# Integrating Neuroeducation Principles into Mathematics Instruction in Tanzanian Public and Private Secondary Schools

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**Abstract**

*Integration of neuroeducation principles into mathematics instruction can significantly improve learning outcomes in Tanzania. Despite technological advancements, secondary schools face challenges in mathematics, necessitating effective teaching methodologies tailored for a digital landscape to enhance student performance. A qualitative study was conducted involving three mathematics teachers from public and private secondary schools in Iringa Municipality to explore their teaching practices in the integration of neuroeducation principles. This study explored the integration of Neuroeducation Principles in mathematics instruction. Data were collected through semi-structured interviews, lesson observations, and document analysis. The findings highlighted discrepancies between teachers' claimed understanding and actual teaching practices in the integration of predominantly traditional neuroeducation principles. Challenges like large class sizes and inadequate resources limited interactive strategies. Recommended interventions include providing sufficient materials, integrating technology, and improving professional development. The study provides insights for policymakers and educators on integrating Neuroeducation Principles with digital technologies to create an engaging, and inclusive mathematics instruction.*

**Keywords:** *neuroeducation, mathematics instruction, Tanzania, teaching strategies*

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## Introduction

Enhancing mathematics education in the digital age is a pressing global challenge, particularly in developing countries like Tanzania. Mathematics education is vital for fostering critical thinking, and problem-solving skills, and preparing students for future career opportunities in an increasingly technological world (Boaler, 2016). However, Tanzanian secondary school students often exhibit difficulties in mathematics subjects, leading to poor performance and diminished interest in scientific inquiry (Kyaruzi et al., 2019). This study investigates the integration of neuroeducation principles to address these challenges, providing a mathematics foundation for effective teaching strategies in mathematics education (Howard-Jones, 2008). Neuroeducation is an interdisciplinary field that merges insights from neuroscience, psychology, and education to enhance understanding of how students learn (Ansari et al., 2012; Carew & Magsamen, 2010). It emphasizes the importance of approaches such as active learning, multisensory instruction, and cognitive load management (Jensen, 2008). Despite its potential benefits, the application of neuroeducation principles in Tanzanian classrooms remains limited (Mazana et al., 2020).

In the context of mathematics education, traditional teaching methods often rely on rote learning and memorization, which may not cater to the diverse learning needs of students (Boaler, 2016). Through integrating neuroeducation principles, educators can create more engaging and effective learning environments that foster deeper understanding and retention of mathematics concepts. This research aims to explore how neuroeducation principles are integrated into mathematics curricula and teaching practices to enhance learning outcomes in the digital age. This study contributes to new insights that can improve mathematics education in Tanzania. By examining the integration of neuroeducation principles into existing teaching practices and identifying barriers to implementation, the findings will provide valuable data to inform educational reforms. The Ministry of Education can leverage these insights to optimize instructional strategies and address persistent challenges related to student performance. Moreover, the research aims to empower educators by offering practical recommendations tailored to the local context.

While prior studies have indicated the potential of neuroeducation to improve student learning outcomes, there is limited empirical evidence regarding its application in mathematics education at the secondary school level (Howard-Jones, 2008; Yates, 2022). This study seeks to address this gap by exploring how teachers perceive and experience the integration of neuroeducation principles into mathematics curricula and teaching practices to enhance learning outcomes in the digital age. The objectives of this study are threefold: first, to investigate how neuroeducation principles are currently integrated into mathematics curricula and teaching practices; second, to analyse the impact of these integrations on student engagement and learning outcomes in the digital age; and third, to identify the challenges and opportunities teachers encounter when applying neuroeducation principles in mathematics instruction. This research builds on existing literature by providing qualitative insights into the practical application of neuroeducation within the Tanzanian educational context (Dekker et al., 2012; Stein & Fischer, 2011).

## Literature Review

Neuroeducation is a multidisciplinary field that integrates education, psychology, neuroscience, and cognitive science, aiming to enhance instructional strategies through insights into how individuals learn (Ansari et al., 2012; Carew & Magsamen, 2010). The development of brain imaging technologies, such as functional magnetic resonance imaging and electroencephalography, has been pivotal in understanding the brain's activity during cognitive tasks (de Hortega & García, 2012; Jolles & Jolles, 2021). Neuroeducation seeks to bridge the gap between neuroscience and education, employing empirical data to inform teaching techniques, curricula, and educational policies (Farah, 2010; Tokuhama-Espinosa, 2015). As a relatively nascent field, neuroeducation has initiated critical discussions among educators, administrators, and brain scientists regarding its practical applications (Howard-Jones & Washbrook, 2011). This discipline emphasizes translating scientific insights into actionable strategies, thereby improving educational outcomes and aligning practices with cognitive processes (Howard-Jones, 2014). Leveraging advances in neuroscience, neuro-education provides evidence-based insights that can transform teaching methodologies and curricular designs, thus promising to revolutionize education (Nouri, 2016). Understanding neuro-education is essential for educators and researchers seeking to explore its applications in diverse educational contexts**.**

### Neuroeducation principles

Neuroeducation is an interdisciplinary approach that combines neuroscience and education to optimize teaching methods and improve learning outcomes (Howard-Jones, 2008; Howard-Jones et al., 2016). Central to neuroeducation is the understanding of how the brain learns, emphasizing the interconnectedness of social and cognitive processes crucial for knowledge construction. This approach promotes strategies such as active, collaborative, and multisensory learning, differentiated instruction, and metacognitive strategies, which are especially effective in teaching mathematics.

