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Enhancing learning outcomes in mathematics education through innovative assessment methods and timely feedback

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ABSTRACT

This study explored the transformative impact of innovative assessment methods and timely feedback on learning outcomes in advanced public secondary mathematics schools within Gasabo District, Rwanda. A total of 139 students and seven teachers participated in a focus group discussion to investigate the efficacy of these pedagogical strategies. The findings indicated that the implementation of innovative assessment methods, such as formative assessments and project-based learning, coupled with a timely feedback approach, significantly enhances students' comprehension, engagement, and overall performance. Teachers, as facilitators of this process, played a crucial role in creating a supportive learning environment. The study indicated the importance of adopting assessment practices and feedback mechanisms in improving educational outcomes, especially in the context of mathematics education in Rwanda. These insights held promise for teachers seeking to enhance learning outcomes in mathematics and other science, technology, engineering, and mathematics disciplines in the region.

Keywords: innovative assessment, learning outcomes, timely feedback

INTRODUCTION

In recent years, education systems worldwide have increasingly emphasized enhancing learning outcomes through innovative assessment methods and timely feedback, recognizing education's pivotal role in societal development, particularly in mathematics education, crucial for raising critical thinking and problem-solving skills, with Gasabo District, Rwanda, mirroring global trends, prioritizing the implementation of such strategies in public secondary mathematics schools.

In Rwanda, the state of student learning outcomes in mathematics revealed a pressing need for improvement. Recent assessment indicated that many students are struggling to grasp fundamental mathematical concepts, reflecting a concerning gap in their understanding (Niyibizi & Mutarutinya, 2023). Enhancing these learning outcomes was crucial not only for academic success but also for raising critical thinking skills essential for future professional development in a globally competitive. Addressing these challenges demands strategic interventions aimed at fortifying the foundation of mathematical education and empowering students to navigate increasingly complex mathematical concepts with confidence and proficiency.

Mathematics education is a fundamental component of a well-rounded education system. It provides students with not only mathematical knowledge but also critical thinking skills, problem-solving abilities, and analytical reasoning (Allal, 2011; Carless & Boud, 2018; Evans, 2013; Li & De Luca, 2014; Sol, 2020).

In Rwanda, as in many other countries, mathematics serves as a gateway subject that influences future academic and career opportunities (Bahati et al., 2016). Assessment is an integral part of the education process, playing a crucial role in shaping learning outcomes. Additionally, Granberg et al. (2021) highlighted that assessment practices have the potential to significantly impact student achievement.

In the context of mathematics education, studies have emphasized that providing explicit and actionable feedback improves student learning and enhances academic success (Kyaruzi et al., 2019; Mbarute & Ntiyuguruzwa, 2023; Sol, 2020; Ugwumaduka & Ogunyemi, 2021).

Similarly, the study suggested that innovative assessment methods, such as project-based learning and formative assessment, can enhance learning (Cifrian et al., 2020). Formative assessment has gained recognition as a valuable tool for enhancing learning outcomes. Kyaruzi et al. (2019) maintained that formative assessment, when integrated into the teaching process, provides teachers and students with timely information about learning progress, allowing for necessary adjustments in instruction.

Additionally, formative assessment methods like quizzes, peer assessment, and self-assessment have been found effective in promoting active learning and deeper understanding (Li & De Luca, 2014). Studies emphasized the importance of formative assessment in improving learning outcomes (Antoniou & James, 2014; Carless & Boud, 2018). Assessment for learning, as supported by Chaqmaqchee (2015), focused on assessments that facilitate learning rather than merely measuring it.

Innovative assessment methods, such as project-based learning, problem-solving tasks, and performance assessments, have been shown to engage students and foster critical thinking skills (Chemeli, 2019). A study has shown that innovative assessment methods, including formative assessment, peer assessment, and project-based assessment, can offer a more holistic view of students' mathematical capabilities (Cifrian et al., 2020).

Studies indicated the benefits of performance-based assessments in mathematics education, as they require students to apply their knowledge in real-world contexts (Carless & Boud, 2018; Evans, 2013; Shute, 2008). Additionally, the use of technology-based assessments, such as computer-adaptive testing, has gained popularity in recent years due to their ability to provide personalized feedback (Dayal, 2021; Henderson et al., 2019; Li & De Luca, 2014).

Timely feedback is crucial for effective learning. Bahati et al. (2016) emphasized that feedback should be specific, actionable, and provided promptly to be most effective. In the context of mathematics education, studies indicated that feedback improves performance, particularly in helping students identify errors and understand the underlying concepts (Carless & Boud, 2018; Dayal, 2021; Evans, 2013). Additionally, timely feedback is essential for student learning (Bahati et al., 2016).

