



Rwandan Secondary-School Students' Perceptions and Experiences of AI-Generated Visual Instructional Materials in Geometry

Joel Sindikubwabo^{1*}  & Onesme Niyibizi² 

¹University of Rwanda College of Education (URCE), Rwanda

²Institut Catholique de Kabgayi (ICK), Rwanda

Abstract

This qualitative case study explored how Senior Five (S5) students in one Rwandan secondary school perceived and experienced AI-generated visual instructional materials used within teacher-led geometry lessons. Two objectives guided the study: to explore students' perceptions of the materials, and to explore how students described the materials as supporting their understanding of geometric concepts. Ten S5 students who had taken part in the lessons were purposively selected, and individual semi-structured interviews were conducted after the lessons. The interview data were analysed thematically. Participants generally perceived the materials favourably. They described the visuals as making geometric relationships easier to see, the lessons as more engaging, and difficult topics such as three-dimensional figures as more approachable. Participants also described the materials as helping them form clearer mental images, link diagrams to mathematical explanations, follow procedures, and remember content. Reservations centred on occasional unclear or inaccurate content and on the continuing need for teacher explanation, questioning, and practice. Because the study relied on self-reported experience, examined a teacher-mediated intervention, and had no comparison group or independent measure of learning, the findings describe perceived support for understanding rather than demonstrated conceptual gains or effects attributable to AI. The study suggests that AI-generated visual materials may be considered as supplementary resources in Rwandan geometry teaching, provided that teachers verify them and integrate them with conventional teaching and learning activities.

Keywords: Artificial intelligence; Student perceptions; Visual instructional materials; Geometry; Qualitative case study

Article information

Received: 08/09/2025;

Reviewed: 11/09/2026;

Revised: 19/09/2026;

Accepted: 21/09/2026

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

How to cite this article: Sindikubwabo, J., Niyibizi, O. (2026) 'Rwandan Secondary-School Students' Perceptions and Experiences of AI-Generated Visual Instructional Materials in Geometry', *Parabolum Education*, 1(1), pp. 57–71. Doi: <https://doi.org/10.58197/j6z7yk29>

Introduction

Artificial intelligence (AI) is increasingly embedded in educational practice through generative tools that can produce explanations, diagrams, animations and other visual learning resources on demand. This is particularly relevant to geometry, a domain in which learning depends on students' ability to interpret,

manipulate, and connect visual, symbolic, and spatial representations (Arcavi, 2003; Herbst et al., 2025). Generative AI therefore offers teachers a fast way of producing visual materials, but the outputs may be inaccurate or unclear and require human oversight (Kasneci et al., 2023).

International reviews indicate that AI-supported mathematics education is associated with gains in reasoning, personalisation, engagement, and conceptual development, yet the evidence base is methodologically uneven, predominantly quantitative, and concentrated in higher-income countries (Mohamed et al., 2022; Nanda & Pradhan, 2025). In Rwanda, digital technology has been actively promoted in education, but research has largely addressed general ICT integration, teachers' practices, or conventional digital resources.

The gap this study addresses is therefore specific: qualitative evidence on how Rwandan secondary-school students themselves experience AI-generated visual materials in geometry is limited. This gap is not filled by research on AI in mathematics education in general, nor by the substantial literature on established digital visual tools such as GeoGebra. In tools of the latter kind, the mathematical relationships are built into the software by construction. AI-generated visuals, by contrast, are produced from prompts, can be created quickly for almost any topic, and vary in accuracy and clarity, so that teacher verification becomes part of their use. Students' views of such materials cannot simply be inferred from studies of tools designed specifically for mathematics, or from studies of AI that do not concern visual materials.

The study is exploratory. It examines students' perceptions and reported experiences of AI-generated visual materials that were used within teacher-led lessons; it does not measure learning or test the effectiveness of the materials. Accordingly, the second objective concerns students' perceived support for understanding geometric concepts, which is a different matter from demonstrated conceptual understanding.

Research objectives

1. To explore S5 students' perceptions of AI-generated visual instructional materials used, alongside teacher-led instruction, in learning geometry in a secondary school in Rwanda.
2. To explore how S5 students describe AI-generated visual instructional materials as supporting their understanding of geometric concepts.