***Active learning*** as a key principle, engages students in their learning process, fostering strong neural connections and enhancing memory (Jensen, 2008). Techniques like hands-on activities and group discussions deepen understanding of mathematical concepts (Fisher & Frey, 2014). The principle of ***Emotion and motivation*** underscores the importance of creating a positive emotional classroom environment, enhancing motivation through autonomy and real-life applications (Pekrun et al., 2011; Reeve, 2016). ***Timely feedback*** is crucial for guiding student progress and addressing misconceptions in mathematics (Hattie & Timperley, 2007). ***Multisensory instruction*** enhances engagement and retention by integrating various sensory modalities (Kestel et al., 2012). Effective ***Cognitive load*** management alleviates mental effort by breaking down complex tasks and using scaffolds (Sweller et al., 2011b). Finally, the Principle of ***Multiple intelligences*** encourages educators to tailor instruction to diverse learning styles, enhancing engagement and understanding across varied student profiles (Gardner, 2015; Gardner & Hatch, 1989). While strategies like active, collaborative, and multisensory learning, as well as differentiated instruction and metacognitive strategies, are indeed emphasized in the curriculum, this study explores how integrating neuroeducation principles can deepen understanding of how the brain learns and processes mathematical concepts. By examining the alignment of these principles with the latest neuroscience research, the study seeks to further enhance the cognitive engagement of students, optimize teaching practices, and contribute to more effective and evidence-based approaches to teaching mathematics in the digital age.

The field of neuroeducation, which merges insights from neuroscience with educational practices, presents a promising avenue for enhancing learning outcomes, particularly in mathematics and science education. However, while there is an extensive body of research on neuroeducation principles, including studies on active learning (example, Vavrus, 2009; Vavrus & Barlett, 2012; Mtitu, 2014) and assessment and feedback (example., Kyaruzi et al. 2009), there remains a need for more in-depth research on how these principles are specifically applied within the context of Tanzanian mathematics education. This study aims to explore how these established principles can be further integrated and adapted to local teaching practices, fostering a deeper understanding of their impact on student engagement and learning outcomes in the digital age." Existing studies often fail to address local educational challenges and cultural nuances that may affect the implementation of neuro-education strategies. Furthermore, despite theoretical support for neuro-education principles, there is ***limited empirical research exploring how these concepts can be translated into classroom practices***. The complexities involved in practical implementations such as curriculum constraints, teacher training, and resource availability are often overlooked in current literature.

## Complexity in teaching and learning mathematics

Neuroeducation principles are essential in addressing the complexities of teaching and learning mathematics, aligning instructional methods with cognitive processes to enhance educational outcomes. The intricacies of mathematics education are influenced by cultural contexts, learning styles, and educational systems. For example, in the United States, educators implement active learning strategies and multisensory approaches to engage students (Goswami, 2006). Japan emphasizes collaborative problem-solving and real-world applications, fostering a culture of perseverance (Hiebert et al., 1999). Finland's holistic approach prioritizes student well-being and motivation (Sahlberg, 2011), while Singapore's curriculum encourages connections between mathematical concepts (Kaur & Gupta, 2013). In Tanzania, challenges such as linguistic diversity and resource limitations are addressed through multisensory learning, active engagement, and technology integration (Kisanga, 2017; Chogo et al., 2017). Overall, neuroeducation provides a framework for educators to create meaningful learning experiences by acknowledging and catering to the diverse needs of students.

## Integration of neuroeducation principles into mathematics instruction

The integration of neuroeducation principles into mathematics education has garnered significant attention in contemporary academic discourse, as researchers explore the potential benefits of applying neuroscience insights to enhance learning outcomes, engagement, and student motivation (Tokuhama-Espinosa, 2011; Jensen, 2008). In Africa, studies by Machumu and Mbeba (2017) and Mvududu et al. (2016) emphasize the relevance of neuroscience concepts in addressing educational challenges. However, in Tanzania, research on this integration within mathematics instruction remains limited.

Recent studies indicate a critical need to improve mathematics education in Tanzania (Mwakapenda et al., 2020; Mgaya & Mgaya, 2019). Tanzanian schools are increasingly considering Neuroeducation Principles to engage diverse learners and enhance academic performance. Although progress is being made, further research is essential to deepen understanding of these principles within the Tanzanian context. Integrating Neuroeducation Principles is expected to revolutionise mathematics instruction, providing a more innovative and fulfilling learning experience. Fischer et al. (2007) assert that this integration aligns teaching with the brain's cognitive processes, improving information retention and academic success. Howard-Jones (2014) emphasizes the creation of instructional environments that resonate with natural brain function, fostering innovation in learning.

## Benefits of neuroeducation

The integration of neuroeducation principles in teaching has been shown to yield significant benefits, extending beyond traditional academic outcomes. Jensen (2008), Nouri et al. (2022), and Stein and Fischer (2011) highlight that these principles facilitate the development of critical cognitive skills and create engaging, nurturing learning environments. Jensen (2008) emphasizes that aligning educational settings with cognitive and neurological processes enhances student engagement and fosters a positive atmosphere for learning. Nouri et al. (2022) further assert that applying neuro-education principles equips students with essential skills such as analytical thinking and problem-solving, which are vital for academic success. Stein and Fischer (2011) underscore the importance of these principles in providing students with cognitive tools that enhance traditional learning while promoting transferable skills applicable across various domains. Collectively, this evidence supports the notion that neuro-education principles not only improve educational practices but also prepare students for future challenges. The continuous application and understanding of these principles represent viable strategies for enhancing student outcomes and raising overall educational standards as the field of neuro-education evolves.

