American Journal of Educational Research, 2026, Vol. 14, No. 8, 289-297
Available online at http://pubs.sciepub.com/education/14/8/4
Published by Science and Education Publishing
DOI:10.12691/education-14-8-4

Experiences, Challenges, and Resource Needs of Teachers in Implementing Innovative Teaching Methods for 3D Geometry Instruction

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Received July 23, 2026; Revised August 25, 2026; Accepted September 03, 2026

Abstract This study explored the experiences, challenges, and resource needs of teachers in implementing innovative teaching methods for 3D geometry instruction in public day secondary schools in Musanze District, Rwanda. The study focused on teachers' experiences with technology integration, inquiry-based learning, guided discovery learning, collaborative learning, and visualization strategies, as well as the challenges and support required for their effective implementation. A qualitative research approach was adopted, involving 20 purposively selected mathematics teachers who participated in semi-structured interviews. Each interview lasted approximately 30-45 minutes, and the interviews were digitally recorded and transcribed verbatim with participants' consent. The qualitative data were analyzed manually using Braun and Clarke's six-phase thematic analysis framework. Four major themes emerged: Pedagogical Pivot towards Conceptual and Spatial Visualization; Behavioral and Affective Shifts in Learner Engagement; Systemic Deficits and Contextual Constraints to Implementation; and Institutional Scaffolding and Professional Capacity Building. The findings indicated that teachers experienced innovative teaching methods as useful for presenting abstract 3D geometry concepts, supporting visualization, encouraging active participation, and promoting learner engagement. However, inadequate computers and ICT resources, unreliable electricity and internet connectivity, large class sizes, limited instructional time, and insufficient teacher training constrained effective implementation. Teachers identified the need for computers, projectors, concrete geometry models, instructional materials, improved ICT infrastructure, and continuous professional development. The study concludes that effective implementation of innovative teaching methods for 3D geometry instruction requires adequate instructional and technological resources, continuous professional development, and supportive institutional conditions.

Keywords: *innovative teaching methods, 3D geometry, teachers' experiences, implementation challenges, resource needs, mathematics instruction, Musanze District, Rwanda*

Cite This Article: Emmanuel Byiringiro, Prof. Catherine Muhonja Aurah, and Dr. Beatrice Nakhanu Shikuku, "Experiences, Challenges, and Resource Needs of Teachers in Implementing Innovative Teaching Methods for 3D Geometry Instruction." *American Journal of Educational Research*, vol. 14, no. 8 (2026): 289-297. doi: 10.12691/education-14-8-4.

1. Introduction

Globally, mathematics is an important component of secondary education because it contributes to the development of logical reasoning, critical thinking, problem-solving, analytical abilities, and spatial thinking that are important for further education and participation in science, technology, engineering, and mathematics (STEM) [1]. Geometry is particularly important because it requires learners to interpret representations, recognize relationships among geometric elements, and apply spatial reasoning to solve mathematical problems. Three-dimensional geometry presents additional demands because it requires learners to understand objects involving length, width, and height and to interpret spatial relationships that may not be immediately visible through conventional two-dimensional representations. Research has established a relationship between spatial skills and mathematical performance and has demonstrated that spatial abilities can be developed through appropriate educational experiences [2].

In Europe, mathematics education has increasingly incorporated digital technologies and innovative pedagogical approaches that require teachers to develop appropriate technological and pedagogical competencies [3]. Technology-supported geometry instruction provides teachers with opportunities to use dynamic representations and interactive mathematical environments to support the teaching of geometric concepts. Research on the use of GeoGebra in geometry education has highlighted the importance of technology-supported visualization and the preparation of mathematics teachers to integrate digital

tools into their instructional practices [4]. Effective implementation, however, requires more than access to technological tools because teachers need appropriate technological, pedagogical, and content knowledge to select and use digital resources meaningfully in their classrooms [4].

Across Africa, the implementation of innovative mathematics teaching methods continues to be influenced by teachers' technological competencies, availability of instructional resources, and the conditions in which teaching takes place. These issues are particularly relevant to geometry because teachers require appropriate representations, teaching materials, technological facilities, and pedagogical skills to support the visualization of abstract and spatial concepts. Research on mathematics teachers' technological pedagogical content knowledge has shown that teachers' ability to integrate technology into mathematics instruction is influenced by their knowledge and the context in which technology is used [4,5]. Evidence from African mathematics education also indicates that teachers' experiences with digital resources and professional learning are shaped by issues such as access to technology, internet connectivity, and opportunities to develop digital competencies [5].

