduce educational inequalities if students differ substantially in their digital literacy, access to technology and capacity to critically evaluate AI-generated information.

Method

The study adopted a mixed-methods research design, specifically an explanatory sequential design. This design allows collecting and analyzing quantitative data first, followed by qualitative data, and then integrated to provide a holistic understanding of research problem (Creswell, 2018). The target population is all the senior secondary school two mathematics students of 2025/2026 session promoted to SS3 in Igbo-Eze North LGA of Enugu state, Nigeria. Purposive sampling technique was used in selecting one study centre (lesson centre) for the study. The choice of that was because, it was the only lesson centre within the local government with students from different schools across the area. All the 62 students found in the lesson centre were used for the study. The subset of 8 students were used for the semi-structure interview. The choice of using SS2 promoted to SS3 was because digital literacy and AI-supported STEM learning at their level is particularly an important educational issue.

Instruments for data collections were "Digital Literacy and Competence in Mathematics Questionnaire" (DLCMQ), and Semi-structured interview guide for students. The Digital Literacy and Competence in Mathematics Questionnaire" (DLCMQ) was adapted from (Vuorikari et al., 2022), while the Semi-structured interview guide was adapted from (Long & Magerko, 2020). The instrument contained two sections: Section A meant for instruction

on how to respond to the questionnaire while Section B was the item statements. The item statement was made up of 20 items seeking information about data literacy, digital content creation, digital safety and responsible use, digital problem-solving, understanding generative AI, evaluation of AI-generated information which were needed to answer the posed research questions. The items were responded based on Strongly Agree (SA=4points), Agree (A=3points), Disagree (D=2points), and Strongly Disagree (SD=1point). Some items were negated to avoid response set. The Semi-structured interview guide for students contained ten selected questions that were contextualized. The reliability coefficient of 0.77 for DLQM was established using Cronbach's alpha statistics.

Data analysis were done using SPSS version 22. Mean and standard deviation was used to provide answer to the quantitative data, while thematic analysis was for qualitative data. Integration of the results provided a holistic understanding of the research problem. The criteria for judgment was based on the followings: 1.0 -1.4 indicate very low rate, 1.5-2.4 indicate low rate, 2.5-3.4 indicate high rate, and 3.5 and above indicate very high rate.

Ethical confidentiality and anonymity of participants were ensured. Participants had the right to withdraw at any stage when no longer interested in responding to the questionnaire or the interview for any reason what so ever.

Results:

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Theme1	62	2.00	4.00	2.6475	.47971	-.625	.219	-1.636	.435
Theme2	62	1.00	3.00	2.3885	.46501	-.824	.219	-1.343	.435
Theme3	62	2.00	3.00	2.5984	.49225	-.406	.219	-1.866	.435
Theme4	62	1.00	3.00	2.6967	.46157	-.867	.219	-1.270	.435
Theme5	62	3.00	4.00	3.5149	.55796	-.910	.219	-1.192	.435
Valid N (listwise)	62								

Table showing the descriptive statistics of the five themes from the research questions

The findings and analysis of the data are presented in accordance with the research questions which have been aligned to the respective themes. In each theme, the quantitative data analysis is presented seconded by the qualitative insight from for a deeper understanding of the research problem.

Theme 1: Digital literacy knowledge level

From the quantitative data table above students have a high digital literacy rate (Mean= 2.64; SD= 0.48). This result was supported by the qualitative data where majority of students mentioned that they know when AI make mistake. For example: ST 2: "I will point out the mistake of the generative AI".

Theme 2: Competence in generative AI-supported

From the quantitative data table above students have a low competence in using generative AI-support in mathematics problem-solving (Mean= 2.39; SD= 0.47). This result was not supported by the qualitative data where majority of students indicated that they use AI in learning competently. For example: ST 1: "If I ask AI to give the answer then it will only provide the answer".

Theme 3: Usage of Gen.AI in solving mathematics problem

From the quantitative data table above students have a high usage of generative AI (Mean= 2.60; SD= 0.49). This result is supported by the qualitative data where majority of students said they use AI mostly in getting the steps involve in solving a problem i.e. seeking clarifications and explanations. For instance: ST 1 said: "I use AI when I get stuck on a problem, it will explain the steps clearly and give examples, so I understand better than just copying from the a textbook".

Theme 4: Students evaluation and verification of generated AI

Quantitative survey table above indicated low rate of verification and evaluation of generated AI (Mean = 2.31; SD= 0.46). The was not backed by the interview response where most of students asserted that they don't normally care about verifying or evaluating generated AI, that all they need is get the problem solved. For instance: ST 8 asserted that: "I ask AI questions that are relatively difficult for me, so I don't know how to verify the answer unless when the question was copied from textbook".

Theme 5: Challenges students' experience using generative AI

Quantitative data table above showed that students have a very high challenges using generative AI (Mean =3.51; SD= 0.56). Interview data from them supported this result as most of them mentioned that they don't know which generated AI to agree with since they normally produce different solutions. For instance: ST 6 said that: "I have experience AI giving wrong formula and answer when the question is tricky".

