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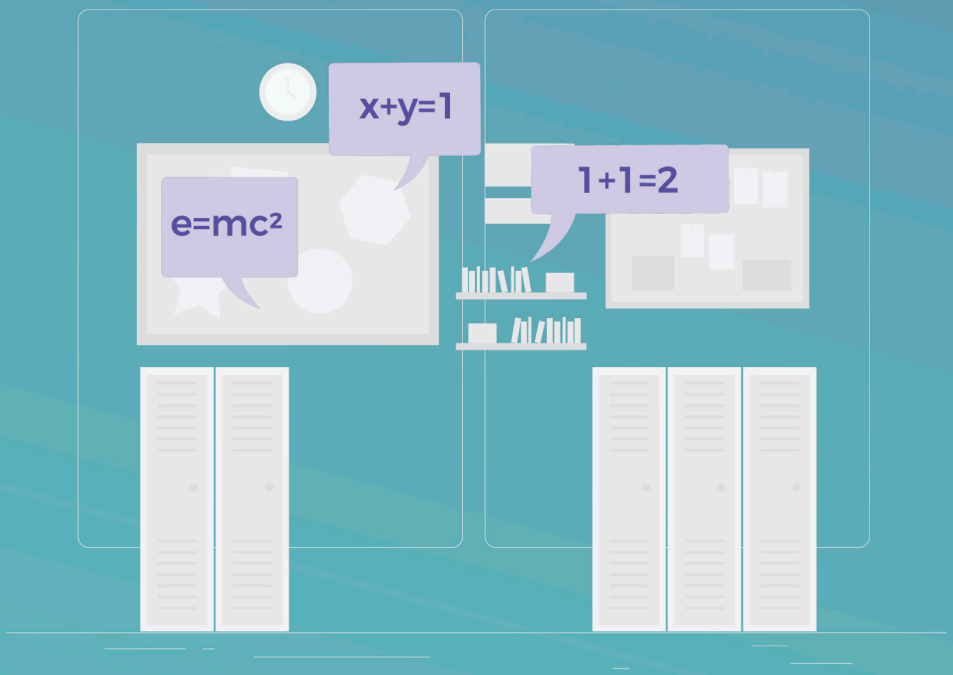

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Effect of Innovative Teaching Methods on Students' Mathematics Self-Efficacy Beliefs in Three-Dimensional Geometry in Public Day Secondary Schools in Musanze District, Rwanda

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ABSTRACT

The paper reports findings of a study that sought to examine the effect of innovative teaching methods on students' mathematics self-efficacy in three-dimensional geometry in public day secondary schools in Musanze District, Rwanda. The study was based on Self-Efficacy Theory and Social Cognitive Theory. A mixed-methods research design employing quasi-experimental and descriptive approaches was used for the study. Multistage sampling techniques were used to select a sample of 269 students from public day secondary schools in Musanze District. Students' mathematics self-efficacy questionnaires, achievement tests, and semi-structured interview guides were used to collect data from respondents. Quantitative data were analyzed using descriptive statistics and an independent samples t-test, while qualitative data were analyzed thematically. The results indicate that students exposed to innovative teaching methods attained slightly higher mathematics self-efficacy scores than students taught using traditional instructional approaches. However, the difference was not statistically significant, indicating that innovative teaching methods did not significantly influence students' mathematics self-efficacy beliefs in three-dimensional geometry. The study provides a basis upon which mathematics teachers, curriculum developers, and educational policymakers can strengthen learner-centered instructional approaches and create supportive learning environments that promote students' confidence, motivation, and participation in mathematics learning.

INTRODUCTION

Mathematics is widely recognized as a fundamental discipline for developing analytical thinking, logical reasoning, and problem-solving abilities that are essential for success in modern knowledge-based societies (Flores-Bascuñana *et al.*, 2020). The subject provides learners with critical competencies required for scientific inquiry, technological advancement, and informed decision-making in everyday life. As education systems increasingly emphasize the development of twenty-first-century skills, mathematics continues to serve as a foundation for innovation, creativity, and economic transformation (Anderson & Krathwohl, 2021). In addition, mathematics contributes significantly to the development of critical thinking and higher-order cognitive skills required in Science, Technology, Engineering, and Mathematics (STEM) disciplines (Mayer, 2022; Hattie, 2023).