Within East Africa, increasing attention has been given to ICT-supported mathematics instruction, innovative pedagogical approaches, and teacher professional development. Research in the region has emphasized that teachers require more than technical knowledge of digital tools; they also need to understand how technological resources can be integrated with mathematical content and appropriate teaching strategies. The TPACK framework emphasizes that effective technology-supported instruction requires the integration of technological, pedagogical, and content knowledge [4]. In addition, evidence from Rwanda indicates that mathematics and science teachers have increasingly used modernized teaching tools and innovative methods, while professional development has been identified as an important component of strengthening teachers' instructional capacity [6,7].

In Rwanda, mathematics education has undergone pedagogical changes associated with curriculum reform and efforts to strengthen learner-centered and innovative teaching practices. Uworwabayeho [8] documented mathematics teachers' movement toward learner-centered pedagogy and greater acceptance of learner autonomy, while also showing that the introduction of dynamic geometry software challenged established classroom practices and encouraged teachers to reflect on their approaches to mathematics teaching. More recent research involving mathematics and science teachers in Rwanda has examined the use of modernized tools and innovative teaching methods and has highlighted the continuing importance of professional development and access to instructional resources [6,7]. Research has also specifically examined GeoGebra in 3D geometry instruction in Rwanda, including studies involving students from Musanze District [9,10]. Although these studies provide useful evidence concerning innovative mathematics instruction and technology-supported 3D geometry, they provide comparatively less attention to teachers' own experiences of implementing different innovative teaching methods and the practical challenges and resources associated with their implementation.

In Musanze District, Rwanda, an important research gap remains concerning teachers' experiences, challenges, and resource needs in implementing innovative teaching methods for 3D geometry instruction in public day secondary schools. Previous studies in Rwanda have examined the use of modernized teaching tools and innovative methods among mathematics and science teachers [6], teachers' professional development and pedagogical content knowledge [7], and the use of GeoGebra in teaching and learning three-dimensional geometry [9,10]. These studies provide important evidence on technology-supported mathematics instruction and teacher development; however, they do not sufficiently explain how mathematics teachers experience the implementation of a range of innovative teaching methods, what challenges they encounter during implementation, and what instructional, technological, and professional resources they consider necessary for teaching 3D geometry effectively. The present study addresses this gap by exploring teachers' experiences with technology integration, inquiry-based learning, guided discovery learning, collaborative learning, and visualization strategies, while also examining the infrastructural, classroom, curriculum, and professional challenges affecting implementation and the resources and institutional support required by teachers.

2. Purpose and Objectives of the Study

The purpose of this study was to explore the experiences, challenges, and resource needs of teachers in implementing innovative teaching methods for 3D geometry instruction in public day secondary schools in Musanze District, Rwanda. The study sought to understand how mathematics teachers experience the use of innovative instructional approaches, identify the challenges that affect their implementation, and establish the resources and professional support required for effective teaching and learning of 3D geometry.

3. Theoretical Framework

This study was guided by Constructivist Learning Theory and the Technological Pedagogical Content Knowledge (TPACK) Framework. The two theoretical perspectives were considered appropriate because the study explores teachers' experiences, challenges, and resource needs in implementing innovative teaching methods for 3D geometry instruction

Constructivist Learning Theory

Constructivist Learning Theory is associated with the work of Piaget [11] and Vygotsky [12] and is based on the view that learners actively construct knowledge through interaction with their environment, prior experiences, teachers, peers, and learning resources. Piaget [11] emphasized learning as an active process in which learners develop understanding through interaction with their environment and the construction of cognitive structures. Similarly, Vygotsky [12] emphasized the social nature of

learning and the importance of interaction, language, collaboration, and guidance in the development of knowledge. The theory therefore views learners as active participants in the learning process rather than passive recipients of information and supports instructional approaches that provide opportunities for exploration, interaction, inquiry, and problem solving.

Constructivist Learning Theory also provides a basis for understanding the behavioral and affective changes reported by teachers during innovative 3D geometry instruction. Teachers in the present study reported that students became more interested, curious, active, and willing to ask questions when innovative instructional approaches were used. They also reported increased peer-to-peer collaboration and reduced dependence on passive lecture-based instruction. These experiences are consistent with the constructivist view that meaningful learning develops through active engagement and social interaction. Vygotsky's emphasis on social interaction and guided learning is particularly relevant to collaborative and inquiry-based classroom activities in which teachers provide support while learners work with peers to develop mathematical understanding [11,12].