Related Literature

Visual representation and digital visual tools in geometry learning

Visualisation allows learners to construct, interpret, and reflect on mathematical images and relationships, although visual representations can also mislead when misread (Arcavi, 2003). Research on dynamic mathematics technologies reinforces the importance of visual representation: interactive environments allow students to explore relationships, connect multiple representations, and build conceptual understanding (Hamzah & Hidayat, 2022; Ng & Rosli, 2023). Systematic reviews of GeoGebra research identify geometry and upper-secondary mathematics as major areas of application, with most studies examining performance, higher-order thinking, attitudes, opinions, and perceptions, and comparatively little attention paid to engagement and other learner experiences (Ng & Rosli, 2023). A recent review of secondary geometry education likewise foregrounds digital technologies, visualisation, and spatial thinking, while calling for closer links between research and classroom practice (Herbst et al., 2025). This literature is relevant to the present study, but it concerns tools in which the teacher or designer constructs mathematical

objects that behave according to encoded geometric relationships. It does not address materials generated by AI from natural-language prompts, whose accuracy and clarity cannot be assumed and must be checked.

AI in mathematics education and AI-generated content

AI research in education has moved beyond traditional intelligent tutoring systems toward generative and multimodal tools capable of producing educational content and mathematical representations. Mohamed et al. (2022) found that AI research in mathematics education has addressed conceptual understanding, instructional strategies, and learner outcomes, but that most studies were quantitative and concentrated in countries such as the United States and Mexico. Nanda and Pradhan (2025) report a similar pattern, with empirical and descriptive studies dominated by high-income settings and limited evidence from low-resource contexts. Evidence specific to mathematics suggests that AI-supported learning can yield positive cognitive outcomes, including in geometry, but it derives largely from quantitative or intervention-based research rather than from detailed qualitative accounts of students' experiences (Molemane et al., 2026). Systematic reviews continue to stress the need to understand how AI is actually experienced and integrated by learners and teachers (Almasri, 2024), and Kasneci et al. (2023) argue that AI-generated educational content can enhance engagement and personalisation but requires human oversight because it may contain inaccuracies or biases. Taken together, this literature establishes the potential value of AI and of visual technologies, but leaves insufficiently understood how secondary-school students perceive AI-generated *visual* materials and how they experience them as support for understanding geometry.

Technology and instructional materials in Rwandan mathematics education

Rwanda has invested substantially in ICT in education. Earlier research showed that providing computers and infrastructure alone does not guarantee meaningful classroom use: teacher capacity, school context, and pedagogical practice shape how technology contributes to learning (Rubagiza et al., 2010), and ICT can support science and mathematics education when accompanied by professional development and student-centred approaches (Sutherland, 2010). More recent studies in mathematics education highlight technology's potential to increase motivation and engagement while recommending stronger teacher professional development (Irakarama et al., 2024), and they document continuing constraints on ICT facilities (Niyibizi, 2025; Niyibizi & Mutarutinya, 2024). Niyitegeka and Kamuhanda (2026) examined a mobile application for mathematical problem-solving among lower-secondary students, which shows the growing relevance of digital tools but did not concern AI-generated visual materials or geometry.

Studies of instructional materials in Rwandan secondary mathematics found that teachers frequently relied on textbooks and writing materials without consistently offering students opportunities for active interaction with instructional resources (Mugisha et al., 2023), and they emphasised availability, utilisation, and academic performance rather than students' experiences (Uwitatse et al., 2023). Most closely related, Niyibizi (2026) investigated AI-based learning tools and conceptual understanding among pre-service teachers in Rwanda and reported promising evidence; however, that study used a quasi-experimental mixed-methods design with pre-service teachers, and did not examine secondary-school students' perceptions of AI-generated visual materials for geometry.

Conceptual framing: conceptual understanding and perceived support for understanding

Following Hiebert and Lefevre (1986) and Kilpatrick et al. (2001), conceptual understanding is understood here as comprehension of mathematical concepts and relations, reflected in knowledge that is rich in connections among ideas and among representations. In geometry, this includes forming coherent mental

images of figures and relationships and linking diagrams to properties, formulas, and reasoning. Procedural knowledge, by contrast, concerns knowing the steps of a method, and can exist with or without conceptual understanding.

Demonstrating conceptual understanding requires evidence such as students' explanations, problem solving, or performance on suitable tasks. The present study did not collect such evidence. Its interviews elicited what students *said* about their understanding. The study therefore treats participants' descriptions of (a) clearer mental representations and (b) connections between diagrams and mathematical explanations as their perceived support for conceptual understanding. Their descriptions of (c) following geometric procedures and (d) retaining content are treated as related perceived learning benefits, which concern procedural knowledge and retention rather than conceptual understanding in itself.

Methods

Research design

The study was guided by an interpretivist paradigm because it sought to understand how students made sense of, and gave meaning to, their experiences of AI-generated visual materials during geometry learning. A qualitative single-case design (Stake, 1995; Yin, 2018) was used. The case was bounded by one secondary school, one S5 mathematics class, a series of geometry lessons, and students' direct exposure to AI-generated visual materials within those lessons. The unit of analysis was students' experience of these materials as used inside teacher-led lessons.