Furthermore, the use of technology including online platforms and automated grading facilitates the timely delivery of feedback (Ugwumaduka & Ogunyemi, 2021). Therefore, timely and constructive feedback allows students to identify areas of improvement and make necessary adjustments (Antoniou & James, 2014; Evans, 2013; Sol, 2020). The feedback model emphasizes the importance of clarifying goals, providing information, and offering opportunities for self-regulation. In the context of mathematics education, feedback that addresses misconceptions and guides problem-solving is particularly valuable (Shute, 2008).

Moreover, studies emphasized the importance of effective feedback, which is specific, timely, and focused on goals. Constructive feedback can help students understand their mistakes and how to correct them (Chemeli, 2019; Li & De Luca, 2014; Shute, 2008). Besides, various feedback strategies have been proposed. According to Cifrian et al. (2020) suggested that self-regulation is enhanced through self-assessment and peer assessment, where students become active participants in the feedback process.

A study has shown that peer and self-assessment not only enhance learning but also promote metacognition and self-regulation (Carless & Boud, 2018). Also, feedback plays a crucial role in helping students identify and rectify errors, understand their strengths and weaknesses, and build confidence in their mathematical abilities (Allal, 2011). Studies have demonstrated that timely feedback is most effective when it is specific, actionable, and provided as part of a continuous feedback loop (Carless & Boud, 2018; Henderson et al., 2019; Kyaruzi et al., 2019; Ugwumaduka & Ogunyemi, 2021).

Uwineza et al. (2023) highlighted the importance of teacher practices in shaping students' mathematical understanding. Regular feedback improves learning outcomes (Sol, 2020). Immediate feedback, particularly in mathematics, allows students to correct their mistakes and deepen their understanding quickly (Antoniou & James, 2014; Chaqmaqchee, 2015; Chemeli, 2019; Dayal, 2021). The integration of technology into assessment practices has shown promise in enhancing mathematics learning outcomes (Cifrian et al., 2020). Computer-based assessments, online platforms, and educational software provide immediate feedback and adaptive assessments to individual student needs (Chaqmaqchee, 2015; Sol, 2020). Effective implementation of innovative assessment methods and timely feedback often requires extensive teacher training and support. Inadequate teacher preparation delays the successful adoption of these strategies (Dayal, 2021).

Rwanda has been exploring innovative approaches to education, including competency-based education and the use of technology in classrooms (Bahati et al., 2016; Uwineza et al., 2023). These initiatives align to enhance learning outcomes. Also, Rwanda has made significant strides in its education system, with a focus on improving access and quality (Uwineza et al., 2023).

However, challenges such as overcrowded classrooms and limited resources persist and affect the effectiveness of innovative assessment methods and timely feedback. While there is limited research specifically addressing the impact of innovative assessment methods and timely feedback in mathematics education in Rwanda, studies from other countries have demonstrated positive effects (Antoniou & James, 2014; Chaqmaqchee, 2015; Cifrian et al., 2020).

Thus, it was crucial to adapt and implement these strategies within the Rwandan context to address the unique challenges and opportunities. The findings from previous studies highlight the need for further research that investigates the concurrent implementation of innovative assessment methods and timely feedback (Chemeli, 2019; Cifrian et al., 2020; Dayal, 2021; Granberg et al., 2021; Henderson et al., 2019; Kyaruzi et al., 2019; Mbarute & Ntiyuguruzwa, 2023; Sol, 2020; Ugwumaduka & Ogunyemi, 2021; Uwineza et al., 2023).

The current study aimed to contribute to the field of secondary mathematics education by providing insights into the perspectives of various participants and the effects of innovative assessment methods and timely feedback.

Theory Groundworks

A theory that guided the study was the constructivist learning theory (CLT) by Vygotsky. This theory suggests that learners actively construct their knowledge through meaningful interactions with the environment. In the context of the current study, CLT guided the implementation of innovative assessment methods. By incorporating assessment approaches that promote active engagement, critical thinking, and problem-solving, the study was carried out to align with the principles of constructivism. Additionally, innovative methods and timely feedback, key components of the study, were grounded in the theory as they

supported the idea that learners benefit most when provided with immediate information about their performance, allowing them to adjust and refine their understanding. Therefore, CLT served as a guiding framework for designing assessment methods and feedback strategies that aligned with the principles of active knowledge construction.

METHODOLOGY

Research Approach

A phenomenological research approach was adopted to understand the lived experiences of participants in the selected mathematics schools. This approach was well-suited for exploring the perceptions and meanings associated with innovative assessment methods and feedback within the context of mathematics education. Additionally, the study approach was examining and straightforward, seeking to uncover the intricate dynamics of innovative assessment methods and timely feedback within the context of advanced public secondary mathematics education in Gasabo District, Rwanda. Furthermore, the study employed qualitative research with a focus on exploring and understanding the perceptions, experiences, and insights of students and teachers regarding innovative assessment methods and timely feedback in mathematics education.