The theory is further relevant to the challenges identified in the present study. Although constructivist approaches emphasize active learner participation, teachers require appropriate learning materials, classroom conditions, and opportunities to organize meaningful learning experiences. The reported need for concrete geometry models, visualization materials, and other teaching aids is therefore relevant because such resources can provide learners with opportunities to interact with mathematical representations rather than relying exclusively on verbal explanations. Similarly, the teachers' reports concerning large class sizes and limited instructional time indicate contextual conditions that may affect the practical implementation of learner-centered approaches. The theory therefore provides a useful perspective for interpreting both teachers' positive experiences and the contextual challenges associated with implementing innovative teaching methods in 3D geometry.

Technological Pedagogical Content Knowledge (TPACK) Framework

The Technological Pedagogical Content Knowledge (TPACK) Framework was developed by Mishra and Koehler [4] from Shulman's concept of pedagogical content knowledge. The framework explains that effective teaching with technology requires an understanding of the complex interaction among content knowledge, pedagogical knowledge, and technological knowledge. Content knowledge concerns what teachers know about the subject they teach, pedagogical knowledge concerns how teaching and learning are organized, and technological knowledge concerns teachers' understanding of technologies that can support instruction. Mishra and Koehler [4] argue that effective technology integration cannot be achieved by considering these forms of knowledge separately because meaningful teaching with technology depends on their interaction within particular learning contexts.

The TPACK Framework is particularly relevant to innovative mathematics instruction because teachers are expected to combine appropriate pedagogical approaches with technological resources to support learners' understanding. This is especially applicable to three-dimensional geometry, where learners may experience difficulties understanding abstract spatial relationships through conventional explanations and static diagrams. Teachers may use dynamic geometry software, interactive visualizations, digital representations, demonstrations, and collaborative activities to make geometric concepts more accessible and meaningful. However, effective implementation requires teachers to understand both the mathematical content and the pedagogical purpose of the technology being used. The framework therefore provides a useful basis for examining teachers' experiences with GeoGebra and other technology-supported instructional approaches in 3D geometry [4].

The TPACK Framework therefore provides a suitable theoretical explanation for the experiences, challenges, and resource needs identified in this study. Teachers' experiences with GeoGebra, visualization, and technology-supported instruction can be understood in terms of the interaction between technological, pedagogical, and content knowledge. Their reported challenges concerning computers, internet connectivity, electricity, and training demonstrate the contextual conditions required for effective technology integration. The framework consequently supports the interpretation that successful implementation of innovative teaching methods for 3D geometry requires not only teachers' pedagogical and technological competence but also adequate institutional resources and professional support [4,8].

4. Methods

The study adopted a qualitative research approach to explore teachers' experiences, challenges, and resource needs in implementing innovative teaching methods for 3D geometry instruction in public day secondary schools in Musanze District, Rwanda. A qualitative approach was appropriate because the study sought detailed accounts of teachers' experiences, implementation challenges, and professional and institutional support needs rather than numerical estimates of relationships or effects.

The study was conducted in six purposively selected public day secondary schools in Musanze District. The schools were selected from public secondary schools in the district based on their rural and remote location, accessibility, implementation of the Competency-Based Curriculum, and suitability for examining innovative teaching methods under resource-constrained conditions. For the qualitative component, a purposive sample of 20 mathematics teachers was selected because the teachers had direct classroom experience in mathematics and 3D geometry instruction. The participants were selected from the six participating schools to provide in-depth information on teachers' experiences with innovative teaching methods, implementation challenges, and resource and professional support needs.

Semi-structured interviews were used to obtain in-depth information about teachers' experiences with technology integration, inquiry-based learning, guided discovery learning, collaborative learning, and visualization

strategies, as well as the challenges and resources associated with implementation. Each interview lasted approximately 30-45 minutes. With participants' informed consent, the interviews were digitally recorded and transcribed verbatim to ensure accuracy and completeness. The interview protocol was standardized to maintain consistency in the sequencing of questions and probing while allowing participants to elaborate on issues relevant to their classroom experiences. The interview schedule was reviewed by three senior curriculum experts for conceptual alignment with the study objectives, supporting the dependability and credibility of the qualitative instrument.