Among the various branches of mathematics, three-dimensional (3D) geometry remains one of the most challenging areas for secondary school learners because it requires advanced visualization, spatial reasoning, and conceptual understanding of geometric relationships. Students are expected to mentally manipulate objects, interpret diagrams, understand spatial transformations, and apply geometric principles to solve complex problems. However, many learners experience difficulties in visualizing and reasoning about three-dimensional objects, leading to persistent misconceptions and poor academic outcomes (Pinilla, 2024; Battista, 2019). Research further indicates that traditional instructional approaches often fail to adequately support learners in developing the conceptual understanding and spatial reasoning skills necessary for successful learning of 3D geometry (Kavanagh, Richmond, & Rainey, 2020; Uttal, Miller, & Newcombe, 2022).

In many educational systems across the world, innovative teaching methods have increasingly been adopted to address challenges associated with the teaching and learning of geometry. Countries such as the United States, Australia, Finland, and the United Kingdom have integrated technology-supported and learner-centered pedagogies to improve students' understanding of complex mathematical concepts. These approaches emphasize active learning, collaboration, inquiry, exploration, and visualization through the use of instructional technologies such as GeoGebra and SketchUp (Kavanagh, Richmond, & Rainey, 2020; Pinilla, 2024). Studies conducted in these contexts have demonstrated that innovative teaching methods enhance students' conceptual understanding, engagement, and confidence in mathematics learning by providing opportunities for meaningful interaction with abstract concepts (Martin, 2023; Tinker & Krajcik, 2021).

Within the African context, mathematics education continues to face significant challenges despite ongoing educational reforms aimed at improving learning outcomes. In many countries, including Kenya, Uganda, Nigeria, and Rwanda, mathematics instruction remains largely dominated by teacher-centered approaches characterized by lecture-based delivery and passive student participation. Such approaches often limit

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opportunities for conceptual exploration, problem-solving, and collaborative learning, thereby affecting students' understanding of abstract concepts such as three-dimensional geometry (Adu-Gyamfi & Brenya, 2019; Lee & Zuze, 2011). Although several countries have initiated efforts to integrate technology and learner-centered pedagogies into mathematics classrooms, inadequate infrastructure, limited access to digital resources, and insufficient teacher training continue to hinder effective implementation (African Union, 2020; Mutonyi & Norton, 2021).

In Rwanda, the teaching and learning of three-dimensional geometry remains a significant concern, particularly in public day secondary schools located in rural areas. According to the Rwanda Education Board, only 31.4% of students correctly answered three-dimensional geometry questions in national Ordinary Level mathematics examinations. These questions required learners to interpret geometric diagrams, visualize spatial relationships, and calculate geometric measurements such as volume and surface area, competencies that many students found difficult to master (Nzabonimpa & Uwizeyimana, 2023; REB, 2022). The situation is more pronounced in districts such as Musanze, where schools continue to face challenges related to inadequate instructional resources, limited access to ICT infrastructure, and insufficient teacher preparedness in the use of innovative instructional approaches (Mpumuje, 2024; Nkuyubwatsi, Rwampyemana, & Uwizeyimana, 2022).

Besides academic achievement, students' beliefs about their capabilities play a critical role in determining learning outcomes in mathematics. Mathematics self-efficacy refers to learners' judgments about their ability to successfully perform mathematical tasks and solve mathematical problems. Students with high mathematics self-efficacy tend to demonstrate greater persistence, stronger motivation, and higher levels of engagement when confronted with challenging learning tasks. Conversely, students with low self-efficacy often experience anxiety, reduced confidence, and reluctance to participate actively in mathematics learning activities (Dweck, 2020; Schunk, 2020). Research has consistently shown that students' beliefs about their mathematical capabilities significantly influence both their learning behaviours and academic achievement (Van der Graaf, Segers, & Verhoeven, 2022; Maltese & Tai, 2021).

