



Exploring Students' Perceptions of AI-Assisted Learning and Its Role in Developing Procedural Understanding of Mathematics in Secondary Schools

Joel Sindikubwabo¹, Onesme Niyibizi², Mediatrice Umutohi²

¹University of Rwanda College of Education (URCE), Kayanza, P.O. Box 55 Rwamagana, Rwanda

²Institut Catholique de Kabgayi (ICK), Muhanga, Rwanda

Abstract	Article information
This study explored students' perceptions of AI-assisted learning and its perceived role in supporting procedural understanding of mathematics in secondary schools. A qualitative research approach guided by an interpretivist paradigm was employed, using a qualitative case study design. Twelve Senior Two (S2) students (the second year of lower secondary education in Rwanda) were purposively selected from a single secondary school and participated in semi-structured interviews. The interview data were analyzed using narrative and thematic analysis, with frequencies and percentages used descriptively to indicate commonly expressed ideas within this small sample. The findings showed that students generally perceived AI-assisted learning positively. Nine students (75%) reported that AI helped them obtain mathematical explanations, while eight (66.7%) valued its convenience and accessibility. However, five students (41.7%) expressed concerns about overdependence on AI, and six (50%) emphasized the importance of teacher guidance. Regarding procedural understanding, ten students (83.3%) perceived AI as useful for providing step-by-step explanations, eight (66.7%) valued additional examples and practice opportunities, and seven (58.3%) reported that AI supported error identification and increased confidence in carrying out mathematical procedures. Within the limits of a small, single-school case, the study suggests that students perceived AI as a supplementary resource for mathematics learning, particularly for step-by-step procedural support, while also expressing concerns about overdependence, accuracy, the continuing need for teachers, and unequal access to devices and connectivity. Because these are perceptions rather than measured learning outcomes, the study offers methodological and theoretical directions for further research instead of practical prescriptions. Keywords: Artificial Intelligence, Students' Perceptions, Procedural Understanding, Mathematics Education, Rwanda	Received: 13/09/2026; Reviewed: 14/09/2026; Revised: 24/09/2026; Accepted: 26/09/2026

* Corresponding author: Joel Sindikubwabo: sinjoel8@gmail.com

How to cite this article: Sindikubwabo, J., Niyibizi, O., and Umutoni, M. (2026) 'Exploring Students' Perceptions of AI-Assisted Learning and Its Role in Developing Procedural Understanding of Mathematics in Secondary Schools', *Educational Journal of Artificial Intelligence and Machine Learning*, 2(1), pp. 14-33. Available at: <https://doi.org/10.58197/bxsxe770>

1. Introduction

Artificial intelligence (AI), particularly generative AI applications such as ChatGPT, is increasingly becoming part of educational practice by providing learners with explanations, examples, feedback, and individualized learning support. In mathematics education, AI-assisted tools have potential to help students understand how mathematical procedures are performed by providing step-by-step explanations, alternative solution methods, opportunities for practice, and immediate responses to questions. However, the educational value of AI depends not only on its technical capabilities but also on how students perceive, interpret, and use these tools in actual learning situations. International evidence shows that students may appreciate AI for accessibility, personalized explanations, and problem-solving support while simultaneously expressing concerns about inaccurate responses, overdependence, reduced independent thinking, and the need for human guidance (Kasneci et al., 2023; Lo, 2023; Farrokhnia et al., 2024). Therefore, understanding how secondary school students perceive AI-assisted mathematics learning and how they believe it supports their procedural understanding is important for informing responsible and pedagogically appropriate AI integration in Rwandan secondary schools.

In Rwandan secondary schools, mathematics is taught under the Competence-Based Curriculum (Rwanda Education Board [REB], 2015), which expects learners to apply what they learn to solve problems. Carrying out mathematical procedures accurately and with understanding is a foundation for this kind of application. The present study focuses on Senior Two (S₂), the second year of the three-year lower secondary cycle (S₁–S₃) that follows six years of primary education; S₂ learners are typically about 14 to 16 years old (Byusa et al., 2021). Challenges of digital access, infrastructure and proficiency remain in Rwandan schools, and ICT tools are not always well used even where they are available (Baikirize et al., 2024; Twagilimana et al., 2026). Students who use AI chatbots on smartphones or computers do so in a context where the opportunities, risks and inequalities of such use are still poorly understood.

Research Objectives

1. To explore students' perceptions of using AI-assisted learning in mathematics classrooms in secondary schools.
2. To explore how students perceive the role of AI-assisted learning in supporting their procedural understanding of mathematics in secondary schools.

2. Literature Review

2.1 Generative AI in education: international perspectives

The literature demonstrates increasing interest in the use of generative AI in education, but the evidence also presents a complex picture of its contribution to learning. Kasneci et al. (2023) argue that large language models can support personalized learning, provide explanations, generate learning materials, and facilitate problem solving, while emphasizing the importance of critical evaluation and human oversight. Similarly, Lo (2023), in a rapid review of 50 publications, found that ChatGPT can function as a virtual tutor and learning assistant but that its performance varies across subject areas and may be problematic in mathematics because of inaccurate or fabricated responses. Farrokhnia et al. (2024) further identify personalized and real-time responses as important educational strengths of ChatGPT, while noting weaknesses related to accuracy, contextual understanding, bias, and overreliance.