Participants

Participants in this current research included mathematics teachers and students within the selected schools. A purposive sampling technique was used to select a representative sample of schools, teachers, and students. The sample was chosen based on specific criteria to ensure diversity and relevance. The sample was also purposively selected based on their experience and expertise in the subject matter. The present study employed purposeful sampling to select schools and participants. 139 students and seven teachers from selected advanced public secondary mathematics schools in Gasabo District, Rwanda were invited to participate. 146 participants in total.

Data Collection

The current research employed focus group discussions (FGDs) were the primary data collection method. The present study conducted FGDs to gather qualitative data and held separate FGDs for students and teachers to capture their unique perspectives, each FGD consisted of six-10 participants to encourage active participation and rich discussions, FGDs were semi-structured, with open-ended questions and prompts, and sessions were audio-recorded with participants' consent. Developed a set of open-ended questions and prompts for FGDs, focusing on innovative assessment methods, timely feedback, and their impact on learning outcomes.

Data Analysis

Focusing on the enhancement of learning outcomes through innovative assessment methods and timely feedback. Through careful data analysis to identify effective teaching and assessment practices that empower students to raise critical thinking and ultimately lead to better learning outcomes in mathematics. The present study employed thematic analysis to identify recurring themes and patterns in the data, analyzed FGD transcripts independently for students and teachers used qualitative data analysis for data and coding, and identified common themes related to innovative assessment methods and timely feedback.

Trustworthiness

The present study employed triangulated data sources by comparing findings from different focus groups, member checking by sharing preliminary findings with participants to care about the truth of the interpretations, and peer debriefing by tracking input from experts in qualitative research for an external perspective.

Ethical Considerations

The study employed ethical principles, including informed consent, confidentiality, and respect for participants, which were strictly followed throughout the research process. Additionally, the present study obtained informed consent from all participants, ensuring they understood the purpose and nature of the study, maintained the confidentiality and anonymity of participants, and ethical approval was sought from relevant authorities.

RESULTS & DISCUSSION

Results

The current study conducted FGDs with 146 participants in selected advanced public secondary mathematics schools in Gasabo District, Rwanda. The aim was to gain insights into the effectiveness of innovative assessment methods and timely feedback in enhancing learning outcomes in mathematics education. The participants included 139 students and seven mathematics teachers, and their feedback provided valuable insights into the impact of these strategies on learning outcomes.

Theme 1. Positive attitude towards innovative assessment methods

Participants expressed a generally positive attitude towards innovative assessment methods, such as project-based assessments and peer evaluations. They believed these methods enhanced their engagement and interest in mathematics.

Theme 2. Positive impact on student engagement

Many students expressed that innovative assessment methods, such as project-based assessments, quizzes, and interactive assignments, increased their engagement in mathematics learning. They appreciated the opportunity to apply theoretical knowledge to practical problems, which made the subject more interesting and relevant. Participants generally expressed a positive view of the innovative assessment methods introduced in their mathematics classrooms. These methods, including project-based assessments, peer evaluations, and real-world problem-solving tasks, were considered engaging and motivating for students. Participants noted that these methods encouraged critical thinking and creativity, raising a deeper understanding of mathematical concepts.

Theme 3. Improved understanding of concepts

Both students and teachers reported that innovative assessment methods contributed to a better understanding of mathematical concepts. These methods encouraged critical thinking, problem-solving, and deeper exploration of mathematical principles, leading to improved comprehension of the subject matter. An overarching finding of FGDs was a perceived improvement in learning outcomes among students. Participants reported that students showed a better grasp of mathematical concepts, higher problem-solving skills, and increased confidence in their abilities. This improvement in learning outcomes was seen as a positive indicator of the effectiveness of the intervention.

Theme 4. Enhanced motivation to learn

Timely feedback was highlighted as a significant promoter for students. Knowing where they stood in terms of their understanding and performance in mathematics encouraged them to work harder and seek improvement. Teachers mentioned that the timely feedback helped identify students' weaknesses and strongness instruction accordingly. Several participants mentioned a noticeable improvement in student engagement and participation in mathematics classes. They observed that students were more actively involved in discussions, group activities, and problem-solving tasks, which led to a more dynamic and interactive learning environment. This heightened engagement was attributed to the innovative assessment methods, which shifted the focus from rote memorization to practical application.

Theme 5. Improved learning outcomes

Many participants reported improved learning outcomes as a result of innovative assessment methods. They mentioned that these methods helped them understand mathematical concepts better and improved their problem-solving skills.

Theme 6. Timely feedback as a catalyst for improvement

Timely feedback was recognized as a critical component of the intervention's success. Participants emphasized that the provision of immediate and constructive feedback to students allowed for continuous improvement. They noted that students were more motivated to learn and correct their mistakes when they received feedback promptly. Teachers reported that they also benefited from ongoing feedback, enabling them to fine-tune their teaching strategies. Participants emphasized the importance of timely feedback. They found that receiving feedback promptly allowed them to identify their weaknesses and make necessary adjustments, ultimately contributing to better performance.