Innovative teaching methods have been identified as effective approaches for enhancing students' mathematics self-efficacy because they promote active participation, collaborative learning, inquiry, exploration, and meaningful engagement with mathematical concepts. Inquiry-based learning enables students to investigate mathematical relationships and construct knowledge through exploration, while guided discovery learning provides structured opportunities for learners to discover concepts through carefully designed activities. Similarly, technology-enhanced learning environments supported by GeoGebra and SketchUp allow learners to visualize, manipulate, and explore three-dimensional geometric objects dynamically, thereby strengthening their understanding and confidence in mathematics (Martin, 2023; Yoon, Liu, & Schott, 2023). Furthermore, these instructional approaches have been associated with improvements in students' motivation, engagement, conceptual understanding, and mathematics self-efficacy across different educational contexts (Zepeda, Martin, & Butler, 2019; Putri & Musdi, 2024).

Despite growing evidence regarding the benefits of innovative teaching methods, empirical studies examining their influence on students' mathematics self-efficacy in three-dimensional geometry remain limited within the Rwandan context, particularly in rural public day secondary schools. Existing studies have primarily focused on academic achievement, technology integration, or instructional effectiveness without specifically investigating how innovative teaching methods influence learners' confidence and beliefs regarding their mathematical capabilities in geometry learning (Rubagiza, Were, & Sutherland, 2011; Uwurukundo, Niyigena, & Habimana, 2022). This creates a contextual and empirical gap that necessitates further investigation. Therefore, this study sought to examine the effect of innovative teaching methods on students' mathematics self-efficacy in three-dimensional geometry in public day secondary schools in Musanze District, Rwanda.

Purpose and Objectives of the Study

The study sought to investigate the effect of innovative teaching methods on students' mathematics self-efficacy in three-dimensional geometry in public day secondary schools in Musanze District, Rwanda. Specifically, it aimed to determine the effect of inquiry-based learning, guided discovery learning, and the integration of GeoGebra and SketchUp on students' mathematics self-efficacy in three-dimensional geometry.

Theoretical Framework

Social Cognitive Theory

The study was further guided by Social Cognitive Theory (SCT) developed by Bandura (1986). The theory explains that learning occurs through the reciprocal interaction of personal factors, behavioural factors, and environmental influences. According to Bandura (1986), individuals acquire knowledge, skills, attitudes, and beliefs by observing others, interacting with their environment, and reflecting on the outcomes of their actions. The theory emphasizes that human behaviour is shaped not only by external environmental conditions but also by individuals' perceptions, beliefs, expectations, and self-regulatory processes.

Social Cognitive Theory is relevant to this study because innovative teaching methods create learning environments that encourage active participation, collaboration, observation, and interaction among learners. Through inquiry-based learning, guided discovery learning, and

technology-supported instruction using GeoGebra and SketchUp, students are exposed to opportunities for exploration, peer learning, problem-solving, and feedback. These experiences enable learners to develop confidence in their mathematical abilities and strengthen their beliefs regarding successful performance in three-dimensional geometry tasks.

Bandura (1986) further argues that self-efficacy is a central component of Social Cognitive Theory because individuals' beliefs about their capabilities influence their motivation, effort, persistence, and performance. In mathematics learning, students with strong self-efficacy beliefs are more likely to participate actively, persist in solving challenging problems, and achieve positive learning outcomes. Consequently, Social Cognitive Theory provides a useful framework for understanding how innovative teaching methods influence students' mathematics self-efficacy in three-dimensional geometry.

MATERIALS AND METHODS

This study adopted mixed-methods research design grounded in the pragmatic research paradigm. Specifically, the study employed a quasi-experimental design and a descriptive research design to investigate the effect of innovative teaching methods on students' mathematics self-efficacy in three-dimensional geometry in public day secondary schools in Musanze District, Rwanda. The quasi-experimental design was used to compare students exposed to innovative teaching methods with those taught using traditional teaching methods, while the descriptive design facilitated the collection of supplementary information regarding students' perceptions and experiences during the intervention.

The study was conducted in Musanze District in the Northern Province of Rwanda. The target population comprised 2,219 students and 50 mathematics teachers drawn from public day secondary schools. Using multistage sampling techniques and the Yamane formula, a sample of 269 students was selected to participate in the study, while all 50 mathematics teachers were included through a census sampling technique. The study involved Senior Four, Senior Five, and Senior Six students studying three-dimensional geometry.