2.2 Generative AI in mathematics learning

Research specifically concerned with mathematics also provides evidence of both opportunities and limitations. Taani and Alabidib (2024) found that AI applications such as ChatGPT can support mathematics learning through explanations, generation of examples, problem-solving assistance, and test preparation, although accuracy, connectivity, and language limitations remain concerns. Research involving students has similarly shown that learners value AI as a learning companion and source of assistance. For example, a mixed-methods study of Nigerian secondary school students' perceptions of ChatGPT in mathematics, which is one of the closest African comparisons for the present study, found that students appreciated its ability to support understanding and problem solving but expressed concerns about inaccurate or oversimplified answers and possible overreliance (Egara et

al., 2025). In another study, middle school students perceived a generative-AI-powered teachable agent as a learning companion, facilitator, and collaborative problem solver (Song et al., 2025).

More recently, Bulut and Borromeo (2026) examined secondary students' use of ChatGPT in mathematical modelling and found that students mainly used relatively simple prompts and often failed to engage sufficiently with validation and interpretation, suggesting that access to AI does not automatically guarantee deeper mathematical reasoning. Similarly, research on generative AI and mathematical proof indicates that students need guidance to engage critically with AI-generated mathematical responses rather than simply accepting them (Yoon et al., 2024). Experimental evidence from high-school mathematics also raises an important concern: although AI tutoring may improve performance while students have access to the tool, unrestricted assistance can result in weaker independent performance when the AI support is removed, whereas carefully designed hints can reduce this problem (Bastani et al., 2025). These studies therefore suggest that AI may support procedural understanding through explanations, worked examples, feedback, and guided practice, but its contribution depends on how students interact with the technology and whether they remain cognitively engaged.

2.3 Procedural understanding in mathematics

Procedural understanding is used in this study to refer to learners' ability to carry out mathematical procedures, that is, sequences of steps used to solve a class of problems, accurately, efficiently and with awareness of why the steps work. Hiebert and Lefevre (1986) described procedural knowledge as comprising the formal language and symbols of mathematics and the rules, algorithms and step-by-step methods used to complete tasks. Kilpatrick et al. (2001) similarly described procedural fluency as skill in carrying out procedures flexibly, accurately, efficiently and appropriately, and treated it as interwoven with conceptual understanding, strategic competence, adaptive reasoning and a productive disposition. Star (2005) distinguished superficial procedural knowledge, which involves memorizing steps, from deep procedural knowledge, which is associated with comprehension, flexibility and critical judgement, while Rittle-Johnson et al. (2015) showed that procedural and conceptual knowledge develop in iterative, mutually supportive ways.

In this study, therefore, students' perceived procedural understanding means their sense that they can follow, reproduce, check and correct the steps of a mathematical method and can apply it confidently on their own. This working definition guided the interview questions on step-by-step

explanations, additional practice, error identification and confidence (Table 1). It also explains why AI features that display solution steps or generate practice examples are relevant to procedural learning, and why copying answers without engagement is a serious concern.

2.4 Technology and AI in Rwandan education

Rwanda has a national policy framework for AI. The National Artificial Intelligence Policy (MINICT, 2023), approved by Cabinet in April 2023, promotes AI literacy and twenty-first-century skills through education and training at all levels of learning. However, evidence of how secondary school students actually use AI in mathematics, and that is the question addressed.

In Rwanda, existing research has established the importance and challenges of technology integration but has not adequately addressed this emerging AI-specific question. Iyamuremye and Ndiokubwayo (2024) investigated the impact of ChatGPT on students' interest and conceptual understanding of atomic structure and chemical bonding among 92 Senior Two students in Rwanda using a sequential explanatory mixed-methods design. Findings showed a 16.6% improvement in students' performance, with ChatGPT enhancing engagement, curiosity, motivation, and learning experiences, although no statistically significant gender difference was observed. Niyibizi et al. (2023) specifically examined students' perceptions of ICT tools for learning mathematics in selected public secondary schools in Gasabo District, but the study addressed conventional ICT rather than AI-assisted learning. Baikirize et al. (2024) found that ICT tools were available in selected Rwandan secondary schools but were inadequately utilized, while Bazina et al. (2024) investigated mathematics teachers' perceptions of technological tools rather than students' experiences with AI.

Similarly, Mukeshimana and Andala (2024) examined technological usage and mathematics performance in public secondary schools in Kayanza District, emphasizing technology use and performance rather than students' perceptions of AI-assisted procedural learning. More recent Rwandan research continues to demonstrate challenges related to digital access, infrastructure, proficiency, and pedagogical integration (Twagilimana et al., 2026), while research on the integration of virtual laboratories in Rwandan mathematics teaching has examined teachers' perceptions and acceptance rather than students' voices (Ngiruwonsanga et al., 2026).