Theme 7. Peer assessment encourages collaboration

Peer assessment was seen as a valuable component of innovative assessment methods. Participants appreciated the opportunity to evaluate their peers' work and collaborate with them, which raised a sense of community and collective learning.

Theme 8. Teacher professional development

Teachers appreciated the opportunity to develop their skills in designing and implementing innovative assessments. They found that it required them to adopt a more student-centered approach, which improved their pedagogical techniques. They also noted increased collaboration among teachers in sharing effective assessment strategies.

Theme 9. Challenges in implementation

While participants acknowledged the benefits of innovative assessment methods, they also highlighted some challenges in their implementation. These challenges included the need for additional training and resources for teachers to effectively integrate these methods into their teaching practices. Moreover, the assessment of students' performance in these non-traditional methods required more time and effort than traditional exams. Some challenges were identified, primarily related to resource constraints and the need for training in designing innovative assessments. Participants suggested that more support in terms of training and resources would be beneficial to fully realize the potential of these methods.

Theme 10. Preparing students for real-world challenges

Participants stressed the importance of preparing students for real-world challenges through innovative assessment methods. They believed that these methods helped bridge the gap between theoretical knowledge and practical application, equipping students with skills relevant to future careers and life beyond the classroom.

Theme 11. Sustainability and scaling up

Participants discussed the sustainability of the innovative assessment methods and the potential for scaling up the initiative to reach more schools in Gasabo District, Rwanda. They recognized the need for continuous support, including teacher training and resource allocation, to ensure the long-term success of the program.

Discussion

The findings from FGDs indicated that innovative assessment methods and timely feedback have a positive impact on learning outcomes in mathematics education in Gasabo District, Rwanda. Timely feedback emerged as a critical factor in enhancing learning outcomes. The findings highlighted the importance of providing students with constructive feedback promptly to guide their learning. These strategies not only enhance student engagement and comprehension but also motivate students to strive for improvement. Incorporating project-based assessments and interactive assignments aligns with modern educational paradigms that emphasize experiential learning and the practical application of knowledge. This approach better prepares students for real-world challenges, where problem-solving skills are essential.

Peer assessment was found to encourage collaboration and teamwork. Also, the positive impact on teacher professional development underscored the importance of continuous training and support for teachers in adopting innovative assessment methods. Encouraging collaboration among teachers also leads to the sharing of best practices and the collective improvement of mathematics education in Gasabo District, Rwanda. However, the challenges identified in implementation, particularly resource constraints, should not be underestimated. Adequate support from educational authorities is crucial to ensure that schools have the necessary tools and materials to implement innovative assessment methods effectively.

Therefore, the findings suggested that the adoption of innovative assessment methods and timely feedback significantly enhanced learning outcomes in mathematics education in Gasabo District, Rwanda. Addressing the challenges and providing continued support will be essential for sustaining and expanding the positive impact of these strategies in the long term. According to studies from other nations that showed good impacts (Antoniou & James, 2014; Chaqmaqchee, 2015; Cifrian et al., 2020), the current findings are consistent with those. Effective teaching involves creative assessment strategies and timely feedback.

CONCLUSIONS & RECOMMENDATIONS

Conclusions

The findings of this study shed light on several critical aspects that contribute to improving learning outcomes in mathematics education. Firstly, the findings highlighted the importance of innovative assessment methods. It was evident that traditional assessment approaches often fell short in engaging students and promoting a deeper understanding of mathematical concepts. The incorporation of innovative assessment methods, such as project-based assessments, peer assessment, and formative assessment techniques, proved to be effective in capturing students' interest and facilitating meaningful learning experiences. Secondly, timely feedback emerged as a pivotal factor in enhancing learning outcomes. Students' ability to receive constructive feedback on their performance on time was shown to be instrumental in their academic progress. Teachers played a significant role in providing this feedback, and the study emphasized the need for professional development and training to equip teachers with the skills required to deliver effective feedback.

Recommendations

Based on the findings, the study recommended comparing the outcomes of mathematics education in Gasabo District, Rwanda with other regions or countries that employ different assessment methods and feedback strategies. Also to investigate the effectiveness of specific teacher training and professional development programs in improving teachers' ability to implement innovative assessment methods and deliver timely feedback.

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Ethical statement: The authors stated that the study employed ethical principles, including informed consent, confidentiality, & respect for participants, which were strictly followed throughout the research process. The study was approved by the institutional ethics committee of University of Rwanda, College of Education on 16 January 2023 (Approval code: Ref: 03/DRI-CE/005(b)/EN/gi/2023). Written informed consents were obtained from the participants or their legal guardians.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

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