Data saturation was considered during the interview and analysis process. The researcher continuously reviewed and compared participants' responses as the interviews progressed and during coding to identify whether new interviews were generating substantially new information or whether previously identified patterns were recurring. Across the 20 interviews, recurring patterns became evident in relation to teachers' experiences with innovative teaching methods, implementation challenges, and resource and professional support needs. The later interviews largely reinforced the patterns identified in earlier interviews rather than introducing substantially different issues. On this basis, the 20 interviews were considered sufficient to provide adequate coverage and depth of the issues addressed in the interview guide and to support the development of the four major themes reported in the findings.

Although formal member checking was not conducted as a separate validation procedure, measures were taken to enhance the accuracy and credibility of the qualitative findings. The interview schedule was reviewed by three senior curriculum experts to ensure alignment with the study objectives. A standardized interview protocol was used to maintain consistency across interviews, while interviews were audio-recorded and transcribed verbatim with participants' consent to preserve the accuracy and completeness of their accounts. During analysis, codes and emerging themes were systematically cross-checked against the interview transcripts to ensure that the findings remained grounded in participants' responses. These procedures strengthened the credibility and dependability of the qualitative findings.

The qualitative data were analyzed manually using Braun and Clarke's (2006) six-phase thematic analysis framework. The procedure involved: (1) familiarization with the interview transcripts through repeated reading; (2) generation of initial codes from meaningful segments of the data; (3) searching for potential themes by grouping related codes; (4) reviewing and refining themes against the coded extracts and the complete dataset; (5) defining and naming the final themes; and (6) producing the thematic account by integrating the themes with representative interview evidence and relevant literature. The analysis focused on recurring patterns related to teachers' instructional experiences, learner engagement, infrastructural and contextual constraints, and professional and institutional support needs. The analysis was conducted manually; no qualitative data-analysis software such as NVivo, MAXQDA, or Quirkos was used.

Ethical procedures were observed throughout the study. Written informed consent was obtained after participants were informed about the purpose, procedures, risks, benefits, and voluntary nature of participation. Confidentiality and anonymity were maintained by using participant codes rather than names. Interview transcripts and other research records were securely stored, with access restricted to the researcher and supervisors.

5. Results

This section presents the qualitative findings on teachers' experiences, challenges, and resource needs in implementing innovative teaching methods for 3D geometry instruction in public day secondary schools in Musanze District, Rwanda. The findings are based on interviews with 20 mathematics teachers and were analyzed using Braun and Clarke's [13] six-phase thematic analysis framework. The analysis involved systematic identification, coding, categorization, review, and interpretation of recurring patterns emerging from teachers' interview responses. Braun and Clarke's thematic analysis provides a systematic approach for identifying and reporting patterns within qualitative data [13]. The qualitative analysis focused on teachers' experiences with innovative instructional approaches, including technology integration, inquiry-based learning, guided discovery learning, collaborative learning, and visualization strategies. It also examined the challenges affecting implementation and the resources and professional support teachers considered necessary for effective 3D geometry instruction.

Qualitative Coding and Thematic Development

To process the qualitative narrative data gathered from teacher interviews (n = 20), a manual thematic analysis was conducted following Braun and Clarke's [13] six-phase framework. Teachers' interview responses were systematically reviewed and coded to identify recurring concepts related to instructional practices, classroom experiences, learner engagement, infrastructural challenges, and professional support needs. Similar codes were grouped into categories according to their conceptual similarities and subsequently synthesized into broader themes. The coding process resulted in four major themes that captured the teachers' experiences, challenges, and resource needs in implementing innovative teaching methods for 3D geometry instruction.

The coding and categorization process resulted in four major themes: Pedagogical Pivot towards Conceptual and Spatial Visualization, Behavioral and Affective Shifts in Learner Engagement, Systemic Deficits and Contextual Constraints to Implementation, and Institutional Scaffolding and Professional Capacity Building. These themes summarize teachers' classroom experiences, learner responses, implementation challenges, and professional and institutional support needs concerning innovative teaching methods in 3D geometry instruction.