2.5 Research gap and contribution of the present study

An important gap remains. Much of the research on AI in mathematics education reviewed above, which comes largely from outside Rwanda, has focused on university students, teachers, general AI adoption, mathematical modelling, or experimental measures of learning outcomes, while comparatively less qualitative research has examined secondary school students' own perceptions of how AI assists them in carrying out mathematical procedures.

Consequently, there is a contextual, population, and knowledge gap: there is limited qualitative evidence from Rwanda on how secondary school students themselves perceive AI-assisted learning in mathematics and, more specifically, how they understand its role in supporting procedural understanding. Existing Rwandan studies provide useful evidence about ICT availability, technology integration, teachers' perceptions, and mathematics learning, but they do not sufficiently explain what students think about using AI to obtain step-by-step explanations, practice mathematical procedures, identify procedural errors, and develop confidence in independently carrying out mathematical processes. The present study therefore addresses this gap by placing Rwandan secondary school students' voices at the centre of inquiry, focusing specifically on their perceptions of AI-assisted mathematics learning and the perceived role of AI in developing procedural understanding. This focus is particularly timely because Rwanda's National AI Policy (MINICT, 2023) emphasizes AI literacy and skills development through education at all levels of learning. The study is exploratory. It offers context-specific qualitative evidence from one school that can inform, but not prescribe, discussion among teachers, curriculum developers, school leaders and researchers about AI-assisted mathematics learning, including the risks of overdependence, inaccurate information, unequal access and reduced independent mathematical thinking.

3. Methodology

3.1 Research Approach, Paradigm and Design

The study adopted a qualitative research approach to explore students' perceptions of AI-assisted learning and its perceived role in supporting procedural understanding of mathematics in a secondary school context. A qualitative approach was considered appropriate because the study sought to understand students' experiences, views, explanations, and interpretations of using AI-assisted learning rather than to measure its statistical effect on mathematics achievement. The qualitative

approach was also appropriate because students may experience and interpret AI-assisted mathematics learning differently depending on their previous exposure to digital technologies, familiarity with AI tools, and individual learning experiences.

The study was guided by the interpretivist paradigm. Interpretivism assumes that knowledge and meaning are constructed through individuals' experiences and interpretations of social phenomena (Guba & Lincoln, 1994; Cohen et al., 2018). This paradigm was appropriate because the study sought to understand how S2 students interpreted their experiences of using AI-assisted learning in mathematics and how they perceived its contribution to their procedural understanding. The **researchers** therefore treated students' perceptions as meaningful accounts of their experiences rather than as objectively measurable outcomes. During data collection and analysis, attention was given to the participants' descriptions of how they used AI, what they considered useful or challenging, and how they believed AI supported their mathematical procedures.

A qualitative case study design (Yin, 2018; Merriam & Tisdell, 2016) was employed. The case consisted of S2 students' experiences and perceptions of AI-assisted learning in mathematics within **one** selected secondary school in Rwanda. The case study design enabled the researchers to investigate the phenomenon in its natural educational setting and to obtain detailed information from students who had prior, self-initiated experience using AI tools for mathematics. The design was particularly suitable because the study focused on two closely related issues: students' perceptions of using AI-assisted learning and their perceptions of its role in supporting procedural understanding. Rather than attempting to establish a causal relationship between AI use and mathematics achievement, the study examined how students described and interpreted their learning experiences.

3.2 Context and Participants

In Rwanda, basic education comprises six years of primary school followed by three years of lower secondary school (Senior One to Senior Three, S1–S3) and three years of upper secondary school (S4–S6) (REB, 2015). Senior Two (S2) is therefore the middle year of lower secondary education, and S2 learners are typically about 14 to 16 years old (Byusa et al., 2021). Mathematics is a core subject taught under the Competence-Based Curriculum.

The study was conducted in one public secondary school in Rwanda, during second term of academic year 2025-2026. The school was chosen because students were known to use smartphones or school computers for study and the researchers could obtain access.

The target population comprised S2 students in the selected secondary school who were involved in learning mathematics. S2 students were selected because they had sufficient experience with secondary school mathematics after the transition from primary school in S1, while not yet being in S3, the final year of lower secondary education, when learning is strongly shaped by preparation for the national examination. It was not assumed that S2 students have more experience of AI than students in other grades. Students in other grades may hold different views. The study included only students who had at least some exposure to AI-based tools for mathematics learning (the inclusion criterion). This ensured that participants could provide information related to the research objectives, including their perceptions of AI, its usefulness, accessibility, limitations, and perceived contribution to understanding mathematical procedures.

In this study, 'experience' meant that a student had personally used a text-based generative AI chatbot, on a smartphone or computer, to ask at least one mathematics-related question. Formal training was not required, and the researchers gave no AI training or demonstration before the interviews. Experience mattered because the study sought perceptions grounded in students' own use rather than in speculation or hearsay: a student who has actually asked an AI for step-by-step help, checked an answer or practised with it can describe what worked, what did not, and why. The extent of each student's experience (tools used, frequency and purpose of use) was established in the first section of the interview guide and is summarized, so that differences between more and less experienced students could be considered when interpreting the findings.