Integrated Result Interpretation Table.

Research themes	Quantitative finding	Qualitative explanation	Integrated interpretation
Digital literacy Knowledge	High digital literacy Level	Students described being able to point out gen. AI errors	Convergence. Both agree on the level digital literacy knowledge.
Competence in using AI-support	Low competence in using gen.AI	Students described being competent enough in using AI-support in learning of mathematics	Divergence. Both didn't agree in competence of using gen, AI in mathematics problem-solving.
Format of AI usage	High usage in finding steps rather than answers	Students described using generative AI in step by step guidance.	Convergence. They use gen. AI in seeking for more explanations.
Evaluation and verification of generative AI	Low rate of evaluating and verifying gen. AI.	Students always evaluate and verify gen.AI by following the formulae and steps.	Divergence. They didn't agree on result verification before using it.
Challenges of gen.AI	High rate challenges.	Students described greater challenges using generative AI	Convergence. They have a lot of Challenges using AI.

Discussion

The results of the study were discussed under the following themes. Digital literacy knowledge level: The analyzed data from students' response showed a high rate of digital literacy level (Mean= 2.64; SD= 0.48). This was supported by the interview responses which indicated that "students clarify noticing

mistake from the AI” This high digital literacy level could be attributed to several factors, such as students’ high exposure to android phones and laptops. This finding from this study is in harmony with the finding of Marín and Castañeda (2023) who stressed the importance of developing robust digital literacy education among learners to navigate and mitigate the challenges posed by new technologies like ChatGPT.

On the competence of using generative AI in solving mathematical problem the study showed a low competence (Mean = 2.39; SD=0.47). However, the semi-interview responses from students with knowledge of AI-based tools highlight instances where learner have successfully integrated ChatGPT into their learning. The limited integration of AI-based ChatGPT could be due to the challenges students face with technological issues. Also, it could be that all the generative AI support apps use data to function, and when data is on many advertisements normally pumps out thereby being distraction to learner at their stage of life. This finding supports the finding of Sánchez-Ruiz et al. (2023) who asserted that students expressed a high level of confidence in the accuracy of ChatGPT responses, showing a substantial percentage of correct answers compared to numerical solutions.

Generative AI format of usage showed a high rate (Mean = 2.60; SD=0.49) of using AI for explanation and clarifications rather than exploring only the answers. This was equally supported by qualitative data on the usage of generative AI. The reasons behind these low rate need further investigation. It could be that teachers who introduced the usage already told them that AI answers are not always reliable and efficient. Addressing these concerns may involve showcasing successful case studies, providing evidence of improved outcomes, and actively involving teachers in implementing ChatGPT in the classroom. This result is at variance with the finding of Ukwueze and Egbuniwe, (2026) who asserted that students’ usage of ChatGPT app do not effectively influence learning outcomes in mathematics classroom.

On Evaluation and verification of generated AI, the result showed a low rate (Mean=2.31; SD= 0.46). This study reveals that students don’t always verify AI result while learning. The semi-interview responses provide specific details about this, as reported by ST 6: who said that “I give AI question that I don’t have an idea of handling, so any answer it brings become final to me because I don’t know it”. This finding is in line with the finding of Chinoso et al. (2023)

who revealed that some of the problems of ChatGPT are associated with inaccurate solutions thereby leading to students' misconceptions in learning. The result is at variance with the report of Wardat et al. (2023) who indicated that ChatGPT is acknowledged for enhancing mathematical skills and contributing to educational success by offering users foundational knowledge in mathematics and diverse subjects.

On challenges of using generated AI output, the result showed a very high level (Mean=3.51; SD= 0.56). This study showed that students encounter several challenges while using generative AI in mathematics problem-solving exercise. The semi-interview responses provide specific details about this, as reported by ST 8: who said that "If AI gives a wrong answer and we will learn the wrong method because we don't know it". This result is in agreement with the result of Ogurlu and Mossholder (2023) who showed that middle school, and elementary school raises concern of potential loss of higher-order thinking skills, overreliance on technology, lack of authenticity, decreased content comprehension, fear of the unknown, and concern for social-emotional well-being.

Conclusion

In conclusion, while this study indicated a high digital literacy level, low competence level, high usage, low verification and evaluation level, high level challenges among mathematics learners, the qualitative responses provide a complementary deeper understanding of the research problems. The usage of generative AI-support tools provide a faster and alternative ways of learning mathematics based on learners' pace and should be taught by mathematics educators. Also, educators, administrators, and policymakers should proactively educate themselves and their students on the ethical use of generative AI-support tools. The study concludes that students' competence in using generative AI-supported mathematics problem-solving in secondary school level should be enhanced to a greater length for a deeper understanding of the subject.

Recommendations

The study made the following recommendations.

1. Government should sensitize students about generative AI-supported learning as a means of meeting up with STEM aspiration in this modern era.

2. Government and other stakeholders should boast the technological devices in the school to support generative AI usage.
3. Mathematics instructors should promote and facilitate peer collaborative learning among students through online platform.
4. Teachers should endeavor to educate students about the need to use generative AI-support tools in personalized learning.

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