Table 1. Structured Thematic Matrix Generated from Teachers' Interview Responses

Raw Teacher Transcription (Excerpt)	Initial Codes	Category	Emergent Theme
"GeoGebra is useful, but access to computers is limited." / "Students used GeoGebra to rotate geometric solids..."	Software utility; Hardware scarcity; Dynamic spatial manipulation; Spatial translation; Visualization of solids; Reduced abstract strain	Digital Integration & Conceptual Shifts	Theme 1: Pedagogical Pivot towards Conceptual and Spatial Visualization
"Students understand geometric solids more easily because they can visualize shapes."	Spatial translation; Concrete modeling; Reduced abstract strain; Dynamic geometric manipulation	Digital Integration & Conceptual Shifts	Theme 1: Pedagogical Pivot towards Conceptual and Spatial Visualization
Teachers reported increased student participation, curiosity, question asking, and peer-to-peer collaboration and a reduced dependence on passive lectures.	Increased student active participation; Curiosity and question asking; Peer-to-peer collaboration; Rejection of passive lectures	Learner Engagement and Participation	Theme 2: Behavioral and Affective Shifts in Learner Engagement
"Lack of computers and ICT resources... Poor internet/electricity access"	Infrastructure deficits; Energy grid failures; Supply shortages	Structural and Systemic Impediments	Theme 3: Systemic Deficits and Contextual Constraints to Implementation
"Insufficient teacher training... Limited time to complete syllabus"	Pedagogical anxiety; Curriculum pressure; Skill gaps; Large class sizes; Rigid curriculum/syllabus time limits	Structural and Systemic Impediments	Theme 3: Systemic Deficits and Contextual Constraints to Implementation
Teachers requested additional professional development and instructional resources.	Professional development request; Institutional scaffolding; Infrastructure/projector supply needs; Tangible teaching aids; Concrete geometry physical models	Capacity Building Requirements	Theme 4: Institutional Scaffolding and Professional Capacity Building

Source: Field data, 2026

Comprehensive Thematic Analysis

The interview responses were carefully reviewed and manually coded to identify common ideas related to teachers' experiences in implementing innovative teaching methods for 3D geometry instruction. Similar responses were grouped together and organized into broader themes. This process helped the researcher understand the classroom experiences, challenges, and resource needs faced by mathematics teachers in public day secondary schools in Musanze District. The analysis generated four major themes: Pedagogical Pivot towards Conceptual and Spatial Visualization, Behavioral and Affective Shifts in Learner Engagement, Systemic Deficits and Contextual Constraints to Implementation, and Institutional Scaffolding and Professional Capacity Building.

Theme 1: Pedagogical Pivot towards Conceptual and Spatial Visualization

The first theme revealed that innovative teaching methods supported teachers in addressing the abstract and spatial nature of 3D geometry. Teachers explained that the use of GeoGebra, guided discovery learning, and group activities enabled students to visualize geometric solids, manipulate shapes, and develop better understanding of geometry concepts. Teachers particularly emphasized the value of allowing students to see and interact with geometric representations rather than depending entirely on conventional explanations and static diagrams.

Teachers reported that technology-supported visualization enabled students to rotate and examine geometric solids from different perspectives. The use of dynamic representations was perceived as helping students translate abstract geometric ideas into more understandable visual forms. One teacher explained that "GeoGebra is useful, but access to computers is limited," while another reported that "Students used GeoGebra to rotate geometric solids." These responses demonstrate that teachers recognized the instructional value of digital visualization while simultaneously identifying limitations in access to the hardware required for its use. Teachers further reported that students understood geometric solids more easily when they were able to visualize the shapes. One teacher stated, "Students understand geometric solids more easily because they can visualize shapes." The response indicates that visualization was considered an important mechanism through which innovative approaches supported the teaching of 3D geometry. Teachers also associated concrete modeling and dynamic manipulation with reduced difficulty in understanding abstract spatial concepts. The findings therefore indicate that teachers experienced a pedagogical shift from predominantly abstract explanation toward approaches that emphasized visualization, manipulation, exploration, and active interaction with geometric representations. The experience reported by teachers suggests that innovative methods provided alternative ways of presenting three-dimensional concepts that were perceived as more accessible to learners.

Theme 2: Behavioral and Affective Shifts in Learner Engagement

The second theme showed that teachers observed changes in students' classroom participation and engagement when innovative teaching methods were used. Teachers reported that students became more interested, curious, and active during geometry lessons. They indicated that inquiry-based activities, group discussions, collaborative learning, and guided discovery encouraged students to ask questions, exchange ideas, and participate more confidently in mathematics activities.