The study involved 12 S2 students who were selected using purposive sampling (Patton, 2015). Purposive sampling was appropriate because the researchers needed participants who could provide relevant information about AI-assisted mathematics learning. The selection was intended to include students with different levels of familiarity with AI-assisted learning so that diverse perceptions could be captured. Participants were assigned codes S1 to S12 to maintain confidentiality and anonymity throughout the presentation of the findings. The sample size was considered appropriate for a qualitative study because the purpose was to obtain rich and detailed information rather than to achieve statistical representativeness (Malterud et al., 2016). Twelve participants from one school cannot represent all Rwandan S2 students, and the findings are not intended to be generalized. The researchers continued interviewing participants until the information obtained was sufficiently rich to address the two research objectives and recurring ideas were evident across participants' responses.

3.3 Data Collection Instrument and Procedure

AI-assisted learning' is used in this paper to mean students' own use of text-based generative AI chatbots, such as ChatGPT, accessed through smartphones or computers to obtain explanations, examples, practice questions and feedback on mathematics tasks. The study did not evaluate a particular tool, did not include AI features built into classroom software, and did not test the mathematical accuracy of the tools' responses; it examined how students themselves perceived the help they received.

The main instrument used for data collection was a semi-structured interview guide. The interview guide was developed directly from the two research objectives. Open-ended questions were used to encourage participants to describe their experiences and perceptions in their own words. The first section of the interview guide collected demographic information, including participants' age, gender, and previous experience with digital and AI-assisted learning tools, specifically which AI tools they had used, how often, and for which mathematics tasks. The second section focused on students' perceptions of using AI-assisted learning in mathematics. Questions addressed students' views concerning the usefulness, convenience, accessibility, benefits, limitations, overdependence, and role of teachers in AI-assisted learning.

The third section focused on the perceived role of AI-assisted learning in supporting procedural understanding of mathematics. Questions explored whether AI provided step-by-step explanations, additional examples and practice opportunities, assistance in identifying mathematical errors, and support for students' confidence when carrying out mathematical procedures.

Follow-up and probing questions were used where necessary to obtain clarification and richer descriptions. For example, when a participant stated that AI helped them understand a mathematical procedure, the **researchers** asked the participant to explain how AI helped, to provide an example, and to describe what they did before and after using AI.

Table 1. Alignment of the interview guide with the research objectives and the analysis

Interview guide section	Research objective	Ideas explored and analyzed
Section 1: Background and AI experience	Context for interpretation (not an objective)	Age and gender; AI tools used, frequency and purpose of use
Section 2: Perceptions of using AI-assisted learning in mathematics	Objective 1	Usefulness of AI explanations; convenience and accessibility; overdependence; role of the teacher
Section 3: Role of AI in supporting procedural understanding	Objective 2	Step-by-step explanations; additional examples and practice; identification and correction of errors; confidence in carrying out procedures

Individual semi-structured interviews were then conducted with the 12 participants in a suitable and quiet environment within the school. Interviews took place outside lesson time, lasted about 30 minutes each, and were conducted in English, Kinyarwanda, or both; responses given in Kinyarwanda were translated into English for reporting. The interviews focused on students' experiences and perceptions of AI-assisted learning in mathematics. The researchers used the interview guide consistently while allowing participants to elaborate on issues that emerged during the interviews.

No AI training, demonstration or classroom activity was provided before the interviews; students spoke about their earlier, self-initiated use. When a student mentioned using AI, the interviewer asked which tool it was, how often and for which mathematics tasks it was used, and how that experience related to the question being discussed, so that answers could be read in the light of actual use.

With appropriate permission, participants' responses were recorded and supplemented by written notes. The recordings were subsequently transcribed to preserve the participants' accounts as accurately as possible. The researchers repeatedly reviewed the transcripts to become familiar with the data before beginning the coding and thematic analysis.

3.4 Data Analysis

The interview data were analyzed using narrative and thematic analysis. The analysis began with repeated reading of the interview transcripts to develop familiarity with the participants' accounts. Relevant statements related to the research objectives were identified and coded. Narrative analysis

was used to present students' accounts in their own words, while thematic analysis (Braun & Clarke, 2006) was used to identify patterns across accounts. Coding was done manually by the first author, with categories reviewed by the other authors and disagreements resolved through discussion.

For the first research objective, codes were developed around students' perceptions of using AI-assisted learning. Similar codes were grouped into broader categories, which resulted in four major ideas: AI as a useful source of mathematical explanations; convenience and accessibility of AI-assisted learning; concerns about overdependence on AI; and the need for teacher guidance.

For the second research objective, the analysis focused specifically on students' perceptions of the role of AI in supporting procedural understanding. The recurring ideas were grouped into four major themes: step-by-step explanations; additional examples and opportunities for practice; identification and correction of procedural errors; and increased confidence in carrying out mathematical procedures.

The researchers also identified the number of participants who expressed each commonly occurring idea. These frequencies were converted into percentages using the total number of participants ($N = 12$) as the denominator.