### Barriers to integration of neuroeducation into mathematics instruction

The integration of neuroeducation principles in mathematics education faces several challenges that require careful attention. Ethical concerns arise, especially regarding brain imaging technologies, where issues of privacy and consent must be navigated (Vroom, 2019). Additionally, interdisciplinary complexity complicates collaboration between educators and neuroscientists, necessitating effective communication to bridge diverse methodologies (Øland et al., 2022). Practical implementation is also challenging, as translating neuroscientific insights into effective teaching strategies requires meticulous planning within educational constraints (Haggard, 2008). Furthermore, individual variability among learners presents obstacles; diverse cognitive profiles and learning styles make it difficult to tailor neuroeducation strategies for equitable outcomes (Borghi & Fini, 2019). Limited understanding of neuroscience, being a developing field, adds to these challenges (Farah & Newman, 2010). Lastly, the gap between research findings and classroom practice hampers the effective application of neuro-education principles, highlighting the need for ongoing dialogue among educators, neuroscientists, and policymakers to navigate these complexities and enhance mathematics instruction.

## Methodology

### Research paradigm, approach, and design

This study adopted a constructivist paradigm, emphasising understanding how teachers integrate neuroeducation principles into mathematics instruction. Constructivism posits that knowledge is constructed through experiences and reflections (Creswell, 2013), valuing subjective interpretations and the dynamic interaction between teachers' prior knowledge and neuroeducation principles. This approach encouraged dialogue and collaboration with participants to co-construct knowledge, providing rich insights into the integration process. Qualitative methodologies were employed to gather data within classroom settings, making them ideal for exploring unknown factors and diverse perspectives. This interpretive and descriptive approach recognises multiple subjective realities connected to specific contexts (Cohen et al., 2017), allowing for an in-depth investigation of integrating neuroeducation principles into Tanzanian mathematics classrooms.

A case study design was utilised, providing a robust framework for detailed exploration and analysis (Creswell, 2021). The design facilitated data collection and evaluation of neuroeducation concepts within real-world settings in two secondary schools. Multiple data collection methods ensured a comprehensive analysis (Yin, 2009), essential for understanding the complexities of integrating neuroeducation principles into mathematics instruction.

## Research setting and participants

The study was conducted in a public and a private secondary school in Iringa Municipality, Southern Tanzania, to provide a comprehensive view of how neuroeducation principles are implemented across different educational contexts. By considering schools with varying socioeconomic backgrounds such as infrastructure, student demographics, teacher qualifications, parental involvement, extracurricular opportunities, and learning environments, the research explored the challenges and benefits of implementing these principles, incorporating a comparative analysis of their integration.

A total of 135 participants were involved, including 36 Form I students, 98 Form III students, and three mathematics teachers. Teachers were purposefully selected due to their critical role in curriculum implementation. The sample included two mathematics teachers from Form III and one from Form I. Teachers were selected purposefully based on their involvement in teaching mathematics and their availability for the study. Including one female teacher aimed to provide gendered perspectives in teaching practices. The gender imbalance resulted from the limited availability of female teachers in the selected schools.

Students were indirectly involved in the study, with their engagement and interactions analysed during lesson observations. This approach provided essential context to evaluate teaching strategies without directly involving students as participants. Qualitative research was prioritized to provide detailed insights into teachers' experiences and practices, enhancing the understanding of neuroeducation principles' application. Despite practical constraints, the strategic selection of teachers from different classes and schools enriched the diversity of perspectives, contributing to a thorough exploration of the challenges and successes in implementing these principles.

In addition to interviewing the teachers, lessons in Form I and Form III were observed to examine how neuroeducation principles are integrated into mathematics education. Observations were limited to avoid disrupting the regular class activities of Form I and III students, who were not involved in national examination preparations and provided essential insights into students' experiences with neuroeducation-based teaching methods. Semi-structured interviews with mathematics teachers complemented the observations, ensuring a well-rounded data collection approach that captured teacher perspectives.

## Methods of data collection

Data collection involved semi-structured interviews with three mathematics teachers, aimed at gaining in-depth insight into their experiences, challenges, and perceptions regarding the integration of neuroeducation principles in mathematics teaching (Alshenqeeti, 2014). Each interview lasted one hour, allowing for comprehensive discussions. Responses were recorded using a smartphone audio recorder, with recordings securely stored for analysis.

Classroom observations were conducted to investigate the teaching environment and dynamics. Observations were carried out in three mathematics lessons—one from Form I and two from Form III—each lasting 40 minutes. Key components analysed included the integration of neuroeducation principles into mathematics instruction, the use of active, multisensory, and collaborative learning strategies, the application of differentiated instruction, and the implementation of metacognitive strategies. The observations aimed to develop a nuanced understanding of how neuroeducation principles were applied in real-world teaching contexts.

Document analysis involved examining various educational documents to understand the integration of neur oeducation principles. This included education policy documents, teacher curriculum guidelines, lesson plans, and teaching materials, providing context for the systematic integration of these principles within the curriculum.