This feature of the design matters for interpretation. The case deliberately includes the teacher's explanations, questioning, and learning activities, because students' experiences could not meaningfully be separated from them. The study therefore does not isolate the contribution of the AI-generated visuals, does not measure achievement, and does not seek causal or statistically generalisable claims.

Setting and instructional context

The study was conducted in one public secondary school in Gasabo District, Kigali City, Rwanda, that offers the S5 Mathematics curriculum under Rwanda's Competence-Based Curriculum (CBC). The geometry topics were geometric shapes, angles, transformations, spatial relationships, areas, volumes, and three-dimensional figures. Specific sub-topics included properties of triangles and quadrilaterals, angle relationships, reflection, rotation and translation, surface area and volume of prisms, cylinders, pyramids and cones, nets of solids, and representations of three-dimensional figures. Six geometry lessons of 80 minutes each were taught over three weeks. The materials were displayed using a laptop and classroom projector, with printed handouts used as backup where projection was difficult. S5 students were selected because they had enough experience of secondary-level geometry to compare the materials with their usual learning experiences.

In every lesson the AI-generated visuals were used as a supplement to instruction. The lessons were taught by the regular class teacher, while the researchers prepared the AI-generated materials and conducted the interviews. The teacher provided accompanying explanations, asked questions, and organised learning activities. Students could ask questions, interpret the representations, and apply the concepts through geometry exercises. The lessons were thus a combination of AI-generated visuals and conventional teacher-led activities, and this combination is the context in which students' experiences arose.

The AI-generated visual materials

Before the lessons, the researchers generated visual materials for the selected topics using generative AI tools ChatGPT-4o with DALL·E 3 (OpenAI), Microsoft Copilot Designer, and Canva Magic Media. The tools were used between 10 January and 5 February 2026. Table 1 documents the materials. Each prompt contained the geometry topic, the S5 grade level, the relevant Rwandan CBC competence, the type of representation requested (diagram, animation, 3-D model, or step-by-step visual explanation), and instructions to avoid distracting text and to label key mathematical features in English. Prompts were refined iteratively when the first output was unclear, inaccurate, or not aligned with the Rwandan curriculum.

Table 1. Documentation of the AI-generated visual materials

Aspect	Description
AI tool(s)	ChatGPT-4o with DALL·E 3, Microsoft Copilot Designer, Canva Magic Media; used 10 January–5 February 2026
Types of material	Diagrams; visual models; short animations; representations of three-dimensional shapes; step-by-step visual explanations
Geometry topics	Geometric shapes; angles; transformations; spatial relationships; areas; volumes; three-dimensional figures. Sub-topics: properties of triangles and quadrilaterals, angle relationships, reflection/rotation/translation, surface area and volume of prisms, cylinders, pyramids and cones, nets of solids.
Number of materials	38 materials were generated; 24 were used in lessons (12 diagrams, 6 animations, 4 3-D models, 2 step-by-step visual explanations).
Verification before use	Checked against the approved Rwandan S5 Mathematics textbook, the national CBC curriculum, and established mathematical principles for accuracy, curriculum relevance, clarity, language appropriateness, suitability for S5, and absence of inappropriate content.
Revision	Six materials judged unclear or mathematically inaccurate were corrected; five were excluded. Problems included mislabelled angles, distorted 3-D proportions, and cluttered diagrams.
Use in lessons	Supplementary to teacher explanation, questioning, and learning activities. Displayed through a projector connected to a laptop; printed handouts used as backup. Used in all six lessons.

Participants and sampling

Purposive sampling was used to select students with direct experience of the phenomenon. Students were eligible if they were enrolled in S5 at the school, were studying mathematics, had participated in the geometry lessons in which the AI-generated materials were used, were willing to participate voluntarily, and provided informed consent or, where applicable, assent together with parental/guardian consent. Students who had not experienced the materials were excluded because they could not give first-hand accounts. The researchers sought variation in students' prior familiarity with digital learning resources and included both

male and female students. The class had 42 S5 Mathematics students. From the eligible students, ten participants were purposively chosen to include six male and four female students and to vary prior experience with digital learning resources. All ten had attended at least five of the six geometry lessons. Participants are identified as S1–S10 throughout.