Teachers also reported increased peer-to-peer collaboration during innovative learning activities. Instead of relying exclusively on teacher explanations, students were provided with opportunities to discuss mathematical ideas with their classmates, investigate problems, and share possible solutions. This classroom interaction was perceived by teachers as contributing to greater student participation in the learning process. The findings further indicated a reduced dependence on passive lecture-based instruction. Teachers described innovative methods as creating classroom environments in which students were more actively involved in learning activities. Curiosity and

question asking were also identified as important changes in learner behavior. These findings suggest that teachers experienced innovative teaching methods not only as alternative instructional techniques but also as approaches that could influence students' participation and attitudes toward learning 3D geometry.

Theme 3: Systemic Deficits and Contextual Constraints to Implementation

The third theme highlighted several challenges that constrained teachers' ability to consistently implement innovative teaching methods. Teachers identified inadequate computers and ICT resources, unreliable electricity and internet access, large class sizes, limited time for syllabus coverage, and insufficient teacher training as major challenges affecting implementation.

One of the major concerns was inadequate ICT infrastructure. Teachers reported that access to computers was limited and that poor internet and electricity access affected their ability to use technology-supported approaches during 3D geometry lessons. These infrastructural limitations were particularly relevant to the use of GeoGebra and other digital visualization strategies because such approaches require functional technological equipment and reliable electricity. Teachers also identified large class sizes as a challenge to implementing learner-centered approaches. Innovative methods such as collaborative learning, guided discovery, inquiry-based activities, and practical visualization may require teachers to organize students into groups and provide guidance during learning activities. Teachers reported that large numbers of students could make such classroom organization more difficult.

Limited instructional time was another important challenge. Teachers reported pressure to complete the prescribed syllabus within the available time. According to the teachers, this curriculum pressure could limit the amount of time available for inquiry, group activities, guided discovery, practical modeling, and technology-supported exploration. Consequently, teachers could be required to balance the use of innovative methods with the need to cover the required mathematics content within the available instructional period.

Insufficient teacher training was also identified as a significant constraint. Teachers indicated that they required additional training to develop the skills and confidence necessary to implement innovative instructional approaches effectively. The reported skill gaps suggest that the availability of innovative methods alone may not be sufficient unless teachers receive appropriate professional preparation and continuing support.

Theme 4: Institutional Scaffolding and Professional Capacity Building

The fourth theme emphasized teachers' need for institutional support and professional development to strengthen the implementation of innovative teaching methods for 3D geometry. Teachers reported the need for additional training workshops, computers, projectors, geometry models, and other instructional materials. Professional development was identified as an important requirement because teachers need opportunities to strengthen their practical knowledge of innovative teaching methods and technologies. Teachers' requests for additional training indicate that professional support should extend beyond general awareness of innovative pedagogy and focus on practical application in 3D geometry instruction.

Teachers also emphasized the importance of tangible teaching aids and concrete geometry models. Such resources could support the visualization of three-dimensional objects and provide learners with physical representations that complement digital tools. The reported need for projectors and other ICT infrastructure similarly demonstrates the importance of institutional investment in the resources required for technology-supported instruction. The findings therefore suggest that effective implementation of innovative teaching methods requires institutional scaffolding that combines professional development with adequate instructional and technological resources. Teachers may be more able to implement learner-centered and technology-supported approaches when they have access to appropriate equipment, teaching materials, training opportunities, and supportive school environments.

Overall, the qualitative findings revealed that teachers experienced innovative teaching methods as useful approaches for supporting visualization, conceptual understanding, participation, and engagement in 3D geometry. Teachers reported that GeoGebra, guided discovery learning, inquiry-based learning, collaborative learning, and visualization strategies helped learners interact more actively with geometric concepts. At the same time, teachers identified inadequate ICT resources, unreliable electricity and internet access, large class sizes, limited syllabus time, and insufficient professional training as important barriers to implementation. Teachers consequently identified computers, projectors, concrete geometry models, other instructional materials, improved ICT infrastructure, and continuous professional development as important resources and support mechanisms for effective implementation.

6. Discussion of Findings

The findings of the study revealed that teachers experienced innovative teaching methods as useful but resource-dependent approaches for teaching 3D geometry in public day secondary schools in Musanze District, Rwanda. The thematic analysis generated four major themes: Pedagogical Pivot towards Conceptual and Spatial Visualization, Behavioral and Affective Shifts in Learner Engagement, Systemic Deficits and Contextual Constraints to Implementation, and Institutional Scaffolding and Professional Capacity Building. These themes demonstrate that teachers' experiences with innovative teaching methods involved both positive classroom experiences and significant implementation challenges. Teachers reported experiences with GeoGebra, guided discovery learning, inquiry-based learning, collaborative learning, and visualization strategies, while also identifying limitations related to ICT resources, electricity, internet connectivity, class size, instructional time, and teacher training.