## Data analysis

Data analysis was conducted using thematic analysis to identify patterns, themes, and categories related to the integration of neuroeducation principles in science education. Following Creswell's (2013) approach, manual transcription of interviews and observations ensured accuracy. Transcriptions were reviewed multiple times to gain a deeper understanding, with keywords and phrases highlighted to create codes and categorize information based on research questions. Repetitive ideas, expressions, and perspectives were identified and merged into coherent themes, presented narratively with visual aids for enhanced understanding.

## Ethical issues

To uphold ethical standards, a researcher secured a research permit from the Regional Administrative Secretary (RAS) of Iringa, which was granted for one month for the designated study sites. The permit was distributed to the Municipal Educational Director (MED) and the Heads of Schools, who facilitated introductions to the selected teachers and scheduled data collection appointments. The participants' consent was obtained by informing them about the study's purpose and their rights. Confidentiality was also prioritised by employing pseudonyms to protect their data. As noted by Arifin (2018), safeguarding human subjects in research requires adherence to appropriate ethical standards.

## Findings

### Demographic Profile of Participants

The inclusion of the demographic profile of participants provides context for understanding the perspectives and experiences shared by the participants. In qualitative research, individual backgrounds, such as teaching experience, educational qualifications, and career stages, play a critical role in shaping how participants perceive and implement educational principles. This section helps in interpreting the diverse viewpoints offered by teachers and the observed classroom dynamics, offering a comprehensive understanding of how neuroeducation principles are integrated into mathematics instruction. The study involved three mathematics teachers who provided rich insights into their demographics and experiences.

Teacher AY/19 is a thirty-three-year-old male with three years of teaching experience and a degree in education. As a relatively early-career educator, he offers perspectives on the challenges faced by new teachers in implementing neuroeducation principles. His emphasis on collaboration suggests openness to modern pedagogical approaches.

Teacher ML/19 is a forty-one-year-old female with fifteen years of teaching experience and a diploma in education. With over a decade of teaching, she provides practical insights into the challenges and benefits of integrating neuroeducation principles, focusing on creating a positive learning environment.

Teacher MY/25 is a fifty-four-year-old male with thirty-three years of teaching experience and a degree in education. His long tenure allows him to offer a historical perspective on changes in teaching methodologies, with an emphasis on fostering critical thinking.

Observations in the schools revealed varied levels of student engagement. In School H's Form One, thirty-six students exhibited passive engagement, while Form Three C's thirty-eight students showed disorganisation and preferred chorus responses. In School M's Form Three, fifty-eight students were notably passive, with some even sleeping during class. Also, in School H's Form Three, forty-two students demonstrated low participation, frequently relying on the teacher for guidance without initiating responses. Moreover, in School M's Form One, forty-five students appeared disengaged, often distracted and less responsive to interactive activities.

## Teachers' perceptions of neuroeducation

The investigation into teachers' perceptions of integrating neuro-education principles in mathematics education revealed varied attitudes, categorized into three primary themes: enthusiasm, scepticism, and confidence. Teachers expressed varying degrees of enthusiasm towards the integration of neuroeducation principles. For example, Teacher AY/19 believes neuroeducation principles positively impact mathematics teaching by developing student interest and engagement, emphasizes the importance of collaborative learning for active engagement, advocates for comprehensive training for teachers in neuroeducation principles and stresses the role of neuroeducation in providing quick feedback on the learning process. This was evident through a statement below:

> Neuroeducation principles have a positive impact on teaching mathematics. First helps to develop student interest in learning mathematics, when teachers use collaborative methods of learning, makes learners active and engage fully in the learning process. This collaborative learning will help those who do not love mathematics to love it. Also, helps a teacher to get quick feedback about the effectiveness of the learning process because learners are fully engaged in the learning process. A teacher can also change his/her teaching style depending on the mood and nature of the learners (Teacher AY/19, Interview, 19.09.2023).

Confidence, the level of confidence in neuroeducation principles varied among the teachers. For example, Teacher ML/19 expressed confidence and sees neuroeducation principles as beneficial for improving mathematics performance and fostering a positive attitude. Emphasizes the importance of policymakers promoting neuroeducation, incentivizing innovative teaching methods, and providing professional development resources. This is proven by the statement,

> The principles are good in improving mathematics performance because help in informing strategies to enhance student engagement

> and motivation in mathematics. Creating activities that align with the learner's ability and find intrinsic rewards can foster a cheerful outlook towards mathematics. They also help create a positive and supportive learning environment in mathematics classrooms that can help reduce anxiety and stress, promoting better cognitive functioning and student interest in learning mathematics. Also, they promote memory and retention of mathematical concepts since learners are fully engaged in the learning process (Teacher ML/19, Interview, 19.09.2023).

In contrast, Teacher MY/25 focuses on developing critical thinking and problem-solving abilities in learners through collaboration. Stresses the need for assessment methods aligned with neuroeducation principles and training teachers on their application. Teachers MY/25 stated that:

> Critical thinking and problem-solving abilities to learners, normally when learners in discussion share ideas and challenge each other, they develop thinking abilities. Also, they develop an interest in learners to love mathematics, when learners collaborate, and help those who have anxiety to reduce it (Teacher MY/25, Interview, 25.09.2023).

Also, Teacher-ML/19 showcased confidence in neuroeducation principles, emphasising their role in improving mathematics performance and fostering a positive attitude.