Table 2. Participant characteristics

Characteristic	Participants (n = 10)
Gender	Six male, four female
Age	17 to 20 years
Prior experience with digital learning resources (videos, animations, educational websites, computer-based tools)	Seven reported prior experience; three reported limited exposure

Sample size

Ten participants can be appropriate for a bounded qualitative case, and the sample size was guided by the concept of information power (Malterud et al., 2016) rather than by data saturation. Information power is higher when the study aim is narrow, participants hold specific relevant experience, and the analysis focuses on patterns across participants. In this study the aim was narrow (perceptions and reported experiences of one kind of material, in one domain and one grade), all participants had direct experience of the same lessons, and all interviews were organised around the same two objectives. On this basis, ten interviews were judged to provide sufficient information for a bounded case. Thematic saturation was not claimed, because it is a contested criterion for thematic analysis (Braun & Clarke, 2021). Recruitment ended at ten interviews by design. The final two interviews largely confirmed the emerging themes, but saturation is not claimed.

Data collection

The principal instrument was a semi-structured interview guide developed from the two objectives. It had three parts: basic participant information (age, gender, and prior experience with digital learning materials); perceptions of the materials (clarity, attractiveness, usefulness, engagement, and limitations); and experiences of understanding geometry (visualisation, connections between representations and explanations, procedures, and recall). Core questions were:

- How did you perceive the use of AI-generated visual materials during geometry lessons?
- What did you find most useful about the visual materials?
- In what ways, if any, did the materials influence your interest or engagement in geometry?
- Which geometry concepts became easier or clearer through the visual materials?
- How did the materials help you understand diagrams, shapes, angles, or three-dimensional figures?
- What difficulties or limitations did you experience when using the AI-generated materials?
- What role did the teacher play when you were learning with the AI-generated visual materials?

Permission was first obtained from the school. Eligible students were then identified and selected, the materials were used in geometry lessons, and individual interviews were conducted afterwards. Interviews were conducted three to seven days after the last lesson in the school library or an empty classroom. They were conducted in Kinyarwanda and English, according to each participant's preference, because students could express nuanced experiences more easily in Kinyarwanda while using English for mathematical terms. Interviews lasted 35–50 minutes, were audio-recorded with consent, and were transcribed verbatim by the researcher. Kinyarwanda extracts were translated into English by the researcher and checked by a bilingual mathematics teacher for accuracy. The interviews were conducted by the researcher. Follow-up probes were used to clarify and deepen responses.

Data analysis

The interview data were analysed thematically, following the phases described by Braun and Clarke (2006). Thematic analysis was used, rather than narrative analysis, because the aim was to identify patterns of meaning across participants' accounts in relation to the two objectives, not to analyse the structure of individual narratives. The transcripts were read repeatedly; meaningful statements were coded; related codes were grouped into categories and developed into themes; and the themes were reviewed against the transcripts and named. The two objectives provided broad domains for organising the analysis, while codes and themes within these domains were developed inductively from the transcripts.

Coding was carried out by the researcher manually using Word and Excel. A second researcher, an experienced mathematics education lecturer, independently coded 30% of the transcripts. The two coders discussed disagreements and alternative interpretations until agreement was reached. Divergent and disconfirming accounts were retained and are reported in the results. In the Results, words such as “most”, “several”, “some”, and “a few” indicate roughly how widely a view was expressed among the ten participants. These are descriptive signposts and not measures of prevalence; with ten purposively selected participants, they should not be read statistically.

Trustworthiness and researcher positionality

Trustworthiness was addressed using the criteria of credibility, dependability, confirmability, and transferability (Lincoln & Guba, 1985).

Credibility. Participants were selected for their direct experience of the lessons, and open questions with probes allowed them to explain their views in their own words. Questions invited difficulties and limitations as well as benefits, and divergent accounts were retained in the analysis. Member checking was used with five participants, who reviewed a summary of their interview and the preliminary themes. Peer debriefing was conducted with two mathematics education colleagues. Triangulation used lesson notes and field notes. A reflexive journal was kept throughout the study.

Dependability. The same core interview guide was used with all participants, and the sequence of selection, classroom exposure, interviewing, transcription, coding, and analysis was documented. An audit trail of coding decisions was kept.

Confirmability. Themes were grounded in participants' accounts, supported by verbatim extracts, and the coding records were retained so that interpretations can be traced to the data. Participants' reservations about the materials were reported rather than set aside.

Transferability. The setting, participants, materials, classroom exposure, and procedures are described so that readers can judge relevance to comparable settings. The findings are not intended to represent all Rwandan secondary-school students.

Researcher positionality. The researcher prepared the AI-generated materials, the regular class teacher taught the lessons, and the researchers conducted the interviews. This creates a risk that participants offered favourable views to please a teacher who had designed the materials, that the researchers' investment in the materials shaped the questions, probes, or interpretations, and that students' comments on the materials were bound up with their views of the teacher. Steps taken included assurances that participation and responses would not affect grades, explicit invitations to criticise the materials, neutral wording of probes, and reflexive notes after each interview. These influences cannot be eliminated. They are taken into account in the interpretation of the findings and are stated as a limitation.