The first theme, Pedagogical Pivot towards Conceptual and Spatial Visualization, indicates that teachers

experienced innovative teaching methods as useful for presenting the abstract and spatial concepts associated with 3D geometry. Teachers reported that GeoGebra, guided discovery, group activities, and concrete modeling enabled learners to visualize geometric solids, manipulate shapes, and understand three-dimensional concepts more easily. This finding is consistent with Uttal et al. [2], whose meta-analysis demonstrated that spatial skills can be developed through training and educational experiences. It also agrees with Atit et al. [1], who established a relationship between spatial skills and mathematical performance. In the present study, however, the emphasis is specifically on teachers' experiences: teachers perceived visualization and manipulation as practical ways of making 3D geometry instruction more understandable and less dependent on static diagrams and verbal explanation.

The finding is further supported by Uwurukundo et al. [9], who investigated the use of GeoGebra in teaching 3D geometry in Rwanda and reported positive effects associated with the technology. Uwurukundo et al. [10] also examined GeoGebra in three-dimensional geometry instruction and provided evidence concerning its use in the Rwandan secondary-school context, including Musanze District. While these studies focused mainly on student outcomes and attitudes, the present study contributes a different perspective by examining how teachers experience the implementation of innovative methods. The teachers' accounts indicate that technology-supported visualization was valued because it allowed geometric solids to be examined dynamically, although access to computers remained a major limitation.

The second theme, Behavioral and Affective Shifts in Learner Engagement, showed that teachers experienced changes in classroom interaction when innovative teaching methods were implemented. Teachers reported increased student participation, curiosity, question asking, and peer-to-peer collaboration. They also reported a reduced dependence on passive lecture-based instruction. From the teachers' perspective, inquiry-based learning, guided discovery, group discussions, and collaborative activities created classroom situations in which learners were more actively involved in 3D geometry activities. This finding is consistent with Constructivist Learning Theory, which emphasizes active participation, interaction, collaboration, and guided learning in the construction of knowledge [11,12].

The finding also relates to Uworwabayeho [8], who examined mathematics teachers' innovative change in Rwanda and documented movement toward learner-centered pedagogy and greater acceptance of learner autonomy. The present study similarly indicates that teachers experienced learner-centered innovative approaches as changing the nature of classroom interaction. Rather than focusing only on teachers' explanations, teachers reported using activities that encouraged learners to ask questions, discuss mathematical ideas, collaborate with peers, and participate more actively. Therefore, the finding demonstrates that teachers' experiences of innovative teaching methods extend beyond the use of technology and include changes in how teachers organize participation and interaction during 3D geometry lessons.

The third theme, Systemic Deficits and Contextual Constraints to Implementation, revealed that teachers faced several challenges that limited their consistent implementation of innovative teaching methods. Teachers identified inadequate computers and ICT resources, unreliable electricity and internet access, large class sizes, limited time for syllabus coverage, and insufficient teacher training. These findings are consistent with Nkundabakura et al. [6], who examined the use of modernized tools and innovative methods among mathematics and science teachers in Rwanda. The present study adds specific qualitative evidence from teachers teaching 3D geometry in public day secondary schools in Musanze District, showing how infrastructural and institutional limitations affect their ability to apply innovative approaches in actual classroom settings.

The challenge of inadequate ICT infrastructure was particularly important in teachers' experiences with technology-supported 3D geometry instruction. Teachers reported that access to computers was limited and that poor electricity and internet access affected their ability to use GeoGebra and other digital visualization approaches. This finding is relevant to the TPACK Framework developed by Mishra and Koehler [4], which emphasizes the interaction of technological, pedagogical, and content knowledge in effective technology-supported teaching. In the present study, the issue was not simply whether teachers knew how to use innovative technology; teachers also needed functioning computers, reliable electricity, appropriate ICT facilities, and other technological resources to translate their knowledge into classroom practice. Teachers also reported large class sizes and limited instructional time as challenges to implementation. Innovative approaches such as inquiry, guided discovery, collaborative learning, and practical visualization require teachers to organize learning activities, monitor groups, provide guidance, and allow learners sufficient time to explore mathematical ideas. Teachers reported that pressure to complete the syllabus could restrict the time available for these activities. Thus, the findings indicate that teachers' ability to implement innovative teaching methods is influenced not only by their pedagogical skills but also by classroom size and curriculum time requirements.