Innovative teaching methods constituted the independent variable and were operationalized through the integration of GeoGebra and SketchUp, inquiry-based learning, and guided discovery learning. The dependent variable was students' mathematics self-efficacy in three-dimensional geometry. Data were collected using a Students' Mathematics Self-Efficacy Questionnaire, achievement tests, and semi-structured interview guides. The questionnaire measured students' confidence, persistence, motivation, and perceived capability in solving three-dimensional geometry tasks. Prior to the main study, a pilot study was conducted to establish the validity and reliability of the research instruments. Content validity was assessed through expert review, while reliability was determined using appropriate statistical procedures.

Quantitative data were analyzed using descriptive statistics and an independent samples t-test to determine whether significant differences existed in mathematics self-efficacy between students taught using innovative teaching methods and those taught using traditional teaching methods. Qualitative data obtained through interviews were analyzed thematically and used to complement the quantitative findings. Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS), and all hypotheses were tested at the 0.05 level of significance

RESULTS AND DISCUSSION

This section presents the findings on the effect of innovative teaching methods on students' mathematics self-efficacy in three-dimensional geometry in public day secondary schools in Musanze District, Rwanda. To achieve this objective, data were collected using students' questionnaires and analyzed using descriptive statistics and an Independent Samples t-test. The analysis sought to determine whether students exposed to innovative teaching methods differed significantly in mathematics self-efficacy from those taught using traditional instructional approaches.

Students' Mathematics Self-Efficacy in Three-Dimensional Geometry

To establish students' levels of mathematics self-efficacy, descriptive statistics were computed for both the Experimental Group and the Control Group. The Students' Mathematics Self-Efficacy Composite Score was analyzed using means and standard deviations. The results are presented in Table 1.

As indicated in Table 1, students exposed to innovative teaching methods recorded a higher mean mathematics self-efficacy score (M = 75.52, SD = 8.486) than students

Table 1: Group Statistics for Students' Mathematics Self-Efficacy

	Treatment Group	N	Mean	Std. Deviation	Std. Error Mean
Students' Mathematics Self-Efficacy Composite Score	Experimental Group	132	75.52	8.486	.739
	Control Group	137	74.74	8.070	.690

Source: Field data, 2026

taught using traditional teaching methods (M = 74.74, SD = 8.070). The results suggest that students in the Experimental Group demonstrated slightly higher levels of confidence, motivation, and belief in their ability to learn and solve three-dimensional geometry problems than their counterparts in the Control Group. However, the small difference between the mean scores indicates that the two groups exhibited relatively similar levels of mathematics self-efficacy. Therefore, further statistical analysis using an Independent Samples t-test was conducted to establish whether the observed difference was statistically significant.

Independent Samples t-Test Results

To determine whether innovative teaching methods significantly influenced students' mathematics self-efficacy in three-dimensional geometry, an Independent Samples t-test was conducted. The analysis sought to establish whether the difference observed between the Experimental Group and the Control Group was statistically significant. The results are presented in Table 2.

Table 2: Independent Samples t-Test for Students' Mathematics Self-Efficacy

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Students' Mathematics Self-Efficacy Composite Score	Equal variances assumed	.083	.773	.771	267	.441	.778	1.009	-1.209	2.766
	Equal variances not assumed			.770	264.976	.442	.778	1.010	-1.211	2.768

Source: Field data, 2026

As indicated in Table 2, Levene's Test for Equality of Variances produced an F statistic value of .083 with a significance value of .773. Since the significance value is greater than .05, the assumption of equal variances was satisfied. Therefore, the "Equal Variances Assumed" results were used for interpretation of the Independent Samples t-test findings.

Examining the t-statistic for the variable, it can be seen that it is associated with a significance value of .441. Since the significance value is greater than .05, the null hypothesis, which stated that there is no statistically significant effect of innovative teaching methods on students' mathematics self-efficacy in three-dimensional geometry, was accepted. This indicates that innovative teaching methods did not significantly influence students' mathematics self-efficacy in three-dimensional geometry. The mean difference of .778 indicates that students exposed to innovative teaching methods obtained slightly higher mathematics self-efficacy scores than students taught using traditional teaching methods. However, the difference was not statistically significant. Therefore, innovative teaching methods were not a significant determinant of students' mathematics self-efficacy in three-dimensional geometry among public day secondary schools in Musanze District, Rwanda.