The frequencies and percentages were used descriptively to demonstrate the prominence of recurring ideas within the qualitative data. They were not treated as statistical evidence or used to generalize the findings to all secondary school students. Narrative descriptions and participant quotations were used alongside the frequencies to preserve the qualitative nature of the findings.

3.5 Trustworthiness and Ethical Considerations

Several measures were employed to enhance the trustworthiness of the findings (Lincoln & Guba, 1985). Credibility was strengthened by the probing questions and the repeated review of transcripts described in Sections 3.3 and 3.4, so that the themes reflected participants' accounts. Dependability was addressed by maintaining a clear and systematic procedure for data collection, coding, categorization, and theme development, with the interview guide aligned with the two research objectives to ensure consistency across participants.

Confirmability was enhanced by grounding the findings in participants' actual statements rather than relying solely on the researchers' interpretations. Participant codes such as S2, S3, S7, and S10 were used when presenting quotations to demonstrate the connection between the themes and the

original interview data. Transferability was supported by providing a clear description of the study context, participants, sampling procedure, and data collection process. This enables readers to determine whether the findings may be relevant to other secondary school contexts with similar characteristics.

Ethical principles were followed throughout the study. Participants were informed about the purpose of the research, the nature of their participation, and their right to participate voluntarily. Confidentiality was maintained by using participant codes rather than students' names. The identities of participants were not disclosed in the presentation or discussion of the findings. Before data collection, authorization was obtained from the school head, because the participants were under 18 years old, consent from parents or guardians and assent from the students was obtained.

The researchers also ensured that the collected information was used exclusively for academic purposes. Interview records and transcripts were handled securely and were accessible only to the researchers and authorized persons where applicable. Participants were informed that they could decline to answer any question or withdraw from the study in accordance with the approved research procedures.

4. Results and Discussion

4.1 Demographic Information of Participants

The study involved 12 S2 students who were purposively selected to provide information about their perceptions and experiences of AI-assisted learning in mathematics. The participants consisted of 7 males (58.3%) and 5 females (41.7%). Their ages ranged from 14 to 17 years, with most participants being 15 or 16 years old. All participants had experience using digital devices such as smartphones, tablets, or computers for educational purposes. However, their levels of familiarity with artificial intelligence tools differed. 8 students (66.7%) reported that they had previously used AI-based tools, particularly for obtaining explanations, solving mathematical problems, and checking their answers, while 4 students (33.3%) had limited experience with AI-assisted learning; they had used AI tools only occasionally to ask mathematics questions, and none was a first-time user. The participants therefore provided varied perspectives regarding the use of AI in learning mathematics. Because every participant had used AI at least occasionally, all met the inclusion criterion, and their views were based on actual use. The four students with limited experience were retained because purposive sampling

aimed to capture a range of familiarity, but their accounts describe occasional use and are not read as evidence of sustained use.

4.2 Results on Objective One: Students' Perceptions of Using AI-Assisted Learning in Mathematics

The first objective explored students' perceptions of using AI-assisted learning in mathematics classrooms. Narrative analysis of the students' responses generated four main ideas: AI as a useful source of mathematical explanations, AI as a convenient learning support tool, concerns about overdependence on AI, and the need for teacher guidance. Most students expressed generally positive perceptions, although some participants also identified limitations associated with the use of AI in mathematics learning.

A common perception was that AI-assisted learning made mathematics explanations easier to obtain and understand. 9 students (75%) described AI as useful because it could provide explanations when they did not understand a mathematical concept during individual study. Students particularly appreciated the possibility of asking questions repeatedly without feeling embarrassed. For example, S3 explained that AI was helpful because "when I do not understand the first explanation, I can ask it to explain again in another way." Similarly, S8 indicated that AI could provide additional examples beyond those presented by the teacher. These responses suggest that students perceived AI as a flexible supplementary learning resource that could respond to individual learning difficulties.

Another common idea concerned the convenience and accessibility of AI-assisted learning. 8 students (66.7%) perceived AI as convenient because it could be accessed using a smartphone or computer and could provide assistance outside normal classroom hours. Students reported using AI to clarify homework instructions, check mathematical procedures, and obtain additional examples. S5 stated that AI was particularly useful when completing homework because it could provide guidance when the teacher was not immediately available. However, 4 students (33.3%) expressed concerns about access to appropriate devices, internet connectivity, and the possibility that not all students would have equal opportunities to use AI. This indicates that students recognized both the potential benefits and practical limitations of incorporating AI into mathematics learning.

The analysis also revealed concerns about overdependence and the need for teacher supervision. 5 students (41.7%) expressed the view that students could become dependent on AI if they simply copied answers without attempting to solve problems independently. S10 observed that "AI can give the answer quickly, but a student may not learn if he or she only copies it." In addition, 6 students (50%)

emphasized that AI should complement rather than replace the mathematics teacher. Students perceived the teacher as important for explaining difficult ideas, correcting misunderstandings, and determining whether an AI-generated answer was correct. Overall, the findings indicate that students generally perceived AI-assisted learning positively, but they also considered responsible use, independent thinking, and teacher guidance essential.