Ethical considerations

Participants were informed of the purpose of the study, the nature of participation, and their right to participate voluntarily and to withdraw without penalty. Because participants were aged 17 to 20, consent was obtained from those who were adults, and assent together with parental/guardian consent was obtained where required. Because the researcher had a teaching relationship with the participants, participation was voluntary. Confidentiality was maintained through the codes S1–S10 and by excluding identifying details from the report. Data were used for academic research only. The AI-generated materials were also screened for inappropriate content before classroom use.

Results

The analysis produced seven themes, four for the first objective and three for the second, together with a cross-cutting concern about teacher mediation. Because participants took part in teacher-led lessons in which the AI-generated visuals were used together with teacher explanation and activities, the themes describe how students perceived the materials in that combined context, and not the effect of the visuals alone.

Table 3. Overview of themes

Objective	Theme	Summary of participants' accounts	Variation among participants
1. Perceptions	1. Seeing geometric relationships	Diagrams, animations, and 3-D representations made relationships among shapes, measurements, and angles easier to see	A few participants said they still preferred textbook diagrams for revision.
1. Perceptions	2. Engagement and interest	Lessons seemed more attractive, interactive, and different from chalkboard- and textbook-based teaching	A few participants perceived little change in interest, especially where the visual was not accompanied by clear explanation

1. Perceptions	3. Making difficult topics more approachable	Seeing a concept from more than one perspective helped with three-dimensional shapes, transformations, angles, and spatial relationships	Some participants still needed repeated practice after the lesson.
1. Perceptions	4. Reservations about clarity and accuracy	Concern that some representations might be unclear or inaccurate; teacher explanation or correction was sometimes needed	Expressed by some participants only
2. Perceived support for understanding	5. Clear mental representations	Animations and models helped students picture relationships among lines, angles, shapes, and dimensions instead of relying on definitions or formulas	A few participants said they could form images only after teacher explanation.
2. Perceived support for understanding	6. Connecting diagrams and explanations	Pairing a visual with a step-by-step explanation made it easier to see why formulas or procedures are used	Some participants linked this mainly to teacher explanation rather than the visual alone.
2. Perceived support for understanding	7. Following procedures and remembering	Visual, sequential demonstration made procedures easier to follow; associations with diagrams and movement aided recall	Several participants still relied on written notes for revision.
Cross-cutting	Visuals alongside teacher mediation	Visuals were not always sufficient; teacher explanation, opportunities to ask questions, and practice supported consolidation	Emphasised explicitly by some participants

Objective 1: Students' perceptions of the AI-generated visual materials

Theme 1: Seeing geometric relationships

Most participants said that the materials made geometric concepts easier to visualise. They referred to diagrams, animations, three-dimensional representations, and step-by-step visual explanations as useful for seeing relationships among shapes, measurements, angles, and spatial features that they sometimes found difficult to interpret from textbook diagrams alone. One participant explained that a visual representation helped them to see how the shape changes when different measurements are applied.

“The diagram showed me how the angles changed when I moved one side. In the textbook it was just a picture, but here I could see the relationship.” (S3)
“When the teacher projected the animation of a rotating shape, I saw that the angles remained the same even when the position changed. That helped me understand transformation better.” (S7)

Accounts of this kind place the value of the materials in making relationships observable and, in the case of animations, in showing change. They show what participants valued and how they described it. They do not show whether students could reason about these relationships without the visuals. A few participants said they still preferred textbook diagrams when revising alone because they could write on them.

Theme 2: Engagement and interest

Most participants described lessons with the AI-generated visuals as more attractive, interactive, or different from conventional chalkboard- and textbook-based teaching, and some said the visuals encouraged closer attention and questioning.

“The lesson was interesting because we saw animations instead of only copying from the chalkboard. I wanted to ask questions.” (S8)

A few participants, however, did not perceive a substantial change in interest, particularly where the visual was not accompanied by a clear explanation.

“For me, it was almost the same. If the teacher did not explain the animation, I just watched it and did not understand.” (S9)

This divergence suggests that engagement was tied to how the visuals were explained and not to the visuals alone. Reported engagement may also partly reflect novelty, since students were comparing the lessons with their usual chalkboard and textbook instruction; the study cannot separate these possibilities.

Theme 3: Making difficult topics more approachable

Several participants found the materials helpful for difficult geometry topics, especially three-dimensional shapes, transformations, angles, and spatial relationships. They valued seeing the same concept represented from more than one perspective.

“Three-dimensional figures were difficult for me. When they showed the prism from the front, side, and top, I started to see how the faces meet.” (S2)

Participants thus linked the usefulness of the materials to topics in which spatial thinking is demanding. This is a statement about perceived helpfulness. It cannot be taken to show that these topics were learned better.