Conversely, teacher MY/25 expressed scepticism, attributing declines in student performance to external factors like technological distractions: "*In previous years, we succeeded because students faced fewer distractions. Now everyone passes, diminishing the competitive learning environment*" (Teacher MY/25, Interview, 25.09.2023).

## Neuroeducation principles integrated into mathematics classrooms

The findings indicate that teachers are implementing several neuro-education principles, including active learning, multisensory learning, emotional and motivational engagement, and feedback mechanisms.

### *Active learning*

Most teachers reported using active learning strategies, such as group discussions and hands-on activities, to foster student engagement. Teacher AY/19 explained, "*I design hands-on activities that require students to engage in practical exercises* *related to the concepts being taught"* (Teacher AY/19, personal communication, September 2023). Teacher ML/19 also emphasized the importance of active learning, stating, *"I incorporate group work where students collaborate on problem-solving tasks to enhance their understanding of mathematical concepts"* (Teacher ML/19, personal communication, 2023). Additionally, Teacher ZM/22 noted, "*I encourage peer discussions and use manipulatives to help students visualize mathematical operations*" (Teacher AY/19, personal communication, 2023).

However, an analysis of lesson plans revealed that although teachers included active learning strategies, such as group discussions and hands-on activities, their execution in practice often fell short of effectively engaging students. The lesson plans outlined activities designed to promote student participation, but classroom observations indicated that these strategies were not effectively implemented. In School H's Form I, for instance, although the teacher planned a group discussion, students were mostly passive, with few actively contributing to the conversation. Similarly, in School M's Form III, despite the inclusion of group tasks in the lesson plans, students seemed disengaged, and the teacher did not facilitate meaningful interaction or ensure equal participation. Teacher MY/25 from School M observed, "*The group work is intended to make students interact, but in reality, only a few dominate the conversation, and others just listen*" (Teacher MY/25, personal communication, 2023). These observations suggest a gap in teachers' understanding of how to properly implement active learning techniques, as the intended strategies often failed to maximize student engagement in practice.

### *Multisensory learning*

Teachers reported using multisensory experiences to reinforce concepts, although these practices were not always consistently applied in classrooms. Teacher AY/19 highlighted his use of hands-on materials, stating, "*I provide students with base-ten blocks to represent mathematical concepts*" (*Teacher AY/19, personal communication, 2023). Teacher ML/19 shared her approach, saying, "I use visual aids such as graphs and charts to help students visualize abstract mathematical ideas"* (Teacher ML/19, personal communication, 2023).

Despite these claims, classroom observations indicated a strong reliance on traditional teaching methods, with limited incorporation of multisensory activities. In School H's Form I, the lesson primarily involved lecture-style teaching, with little use of visual or hands-on materials. Students were mostly engaged in note-taking, with few interactive or sensory activities. Teacher MY/25 in School M shared, "*We try to use visual aids, but due to large class sizes and lack of resources, it becomes difficult*" (Teacher MY/25, personal communication, 2023). During an observed lesson in School M's Form III, the lesson consisted of textbook readings and oral explanations, with no attempt to incorporate tactile or auditory learning methods. Only one teacher in School H's Form I used a visual aid (a diagram) to explain a mathematical concept, but no further multisensory approaches, such as tactile or auditory materials, were included in the lesson. These observations suggest that, while some teachers intended to use multisensory strategies, their application was minimal because of classroom constraints.

### *Emotional and motivational engagement*

Teachers acknowledged the importance of emotional engagement in fostering a positive learning environment. In School M, teachers attempted to create such an environment, but large class sizes hindered their ability to connect with students on an individual level. For example, in one observed lesson, the teacher used encouraging language, such as, "Great effort, let's keep trying." However, despite these efforts, the overall classroom atmosphere remained subdued, with many students appearing disengaged and passive. Teacher MY/25 from School M noted: "*It's difficult to manage emotional engagement with so many students; they don't get the individual attention they need*" (Teacher MY/25, personal communication, 2023).

In School H's Form I, the teacher focused on promoting a supportive environment by using phrases like "You can do it!" and "Don't be afraid to make mistakes." Despite these efforts, the emotional engagement was undermined by the teacher's reliance on traditional lecturing and lack of interactive activities. During the observed lesson, many students appeared unmotivated, and only a few actively participated. Teacher AY/19 from School H emphasized, *"Positive emotions lead to enjoyable learning experiences, fostering engagement"* (Teacher AY/19, personal communication, 2023), but classroom dynamics suggested that emotional engagement was not fully realized in practice.

### *Feedback and error collection*

Teachers acknowledged the importance of timely feedback but faced challenges in its consistent application. In School H's Form I, feedback was typically given only at the end of the lesson after students completed individual exercises, offering limited opportunities for immediate correction. In School M's Form III, teachers expressed difficulty in providing individualized feedback due to large class sizes. Teacher MY/25 from School M stated, "*With so many students, it's hard to give personalised feedback. Some students don't even receive any feedback during the lesson*" (Teacher MY/25, personal communication, 2023).

In School H's Form III, feedback was occasionally provided during group work, but due to resource constraints, it was often limited to verbal comments. There was minimal follow-up on errors or opportunities for students to correct mistakes. Teacher ZM/22 from School M added, "*Feedback is important, but larger class sizes make it hard to keep up with every student. We often don't have time to address every error*" (Teacher ZM/22, personal communication, 2023). These challenges highlight the significant barriers posed by large class sizes and limited resources in providing timely, personalized feedback.