The fourth theme, Institutional Scaffolding and Professional Capacity Building, showed that teachers considered professional development and institutional resources necessary for effective implementation. Teachers requested additional training workshops, computers, projectors, geometry models, and other instructional materials. This finding is consistent with Nkundabakura et al. [6], who examined continuous professional development and teachers' pedagogical content knowledge in Rwanda. The present findings extend this evidence by showing that teachers themselves identified professional development as an important resource need for implementing innovative teaching methods specifically in 3D geometry. Teachers therefore require practical opportunities to strengthen their ability to select, adapt, and apply innovative approaches to particular geometry concepts.

The teachers' reported need for concrete geometry models and other teaching aids is also important for 3D geometry instruction. Physical models can provide

tangible representations of three-dimensional objects and can complement digital visualization tools. Teachers' requests for projectors and ICT infrastructure similarly demonstrate that effective implementation requires access to both technological and non-technological instructional resources. These findings are consistent with the TPACK perspective because effective technology integration requires appropriate technological resources to be combined with suitable pedagogy and subject content [4]. The findings therefore indicate that teachers' resource needs are an important component of understanding the implementation of innovative teaching methods.

Overall, the findings demonstrate that teachers' experiences in implementing innovative teaching methods for 3D geometry were characterized by pedagogical opportunities, learner-engagement experiences, implementation constraints, and institutional support needs. Teachers reported that visualization, GeoGebra, guided discovery, inquiry, and collaborative learning provided useful ways of organizing 3D geometry instruction. At the same time, inadequate ICT resources, unreliable electricity and internet access, large classes, limited syllabus time, and insufficient training constrained their implementation. Teachers consequently identified professional development, computers, projectors, concrete geometry models, instructional materials, and improved ICT infrastructure as important requirements for effective implementation.

7. Implications

The findings imply that mathematics teachers in public day secondary schools in Musanze District should strengthen the consistent use of innovative teaching methods when teaching 3D geometry. In particular, teachers should incorporate GeoGebra, inquiry-based learning, guided discovery, collaborative learning, visualization strategies, and concrete modeling into geometry lessons. These approaches can provide teachers with practical ways of presenting three-dimensional concepts and can create opportunities for learners to visualize, manipulate, discuss, and explore geometric objects. The implication is particularly important because teachers in the study reported that visualization and active participation improved their classroom experiences when teaching 3D geometry.

The findings also imply that school heads and school administrators should provide adequate instructional and ICT resources to support teachers' implementation of innovative teaching methods. Teachers identified limited access to computers, inadequate ICT resources, unreliable electricity and internet connectivity, and the need for projectors as important implementation challenges. Schools should therefore prioritize functional computers, projectors, reliable electricity, internet connectivity, geometry models, and other teaching materials required for 3D geometry instruction. Providing these resources would help teachers translate innovative teaching approaches into regular classroom practice.

For teacher professional development, the findings imply that training should focus specifically on the practical implementation of innovative teaching methods for 3D geometry. Teachers should receive training on the use of GeoGebra and other appropriate digital tools, inquiry-based learning, guided discovery, collaborative learning, visualization techniques, and the use of concrete geometry models. The training should be continuous and practical rather than limited to theoretical introduction. This implication is consistent with the need for sustained professional development identified in research on mathematics and science teachers in Rwanda [6,7].

The findings further imply that education policymakers and curriculum developers should consider the practical conditions under which teachers implement innovative teaching methods. Curriculum expectations should be accompanied by adequate ICT infrastructure, instructional materials, teacher training, and sufficient time for classroom implementation. Teachers reported that large class sizes and pressure to complete the syllabus limited their ability to consistently use inquiry, guided discovery, group activities, and technology-supported visualization. Curriculum implementation strategies should therefore recognize the time and classroom-management requirements associated with innovative teaching methods.

For school leaders and education stakeholders, the findings imply that the provision of resources should be accompanied by institutional support and follow-up. Computers, projectors, and geometry models may have limited value if teachers do not have sufficient training or opportunities to use them effectively. School leaders should therefore create supportive conditions in which mathematics teachers can practice innovative methods, share experiences, participate in professional development, and access the resources required for 3D geometry instruction. This would strengthen the connection between teachers' professional capacity and the resources available within schools.

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