Theme 4: Reservations about clarity and accuracy

Some participants expressed concern about possible inaccuracies or unclear representations and indicated that teacher explanation or correction was sometimes necessary. These participants expected that the materials should be checked and interpreted with teacher support.

“Sometimes the drawing was not clear; the lines were mixed, so I waited for the teacher to correct it.” (S5)

These accounts qualify the generally positive perceptions above. They also indicate that students positioned

the teacher as verifier and interpreter of the visuals, which may reflect the authority teachers hold in the classroom as well as the practical need for verification. Although the materials were reviewed before use, students' concerns show that clarity, and not only accuracy, matters to how the materials are experienced.

Objective 2: Students' perceived support for understanding geometric concepts

Theme 5: Clearer mental representations

Most participants reported that the materials helped them form clearer mental representations of geometric concepts. They described animations and visual models as helping them observe relationships among lines, angles, shapes, dimensions, and spatial features, instead of relying only on verbal definitions or formulas.

"I can now picture the triangle in my mind. Even when I close the book, I remember how the height and base relate." (S1)

Participants experienced the visuals as a bridge between abstract mathematical ideas and observable representations. What is captured here is the students' sense of having a clearer mental image; the interviews did not test whether the images were mathematically correct or usable in problem solving.

Theme 6: Connecting diagrams and mathematical explanations

Most participants said that combining a visual representation with a step-by-step explanation made it easier to understand why particular formulas or procedures were used. This was most apparent in their descriptions of areas, volumes, angles, and properties of three-dimensional figures.

"When the teacher showed the diagram with the formula for area, I understood why we multiply base and height, not just memorize." (S4)

Connecting representations with explanations is a recognised feature of conceptual understanding (Hiebert & Lefevre, 1986; Kilpatrick et al., 2001), so these accounts point to a dimension of understanding that participants believed the materials supported. They remain perceptions. The step-by-step explanation was also delivered within teacher-led lessons, and it is not possible to say how much of the connection-making came from the visual and how much from the accompanying explanation.

Theme 7: Following procedures and remembering

Several participants reported that they understood geometric procedures better when processes were shown visually and sequentially, and several reported that the visuals helped them retain concepts for longer because they could associate mathematical information with diagrams, movement, or visual examples.

"The steps were shown one by one, so I could follow how to construct the angle. The movement helped me remember." (S6)

These accounts concern perceived procedural understanding and recall. No delayed assessment was carried out, so the statements about remembering are participants' impressions and not measures of retention.

Cross-cutting: Visuals alongside teacher mediation

Some participants stated explicitly that the visual materials alone were not always sufficient. They identified

teacher explanation, opportunities to ask questions, and subsequent practice as important for consolidating understanding.

“The visual alone was not enough for me. I needed the teacher to explain and then we practised exercises.”
(S10)

These accounts are important for interpreting all seven themes. Students experienced the AI-generated visuals as a supplementary support, and in the context of teacher-led instruction, and not as a replacement for the teacher.

Discussions

The findings describe how ten S5 students in one school perceived AI-generated visual materials used within teacher-led geometry lessons. Their perceptions were generally favourable, but the study’s design supports claims about perceived support for understanding, not about demonstrated conceptual gains or about the effects of AI as such.

The prominence of visualisation in participants’ accounts is consistent with Arcavi (2003) argument that visual representations help learners construct and interpret mathematical relationships, and with research on dynamic mathematics technologies showing that visual and interactive environments support exploration of relationships and connections among representations (Hamzah & Hidayat, 2022; Ng & Rosli, 2023). The emphasis on three-dimensional figures and spatial relationships also fits the attention that reviews of secondary geometry education give to visualisation and spatial thinking (Herbst et al., 2025). An important qualification, however, follows from the design. The study did not compare AI-generated visuals with visuals from other sources, such as textbooks, hand-drawn diagrams, or dynamic geometry software. Participants’ appreciation may therefore reflect the visual and dynamic character of the materials, which might be achieved by other means, and not the fact that the materials were generated by AI. What may be distinctive about AI-generated materials is the ease with which they can be produced for a range of topics and, as participants’ reservations indicate, the need for their clarity and accuracy to be checked (Kasneci et al., 2023).