These findings are consistent with Kasneci et al. (2023), who reported that AI can support personalized learning, explanations, and problem solving, and with Lo (2023) and Farrokhnia et al. (2024), who noted both the educational benefits and risks of AI, including inaccurate information and overreliance. Similarly, Egara et al. (2025) found that secondary students appreciated ChatGPT for supporting mathematics learning but raised concerns about inaccurate responses and dependence on AI, while Song et al. (2025) found that students perceived generative AI as a learning companion and facilitator. The present findings extend these studies by suggesting that the Rwandan S2 students in this case similarly perceive AI as a supplementary mathematics-learning resource while emphasizing the continuing importance of teachers. This finding is particularly relevant in Rwanda because previous studies have mainly examined conventional ICT use and technology integration rather than students' perceptions of generative AI in mathematics (Iyamuremye et al., 2022; Niyibizi et al., 2023; Bazina et al., 2024). Therefore, the present study contributes context-specific evidence that the participating students were receptive to AI-assisted learning and that they themselves linked its use to teacher guidance, critical evaluation, and responsible use.

Two of these findings need to be read in the Rwandan context. First, the concerns of four students about devices and connectivity are consistent with Rwandan studies reporting challenges of access, infrastructure and proficiency (Baikirize et al., 2024; Twagilimana et al., 2026): where AI use depends on personal smartphones and internet access, it may benefit some learners more than others. Second, the emphasis that half of the students placed on teacher guidance is consistent with the facilitating role expected of teachers in the Competence-Based Curriculum (REB, 2015). These interpretations are tentative because the study did not compare schools or examine access directly.

4.3 Results on Objective Two: Students' Perceptions of the Role of AI-Assisted Learning in Supporting Procedural Understanding

The second objective explored how students perceived the role of AI-assisted learning in supporting their procedural understanding of mathematics. Four prominent ideas emerged from the narrative

analysis: step-by-step explanations, opportunities for repeated practice, identification and correction of procedural errors, and increased confidence in solving mathematical problems. The findings suggest that students mainly viewed AI as a supplementary tool for understanding how mathematical procedures are carried out.

The most frequently reported perception was that AI supported procedural understanding by providing step-by-step explanations. 10 students (83.3%) reported that AI-assisted learning helped them understand the sequence of steps required to solve mathematical problems. Students explained that instead of receiving only a final answer, they could request an explanation of how the answer was obtained. S2 reported that AI was useful because “it shows me the steps from the beginning until the answer.” Similarly, S7 indicated that seeing the procedure in smaller steps made it easier to identify where a mistake had occurred. These responses suggest that students perceived AI as particularly useful for making mathematical procedures explicit and sequential.

The second major finding was that 8 students (66.7%) perceived AI as useful for providing additional examples and opportunities for practice. Students explained that after learning a particular procedure, they could ask AI to generate similar mathematical problems and then compare their solutions with the explanations provided. This was perceived as useful for reinforcing procedural knowledge. For instance, S4 explained that AI allowed the student to “practice the same type of question many times until I know the steps.” The students’ responses therefore suggest that AI was perceived not only as an answer-providing tool but also as a source of additional practice that could help students become more familiar with mathematical procedures.

Another important theme was error identification and correction. 7 students (58.3%) reported that AI helped them identify mistakes in mathematical procedures, particularly when they entered their own attempted solutions and requested an explanation of where they had gone wrong. Students described this feature as useful because it enabled them to compare their procedure with an alternative solution. However, 3 students (25%) noted that AI could sometimes provide explanations or answers that they were not certain were correct. This finding highlights the importance of students critically checking AI-generated responses rather than automatically accepting them. The students therefore perceived AI as helpful for procedural feedback, but not as an infallible source of mathematical knowledge.

Finally, 7 students (58.3%) reported that AI-assisted learning increased their confidence in carrying out mathematical procedures independently. Students explained that repeated explanations, worked

examples, and opportunities to correct mistakes made them more willing to attempt mathematics problems. S9 stated that after receiving a step-by-step explanation, the student could “try the question again without asking someone immediately.” Nevertheless, students emphasized that AI should be used as a support rather than as a replacement for personal effort. Overall, the findings indicate that students perceived AI-assisted learning as supporting procedural understanding primarily through step-by-step guidance, repeated practice, error correction, and confidence development, while responsible use and teacher supervision remained important.