The findings from curriculum analysis, teaching guides, and lesson plans revealed that teachers are indeed attempting to incorporate neuroeducation principles, though the extent and effectiveness of integration vary. For instance, the curriculum documents outlined active learning strategies that align with neuroeducation principles. In the mathematics curriculum, the competence-based curriculum emphasizes "student-centred approaches" and "hands-on activities" to promote deeper learning and engagement, which reflect neuroeducation's focus on multisensory learning and active participation. In the teaching guides, there are explicit references to collaborative learning techniques, including group discussions and peer feedback, which resonate with neuroeducation's principles of social and emotional engagement.

For example, one teaching guide for Form I mathematics included a section on *"engaging students through problem-solving tasks" and "utilizing real-world applications," both of which align with neuroeducation's focus on context-based learning and emotional motivation* (Curriculum Guide, 2023). Additionally, the lesson plans reviewed often incorporated activities such as "interactive group discussions" and "hands-on problem-solving," which were intended to engage multiple senses and promote cognitive processing, a key principle of neuroeducation. "*One teacher's lesson plan for a geometry class included activities where students used physical objects (e.g., base-ten blocks) to explore geometric concepts, reflecting a multisensory approach*" (Lesson Plan, Teacher AY/19, September 2023).

However, the document analysis also highlighted inconsistencies in the actual implementation of these principles. While the documents reflected an intention to incorporate neuroeducation principles, some lesson plans lacked detailed strategies for how to fully engage students with these activities. For example, in several lesson plans, the inclusion of "group work" was mentioned, but there were few specific guidelines for how to facilitate active participation, a core aspect of neuroeducation's approach to social and cognitive engagement. Furthermore, some teaching guides mentioned "active learning techniques," but did not provide concrete examples of how to effectively implement these techniques in large class settings, where managing student engagement is more challenging. Thus, while the curriculum documents and lesson plans indicate an intention to incorporate neuroeducation principles, the actual integration is inconsistent and varies in its application across different teachers and schools.

## Challenges faced in implementing neuroeducation principles

Teachers identified several challenges in integrating neuro-education principles, including a lack of teaching materials, limited technology access, poor student engagement, time constraints, and a scarcity of professional development programs.

### *Lack of leaching materials*

Teachers highlighted the difficulty in accessing appropriate teaching materials to effectively implement neuroeducation principles. For instance, Teacher AY/19 pointed out, *"Lack of teaching aids can hinder the variety of methods to cater to student learning differences"* (Teacher AY/19, personal communication, September 2023). Specific materials that were identified as lacking included visual aids such as diagrams and charts, manipulatives like base-ten blocks or geometric shapes, and digital tools like interactive whiteboards or tablets. These materials are integral to the multisensory learning approach advocated by neuroeducation, which emphasizes engaging multiple senses to enhance cognitive processing.

For example, in the absence of physical objects like base-ten blocks, teachers found it challenging to help students visualize abstract mathematical concepts, such as place value and fraction decomposition. Teacher ML/19 remarked, *"Without hands-on materials like blocks or visual aids, it's hard to make abstract concepts tangible for students. It leads to students struggling with understanding key ideas"* (Teacher ML/19, personal communication, September 2023). This lack of concrete resources can undermine the effectiveness of multisensory learning, which relies on engaging students' senses to facilitate deeper learning and retention. In schools with limited access to technology, teachers faced difficulties in incorporating digital tools to enhance student engagement and provide immediate feedback, as key elements of neuroeducation. Teacher ML/19 shared, *"We don't have enough computers or interactive platforms to make learning more interactive, and students miss out on opportunities to engage with educational apps and simulations"* (Teacher ML/19, September 2023). The lack of technology further limits teachers' ability to incorporate neuroeducation principles, such as personalized learning through adaptive platforms or real-time feedback mechanisms, which could otherwise enhance student engagement and learning outcomes.

During the classroom observations, it was evident that the lack of essential teaching aids impeded the integration of neuroeducation principles. In School H, for example, the lesson on fractions in Form I lacked visual aids such as diagrams, charts, or manipulatives like base-ten blocks or fraction strips. Despite the lesson plan indicating the use of these aids, only verbal explanations were given. In the observed Form III class at School M, the lesson on algebra was conducted without any visual aids (e.g., diagrams or graphs) or hands-on materials. The teacher relied solely on the chalkboard for explanations, and no multimedia tools such as projectors or interactive digital tools were used. This absence of teaching aids, especially in a subject like mathematics, where visual and tactile tools are essential for conceptual understanding, made it difficult for students to engage fully with the content.

### *Technology access*

Limited access to technology was consistently identified as a significant barrier to the effective integration of neuroeducation principles. Teacher AY/19 noted, *"Limited access to technology impedes the integration of neuroeducation strategies"* (Teacher AY/19, September 2023). Classroom observations further emphasized this challenge, revealing that technology, such as digital devices, interactive tools, or multimedia resources, was largely absent in the observed lessons across both schools. In School M, no digital tools were used to support the lesson, and the teacher solely relied on a chalkboard and textbook readings. The absence of apps, videos, or interactive platforms meant that students were not exposed to the digital engagement and multisensory experiences advocated by neuroeducation principles.