Regarding conceptual understanding, participants described forming clearer mental images and connecting diagrams with explanations, which are features of understanding that is rich in connections (Hiebert & Lefevre, 1986; Kilpatrick et al., 2001). These are important perceptions, and they suggest aspects of learning that future studies could examine directly. But self-reports of understanding are not evidence of understanding. Verifying whether the materials support conceptual understanding would require, for example, tasks in which students explain the reasons for a formula, pre- and post-lesson assessments, or comparison with students taught without such materials. The present study complements, and does not test, the promising findings of Niyibizi (2026) on AI-based tools and conceptual understanding among Rwandan pre-service mathematics teachers, whose quasi-experimental design allowed comparisons that this study does not, and whose participants and content focus differ.

Participants did not describe the visuals as sufficient on their own, and the divergence in engagement suggests that the way visuals were explained mattered. This is in line with Rwandan literature showing that the contribution of technology depends on teacher capacity, pedagogical practice, and meaningful integration (Rubagiza et al., 2010; Niyibizi & Maturutinya, 2024). It may also be significant that participants compared the lessons with teaching that relied largely on textbooks and writing materials, a pattern documented in Rwandan secondary mathematics classrooms (Mugisha et al., 2023). The contrast with usual practice, and not only the AI origin of the visuals, may have shaped their responses.

The contribution of the study is therefore a qualitative, student-centred account, from a Rwandan secondary school, of how AI-generated visual materials were perceived when used alongside teacher-led instruction. It suggests where future evaluative research should look: at the role of teacher mediation, at the clarity and accuracy of generated visuals, and at whether perceived support translates into demonstrated understanding.

Limitations of the Study

The study was conducted in one school and involved ten purposively selected S5 students, so the findings are context-specific and not statistically generalisable. Data were self-reported by students after classroom exposure, so the study does not independently measure changes in achievement or conceptual understanding. There was no comparison group and no pre/post assessment, and the design therefore cannot show that the AI-generated materials caused improvement in learning.

The AI-generated materials were used together with teacher explanations, questioning, and learning activities. Students' experiences cannot be attributed to the visuals alone, and the contribution of the teacher's mediation cannot be separated from that of the materials. In addition, the study examined a researcher-prepared set of materials produced with ChatGPT-4o with DALL·E 3, Microsoft Copilot Designer, and Canva Magic Media, and not a single standardised tool, which limits replication. The researcher's roles in preparing the materials, the regular teacher's role in teaching the lessons, and the researcher's role in conducting the interviews may have led participants to give favourable responses, and reported engagement may partly reflect the novelty of the materials. A further limitation is that interviews were conducted in Kinyarwanda and English and translated into English, so some information may have been lost despite checking by a bilingual mathematics teacher.

Conclusion and Recommendations

Conclusion

The ten S5 participants generally perceived AI-generated visual instructional materials favourably when they were used within teacher-led geometry lessons. They valued the materials for making geometric relationships more visible, for making lessons more engaging (although not for all), and for making difficult topics more approachable. They described the materials as helping them form clearer mental images, connect diagrams with mathematical explanations, follow procedures, and remember content. They also identified limitations: the possibility of unclear or inaccurate content and the continued need for teacher explanation, questioning, and practice.

Within the limits of this qualitative case study, the evidence supports the conclusion that students perceived the materials as supporting their understanding of geometry, and described ways in which they did so. The study does not establish that the materials improved conceptual understanding or achievement, that AI was the cause of any improvement, or that the findings hold beyond similar settings.

Recommendations

Given the small, single-school, teacher-mediated design, the recommendations are tentative. First, AI-generated visual materials may be considered by Rwandan schools and mathematics teachers as supplementary resources for geometry, provided that teachers verify them for mathematical accuracy, clarity, curriculum relevance, and age appropriateness before use and integrate them with conventional teaching and learning activities, including explanation, questioning, and practice. Second, teacher

professional development that addresses AI-generated materials should cover not only how to generate them but also how to verify them, explain them, question students about them, and connect them to worked examples and practice. Third, further research should include larger and more diverse samples, should assess conceptual understanding directly (for example through explanation tasks, pre/post assessments, or comparison groups), should compare AI-generated visuals with visuals from other sources, should use classroom observation to clarify the role of teacher mediation, and should examine the feasibility of using such materials in schools with limited connectivity or devices.

Use of AI tools: AI tools were used to generate the instructional materials described in the Methods. AI tools were not used to analyse the data or to write the manuscript.