Discussion of Findings

The findings of this study revealed that students who were taught using innovative teaching methods attained slightly higher mathematics self-efficacy scores than those who received traditional instructional approaches. Although the experimental group demonstrated greater confidence, motivation, and belief in their ability to solve three-dimensional geometry problems, the difference between the two groups was not statistically significant. This suggests that inquiry-based learning, guided discovery learning, and the integration of GeoGebra and SketchUp created more engaging learning experiences that encouraged positive perceptions of mathematical ability, but the duration of the intervention may not have been sufficient to produce statistically significant changes in students' self-efficacy. These findings are consistent with those of Putri and Musdi (2024), who reported that learner-centered instructional approaches enhance students' confidence and engagement in mathematics learning. Similarly, Zepeda, Martin, and Butler (2019) found that guided discovery learning promotes active participation and motivation, thereby creating learning environments that support the development of positive attitudes towards mathematics.

The findings also agree with those of Van der Graaf,

Segers, and Verhoeven (2022), who established that inquiry-based learning improves students' conceptual understanding and reasoning skills, while improvements in self-efficacy tend to emerge gradually through continuous learning experiences. Likewise, Zakariya (2022) observed that learner-centered instructional approaches increase students' engagement and participation, although measurable changes in confidence often require sustained instructional support and repeated opportunities for successful task completion.

The findings are further explained by Social Cognitive Theory (Bandura, 1986), which posits that learning occurs through the reciprocal interaction of personal factors, behaviour, and the learning environment. The innovative teaching methods employed in this study provided opportunities for students to observe, interact, collaborate, and actively construct mathematical knowledge using technology-supported learning environments. Such experiences are expected to promote positive beliefs about learning by encouraging greater participation and meaningful engagement with mathematical concepts. However, because students' beliefs and behaviours develop progressively through continuous interaction with supportive learning environments, the relatively short intervention may have limited the extent to which innovative teaching methods influenced mathematics self-efficacy. This interpretation is further supported by Schunk (2020), who argues that students develop stronger confidence when they receive continuous feedback, repeated practice, and opportunities to experience success while learning.

Implications

The findings of this study suggest that innovative teaching methods, including inquiry-based learning, guided discovery learning, and technology-supported instruction through GeoGebra and SketchUp, have the potential to create more engaging and interactive mathematics learning environments that can enhance students' confidence in learning three-dimensional geometry. Although the differences in mathematics self-efficacy between the experimental and control groups were not statistically significant, the slightly higher self-efficacy scores recorded among students exposed to innovative teaching methods indicate that learner-centered instructional approaches may positively influence students' beliefs about their mathematical capabilities. These findings imply that the successful development of mathematics self-efficacy is likely to require sustained implementation of innovative teaching methods, allowing students sufficient time to participate actively, explore mathematical concepts, and gain repeated positive learning experiences that gradually strengthen their confidence.

The study further implies that improving students' mathematics self-efficacy should be viewed as a gradual process rather than an immediate outcome of instructional innovation. While innovative teaching methods provide opportunities for collaboration, inquiry, visualization, and active learning, their effectiveness depends on consistent classroom implementation and continuous learner engagement over time. The findings therefore highlight the need for future research to examine the long-term effects of learner-centered instructional approaches on students' mathematics self-efficacy and related learning outcomes. Such studies would provide a deeper understanding of whether prolonged exposure to innovative teaching methods can produce significant improvements in students' confidence, engagement, and achievement in three-dimensional geometry.

CONCLUSION

This study examined the effect of innovative teaching methods on students' mathematics self-efficacy in three-dimensional geometry among public day secondary schools in Musanze District, Rwanda. The findings revealed that students taught using inquiry-based learning, guided discovery learning, and the integration of GeoGebra and SketchUp attained slightly higher mathematics self-efficacy scores than those taught using traditional instructional approaches. However, the difference between the experimental and control groups was not statistically significant, indicating that innovative teaching methods did not significantly influence students' mathematics self-efficacy during the intervention period. The study therefore concludes that, although innovative teaching methods may contribute to improved confidence and engagement in learning three-dimensional geometry, sustained implementation over a longer period may be necessary to produce statistically significant improvements in students' mathematics self-efficacy. These findings suggest that strengthening learner-centered instructional practices and providing students with continuous opportunities for active participation, practice, and constructive feedback may support the gradual development of mathematics self-efficacy.

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