Similarly, in School H, the teacher faced significant limitations in incorporating multimedia resources, such as videos or interactive simulations, which are vital for fostering deeper learning and engagement in mathematics. In a Form I lesson on algebra, for example, the teacher attempted to explain concepts verbally, without the aid of visual representations, diagrams, or digital simulations that could have reinforced the learning. Teachers expressed awareness of the potential benefits of digital tools but acknowledged that their lack of availability and insufficient training were major obstacles. As Teacher AY/19 explained, *"We know that technology can make a difference, but we simply don't have the resources or the training to effectively integrate it into our teaching*" (Teacher AY/19, September 2023).

### *Poor student engagement*

Teachers reported significant challenges in maintaining consistent student engagement, a core element of neuroeducation. Teacher AY/19 noted, *"When neuroeducation principles are used frequently, learners develop an interest in collaborative learning"* (Teacher AY/19, September 2023). Despite this recognition, classroom observations indicated that engagement levels were often low across both schools. In School H's Form I, for example, despite the teacher's efforts to create an engaging atmosphere, many students remained passive throughout the lesson. Only a handful of students actively participated, and the overall environment lacked the energy needed for active, collaborative learning. The teacher attempted to encourage student involvement by using encouraging phrases, such as "Let's work together on this," but many students appeared uninterested and disengaged.

Similarly, in School M's Form III, the level of student engagement was minimal. During group discussions, students showed little enthusiasm and only a few contributed to the discussions. The teacher struggled to motivate students to collaborate, often resorting to more traditional methods like individual work or whole-class questioning. The lesson lacked the interactive or collaborative activities that are central to fostering deeper engagement. This reliance on traditional teaching methods, without incorporating more engaging, participatory activities, contributed to the low levels of student engagement observed in both schools. As Teacher ML/19 from School M remarked, *"It's difficult to get students to engage when they are not excited about the lesson"* (Teacher ML/19, September 2023).

### *Time constraint*

Teachers highlighted time constraints as a major challenge when implementing neuroeducation strategies. The pressure to cover a broad curriculum in a limited timeframe often led to the prioritisation of content over teaching methods. Teacher ML/19 expressed concern, stating, *"Modern methods are time-consuming, and we struggle to maintain student interest"* (Teacher ML/19, September 2023). Classroom observations confirmed that in both schools, teachers were seen rushing through lessons, with little time allocated for interactive activities or group work. In School M, the teacher was unable to incorporate feedback loops or collaborative activities because of the time limitations imposed by the curriculum. This left little room for deeper, more engaging learning experiences that align with neuroeducation principles.

### *Limited professional development opportunities*

A significant challenge identified by teachers was the lack of professional development opportunities specifically focused on neuroeducation principles. Teacher ML/19 stressed the importance of in-service training, saying, *"Policymakers should promote neuroeducation by providing professional development resources"* (Teacher ML/19, September 2023). Classroom observations revealed that teachers were not fully equipped to implement neuroeducation strategies effectively, largely due to the absence of formal training on the topic. In both schools, it was evident that teachers continued to rely heavily on traditional teaching methods with which they were more familiar, as they had not received sufficient training to incorporate newer, research-based approaches.

In School H, for instance, teachers were observed predominantly using lecture-based methods and were not utilizing techniques related to neuroeducation, such as multisensory learning or active learning strategies. Even though teachers expressed an understanding of the benefits of these principles, their lack of training left them unable to integrate them into their lessons. In School M, the use of technology and interactive teaching methods was minimal, and teachers noted that they were unsure how to incorporate these elements into their teaching practice. As Teacher AY/19 from School M put it, *"I would like to use technology more, but I don't know how to integrate it into my lessons without proper training"* (Teacher AY/19, September 2023). These observations highlight that, without targeted professional development, teachers struggled to implement neuroeducation principles effectively in their classrooms.

## Discussion of the Findings

The findings of this study provide valuable insights into the demographic profiles of the teacher participants and students, shedding light on diverse perspectives regarding the integration of neuroeducation principles in mathematics education. Three key themes emerged: *enthusiasm*, *scepticism*, and *confidence*.

### Enthusiasm

Teachers exhibited varying degrees of enthusiasm towards integrating neuroeducation principles. The analysis shows that enthusiasm positively influences student engagement and learning outcomes. According to Fredrickson's Broaden-and-Build Theory of Positive Emotions (Fredrickson, 2001), enthusiasm broadens individuals' thought-action repertoires and builds enduring personal resources. In educational contexts, enthusiastic teachers have been shown to significantly enhance student motivation and academic achievement (Wang & Eccles, 2012). The data aligns with Hiebert et al. (2007), who emphasize that active and collaborative learning improves mathematics learning outcomes. Teachers' positive outlook on neuroeducation principles suggests that fostering enthusiasm through comprehensive training and professional development can enhance instructional effectiveness.

### Scepticism

Scepticism emerged as some teachers attributed declining mathematics performance to external factors such as technological distractions. Scepticism, characterized by critical evaluation and the demand for evidence (Reed, 2015; Sachdev, 2019), can impact the adoption of new methodologies. Descartes' methodological scepticism (Grene, 1999) highlights the importance of evidence-based practices in overcoming doubts. This study's findings echo Shernoff et al. (2015), who noted that teacher scepticism may stem from concerns about new teaching strategies' effectiveness. Addressing this scepticism requires professional development programs that provide empirical evidence of the effectiveness of neuroeducation principles, thereby fostering trust and acceptance among educators.