References

- Almasri, F. (2024). Exploring the impact of artificial intelligence in teaching and learning of science: A systematic review of empirical research. *Research in Science Education*, 54, 977–997. <https://doi.org/10.1007/s11165-024-10176-3>
- Arcavi, A. (2003). The role of visual representations in the learning of mathematics. *Educational Studies in Mathematics*, 52, 215–241. <https://doi.org/10.1023/A:1024312321077>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp0630a>
- Braun, V., & Clarke, V. (2021). To saturate or not to saturate? Questioning data saturation as a useful concept for thematic analysis and sample-size rationales. *Qualitative Research in Sport, Exercise and Health*, 13(2), 201–216. <https://doi.org/10.1080/2159676X.2019.1704846>
- Hamzah, N. A. H., & Hidayat, R. (2022). The role of GeoGebra software in mathematics education: A systematic literature review. *Jurnal Pendidikan Sains dan Matematik Malaysia*, 12(1). <https://doi.org/10.37134/jpsmm.vol12.1.3.2022>
- Herbst, P., Cirillo, M., Fujita, T., Steinhorsdottir, O., Miyakawa, T., & Ng, O. (2025). Geometry education at secondary level: A systematic literature review. *ZDM – Mathematics Education*. <https://doi.org/10.1007/s11858-025-01703-1>
- Irakarama, V., Nteziyaremye, A., Kuradusenge, J. P. R., & Bucyedusenge, V. (2024). ICT integration in teaching and learning mathematics for secondary schools: Case of TTC Gacuba II, Rwanda. *African Journal of Empirical Research*, 5(3), 143–154. <https://doi.org/10.51867/ajernet.5.3.14>
- 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>
- Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Sage.
- 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>
- Mohamed, M. Z., Hidayat, R., Suhaizi, N. N. binti, Sabri, N. binti M., Mahmud, M. K. H. bin, & Baharuddin, S. N. binti. (2022). Artificial intelligence in mathematics education: A systematic literature review. *International Electronic Journal of Mathematics Education*, 17(3), em0694. <https://doi.org/10.29333/iejme/12132>

- Molemane, N., Mosia, M., & Egara, F. O. (2026). Effectiveness of AI-based tutoring and assessment systems in mathematics education: A systematic review. *Discover Education*. <https://doi.org/10.1007/s44217-026-01872-5>
- Mugisha, E., Uworwabayeho, A., & Urwibutso, A. (2023). Teachers' use of instructional materials in the teaching and learning of mathematics in private secondary schools of Gasabo District, Rwanda. *Journal of Research Innovation and Implications in Education*. <https://doi.org/10.59765/qazf3791>
- Nanda, S. B., & Pradhan, D. K. (2025). Artificial intelligence in mathematics education: A systematic review of global trends and emerging themes. *Journal of Mathematics, Science and Technology Education*, 2(2), 153–175. <https://doi.org/10.12973/jmste.2.2.153>
- Ng, A. P., & Rosli, R. (2023). Systematic literature review: The use of GeoGebra software in geometry learning. *Jurnal Pendidikan Sains dan Matematik Malaysia*, 13(1). <https://doi.org/10.37134/jpsmm.vol13.1.6.2023>
- Niyibizi, O. (2025). Enhancing ICT facilities in secondary mathematics education: A literature review. *Journal of Technology-Assisted Learning*, 1(2). <https://doi.org/10.70232/jtal.v1i2.10>
- Niyibizi, O. (2026). Influence of artificial intelligence-based learning tools on pre-service teachers' conceptual understanding of mathematical concepts. *Contemporary Mathematics and Science Education*, 7(1), ep26006. <https://doi.org/10.30935/conmaths/18064>
- Niyibizi, O., & Mutarutinya, V. (2024). Teachers' use of ICT facilities in mathematics education. *International Journal of Studies in Education and Science*. <https://doi.org/10.46328/ijses.79>
- Niyitegeka, T., & Kamuhanda, D. (2026). Evaluating the effectiveness of a mathematics word problem mobile app in enhancing problem-solving skills among lower secondary students in Kicukiro District, Rwanda. *Journal of Research in Mathematics, Science, and Technology Education*, 3(2). <https://doi.org/10.70232/jrmste.v3i2.60>
- Rubagiza, J. M., Were, E., & Sutherland, R. (2010). Introducing ICT into schools in Rwanda: Educational challenges and opportunities. *International Journal of Educational Development*. <https://research-information.bris.ac.uk/en/publications/introducing-ict-into-schools-in-rwanda-educational-challenges-and/>
- Stake, R. E. (1995). *The art of case study research*. Sage.
- Sutherland, R. (2010). *Using ICT to support science and mathematics education in Rwanda: Teacher education key to quality education with ICT* (EdQual Policy Brief No. 3). <https://www.edqual.org/publications/policy-briefs/pb3.pdf>
- Uwitatse, M. C., Niyibizi, O., & Mutarutinya, V. (2023). Assessing the use of instructional materials on learners' academic performance in mathematics: A case of selected ordinary level secondary schools of Musanze District, Rwanda. *Journal of Research Innovation and Implications in Education*, 7(4), 12–19. <https://doi.org/10.59765/prfat8103>
- Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). Sage.