These findings are consistent with Taani and Alabidib (2024), who reported that AI tools such as ChatGPT can provide explanations, examples, and problem-solving support in mathematics, and with Egara et al. (2025), whose findings showed that students perceived ChatGPT as useful for mathematics understanding and problem solving. However, the present finding concerning procedural support should be interpreted alongside Yoon et al. (2024), who emphasized the need for students to critically evaluate AI-generated mathematical responses, and Bastani et al. (2025), who found that unrestricted AI assistance can weaken students’ independent performance when the tool is removed. Similarly, Bulut and Borromeo Ferri (2026) showed that access to ChatGPT does not automatically result in deeper mathematical reasoning because students may use relatively simple prompts without sufficiently validating or interpreting AI responses. In the Rwandan context, the finding extends previous research on ICT-supported mathematics learning (Iyamuremye et al., 2022; Niyibizi et al., 2023) by focusing specifically on AI-assisted procedural understanding rather than general technology use or mathematics performance. The results therefore suggest that AI can be perceived as a valuable supplementary scaffold for procedural learning, but students need guidance to verify AI-generated solutions, understand the reasoning behind procedures, and avoid simply copying answers.

These are students’ perceptions. Because the interviews captured what students said and not how they used AI, the study cannot show whether step-by-step explanations led to deep procedural knowledge that is understood and flexible (Star, 2005) or only to imitation of steps, nor whether the confidence students reported matches their independent performance (Bastani et al., 2025).

Conclusion and Recommendations for Future Research

Within the limits of a small single-school case, the study concluded that the S2 students who took part generally perceived AI-assisted learning positively and considered it a potentially useful

supplementary resource for mathematics learning. Students particularly valued AI for providing accessible explanations, step-by-step procedures, additional practice, error correction, and increased confidence. However, concerns about overdependence, inaccurate responses, unequal access, and reduced independent thinking were also identified.

Limitations

The study has four main limitations. It involved one school and twelve students, so it cannot represent Rwandan S2 students as a whole. It relied on students' self-reports and did not observe how AI was used or check the accuracy of the AI responses students described. Students may have used different tools and different languages when interacting with AI, and these differences were not analysed separately. The percentages describe how many of these twelve students expressed an idea and should not be read as statistical findings.

Methodological and theoretical recommendations

Given the small sample and the exploratory aim, the study offers the following recommendations for future research.

1. Wider sampling. Future studies should include several schools and districts (urban and rural, public and private, day and boarding) and other grades, so that differences in access, language and school support can be examined.
2. Triangulation. Interviews could be combined with classroom observation, think-aloud tasks, screen recordings or analysis of students' chat histories, and with checking of the accuracy of AI-generated solutions, so that perceived and actual use can be compared.
3. Learning outcomes. Mixed-methods or quasi-experimental studies with delayed tests of independent procedural performance (as in Bastani et al., 2025) are needed to find out whether perceived benefits translate into learning.
4. Theoretical framing. Future work could use frameworks that distinguish procedural fluency from conceptual understanding, and superficial from deep procedural knowledge (Kilpatrick et al., 2001; Star, 2005; Rittle-Johnson et al., 2015), to examine how AI-supported procedures connect to understanding of why they work.

5. Language and perspectives. Because Rwandan students typically learn mathematics in English while speaking Kinyarwanda, studies should examine how language shapes students' prompts and their understanding of AI responses, and should include the perspectives of teachers and parents.

References

- Baikirize, M., Mboniyirivuze, A., Byukusenge, C., Iyamuremye, A., & Nsabayezu, E. (2024). The assessment of the use of information communication technology in the teaching and learning in selected Rwandan secondary schools: A case study of Nyagatare district. *Journal of Classroom Practices*. <https://doi.org/10.58197/prbl/XITH3325>
- Bastani, H., Bastani, O., Sungu, A., Ge, H., Kabakcı, Ö., & Marostica, E. (2025). Generative AI without guardrails can harm learning: Evidence from high school mathematics. *Proceedings of the National Academy of Sciences*, 122(26), e2422633122. <https://doi.org/10.1073/pnas.2422633122>
- Bazina, M., Bimenyimana, S., & Idahemuka, M. (2024). Mathematics teachers' perceptions on the use of technological tools in teaching and learning practices in selected Rwandan secondary schools. *African Journal of Empirical Research*, 5(3). <https://doi.org/10.51867/ajernet.5.3.69>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp0630a>
- Bulut, N., & Borromeo Ferri, R. (2026). AI-powered learning: Exploring secondary school students' use of ChatGPT for solving mathematical modelling problems. *ZDM–Mathematics Education*. <https://doi.org/10.1007/s11858-026-01803-6>
- Byusa, E., Kampire, E., & Mwesigye, A. R. (2021). A case study on chemistry classroom practices in the Rwandan secondary schools. *Heliyon*, 7(6), e07352. <https://doi.org/10.1016/j.heliyon.2021.e07352>
- Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education* (8th ed.). Routledge.
- Egara, F. O., Mosimege, M., & Mosia, M. (2025). Secondary school students' perceptions of their usage of artificial intelligence-based ChatGPT in mathematics learning. *Journal of Education*, 98, 124–146. <https://doi.org/10.17159/2520-9868/i98a07>
- Farrokhnia, M., Banihashem, S. K., Noroozi, O., & Wals, A. (2024). A SWOT analysis of ChatGPT: Implications for educational practice and research. *Innovations in Education and Teaching International*, 61(3), 460–474. <https://doi.org/10.1080/14703297.2023.2195846>
- Iyamuremye, A., & Ndiokubwayo, K. (2024). Exploring secondary school students' interest and mastery of atomic structure and chemical bonding through ChatGPT. *Educational Journal of Artificial Intelligence and Machine Learning*, 1(1), 1-13. <https://doi.org/10.58197/prbl/9hk37296>

- Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 105–117). Sage.
- Hiebert, J., & Lefevre, P. (1986). Conceptual and procedural knowledge in mathematics: An introductory analysis. In J. Hiebert (Ed.), *Conceptual and procedural knowledge: The case of mathematics* (pp. 1–27). Lawrence Erlbaum.
- Iyamuremye, E., Njiku, J., Maniraho, J. F., & Ndayambaje, I. (2022). Teaching and learning mathematics using technology in Rwanda basic education schools amidst the COVID-19 pandemic. In *Mathematics education in Africa* (pp. 263–277). Springer.
https://doi.org/10.1007/978-3-031-13927-7_16
- Kasneci, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G., Günnemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeffer, J., Poquet, O., Sailer, M., Schmidt, A., Seidel, T., ... Kasneci, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. *Learning and Individual Differences*, 103, 102274. <https://doi.org/10.1016/j.lindif.2023.102274>
- Kilpatrick, J., Swafford, J., & Findell, B. (Eds.). (2001). *Adding it up: Helping children learn mathematics*. National Academy Press.
- Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Sage.
- Lo, C. K. (2023). What is the impact of ChatGPT on education? A rapid review of the literature. *Education Sciences*, 13(4), 410. <https://doi.org/10.3390/educsci13040410>
- Malterud, K., Siersma, V. D., & Guassora, A. D. (2016). Sample size in qualitative interview studies: Guided by information power. *Qualitative Health Research*, 26(13), 1753–1760.
<https://doi.org/10.1177/1049732315617444>
- Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). Jossey-Bass.
- Ministry of ICT and Innovation. (2023). *The National Artificial Intelligence Policy*. Government of Rwanda. <https://www.minict.gov.rw>
- Mukeshimana, B., & Andala, H. O. (2024). Technological usage and students' performance in mathematics in public secondary schools in Rwanda: A case of Kayonza District. *African Journal of Empirical Research*, 5(4). <https://doi.org/10.51867/ajernet.5.4.86>
- Ngiruwonsanga, A., Nkundabakura, P., Nsengimana, T., & Mwumvaneza, E. (2026). Teachers' perception and acceptance of virtual laboratory integration in mathematics teaching in Rwandan secondary schools using the technology acceptance model. *Discover Education*, 5, Article 115. <https://doi.org/10.1007/s44217-026-01107-7>
- Niyibizi, O., Uwitatse, M. C., Sibomana, J., & Mutarutinya, V. (2023). The perception of students on the use of ICT tools to learn mathematics in Gasabo selected public secondary schools. *Journal of Research Innovation and Implications in Education*.
- Patton, M. Q. (2015). *Qualitative research & evaluation methods* (4th ed.). Sage.

- Republic of Rwanda. (2021). Law No. 058/2021 of 13/10/2021 relating to the protection of personal data and privacy. Official Gazette of the Republic of Rwanda.
- Rittle-Johnson, B., Schneider, M., & Star, J. R. (2015). Not a one-way street: Bidirectional relations between procedural and conceptual knowledge of mathematics. *Educational Psychology Review*, 27(4), 587–597. <https://doi.org/10.1007/s10648-015-9302-x>
- Rwanda Education Board. (2015). Competence-based curriculum: Curriculum framework, pre-primary to upper secondary 2015. Rwanda Education Board.
- Song, Y., Kim, J., Liu, Z., Li, C., & Xing, W. (2025). Students' perceived roles, opportunities, and challenges of a generative AI-powered teachable agent: A case of middle school math class. *Journal of Research on Technology in Education*, 1–19. <https://doi.org/10.1080/15391523.2024.2447727>
- Star, J. R. (2005). Reconceptualizing procedural knowledge. *Journal for Research in Mathematics Education*, 36(5), 404–411.
- Taani, O., & Alabidib, S. (2024). ChatGPT in education: Benefits and challenges of ChatGPT for mathematics and science teaching practices. *International Journal of Mathematical Education in Science and Technology*, 56(9), 1748–1777. <https://doi.org/10.1080/0020739X.2024.2357341>
- Twagilimana, I., Perumal, J., Habimana, O., Dlamini, R., Ndayambaje, I., Emmanuel, O., Niyibizi, E., Makalela, L., Makda, F., & Nsabayezi, E. (2026). Integrating ICT in Rwandan schools to enhance access proficiency and utilization. *Discover Education*, 5, 80. <https://doi.org/10.1007/s44217-025-01091-4>
- Yin, R. K. (2018). Case study research and applications: Design and methods (6th ed.). Sage.
- Yoon, H., Hwang, J., Lee, K., Roh, K. H., & Kwon, O. N. (2024). Students' use of generative artificial intelligence for proving mathematical statements. *ZDM–Mathematics Education*, 56, 1531–1551. <https://doi.org/10.1007/s11858-024-01629-0>