## Confidence

Confidence in neuroeducation principles varied among teachers. According to Bandura's Social Cognitive Theory (Bandura, 1977), self-efficacy—the belief in one's ability to succeed—is crucial for effective teaching. Confident teachers are more likely to invest time and effort into implementing new teaching methodologies, which is essential for successful integration. The findings align with Boaler (2016), who asserts that collaborative learning enhances educational outcomes, and Immordino□ Yang & Damasio (2007), who emphasize the significance of socio-emotional factors in learning. Teachers who demonstrated confidence also highlighted the need for policy support, innovative teaching methods, and professional development, suggesting that these factors are critical for effective neuroeducation implementation. Document analysis indicates a notable alignment between neuroeducation principles and strategies embedded in the competence-based curriculum. Active learning, student-centred approaches, and critical thinking are central to both neuroeducation and the curriculum. Freeman et al. (2014) and Prince (2004) emphasise that active learning enhances cognitive development and mathematical understanding. Zhao (2021) and Bransford et al. (2000) further support student-centred approaches as effective for tailoring education to individual competencies. The emphasis on critical thinking aligns with Facione's (2011) definition, highlighting its importance for academic success and personal growth. The study also reveals that while teachers claim to use these strategies, classroom observations indicate a gap between intention and practice, as noted by Davis et al. (2019) and Cuban (2013).

Despite acknowledging the relevance of neuroeducation principles, many teachers struggled with implementation. This challenge is consistent with findings by Howard-Jones (2008) and Wright et al. (2019), who note that effective integration requires adequate teaching resources and training. Also, the link between student emotions, motivation, and learning outcomes is well-established (Fredrickson, 2001; Pekrun et al., 2011), yet practical application remains inconsistent. Addressing these challenges requires targeted professional development, policy support, and access to teaching resources. Darling-Hammond (2020) emphasises that such support is crucial for optimizing educational experiences, and ensuring that neuroeducation principles are effectively integrated into classroom practices.

## Conclusion

This study highlights the transformative potential of neuroeducation when implemented through evidence-based, culturally relevant strategies that align with local realities. The findings underscore the current practices and challenges in mathematics education in Tanzania, particularly in the context of integrating digital technologies. Addressing issues such as resource limitations, enhancing teacher skills through targeted training programs, and promoting experience-sharing among educators are essential steps toward improving classroom practices. The integration of digital technologies within the neuroeducation framework can further enhance conceptual understanding and foster the development of 21st-century skills among students. These strategies provide significant opportunities to elevate the quality and relevance of mathematics education in Tanzania. By pragmatically incorporating neuroeducation principles alongside digital tools, more engaging and effective learning environments can be created, better-preparing students for success in an increasingly technology-driven world.

## Future research directions

Future research on integrating neuroeducation principles within Tanzanian mathematics education should focus on several key areas. Longitudinal studies are crucial to investigating the long-term effects of neuroeducation on student performance and retention, providing valuable insights into the sustainability of these teaching methods. Additionally, quantitative evaluations should assess the effectiveness of neuroeducation strategies through standardized assessments and performance metrics. Comparative studies across different regions will help identify contextual factors influencing the successful integration of these principles.

Exploring effective models for teacher professional development, such as workshops and online courses, is also critical for training educators in neuroeducation. Research should examine how digital tools can enhance active and multisensory learning, gathering insights from students about their experiences to inform more responsive teaching practices. Furthermore, investigating the barriers teachers face in implementing neuroeducation and identifying facilitators for success will provide a clearer picture of the integration process. Finally, examining how neuroeducation principles can be culturally adapted will increase their relevance and effectiveness in local contexts. Addressing these areas will significantly contribute to optimizing science education in Tanzania, ultimately equipping students with essential skills for the modern world.

## References


Abbas, S., Nadeem, M. A., & Majoka, M. I. (2021). The United Nations sustainable development goal-4: a case study of Pakistan. *Pakistan Journal of International Affairs, 4*(4).

Adams, W. C. (2015). Conducting semi□structured interviews. In K. E. Newcomer, H. P. Hatry, & J. S. Wholey (Eds.), *Handbook of Practical Program Evaluation* (4th ed., pp. 492–505). Jossey-Bass.

Alshenqeeti, H. (2014). Interviewing as a data collection method: a critical review. *English Linguistics Research, 3*(1), 39-45

Ansari, D., De Smedt, B., & Grabner, R. H. (2012). Neuroeducation–a critical overview of an emerging field. *Neuroethics, 5*, 105-117.

Aspers, P., & Corte, U. (2019). What is qualitative in qualitative research? *Qualitative Sociology, 42*, 139-160.

Blanche, M. T., Blanche, M. J. T., Durrheim, K., & Painter, D. (2006). *Research in practice: applied methods for the social sciences*. Juta and Company Ltd.

Boaler, J. (2022). *Mathematical mindsets: unleashing students' potential through creative mathematics, inspiring messages and innovative teaching*. John Wiley & Sons.

Carew, T. J., & Magsamen, S. H. (2010). Neuroscience and education: an ideal partnership for producing evidence-based solutions to guide 21st-century learning. *Neuron, 67*(5), 685-688.

Cohen, L., Manion, L., & Morrison, K. (2017). Approaches to qualitative data analysis. In *Research Methods in Education* (pp. 643-656). Routledge.

Creswell, J. W. (2013). *Steps in conducting a scholarly mixed methods study*. SAGE Publications.

Creswell, J. W. (2021). *A concise introduction to mixed methods research*. SAGE publications.

Darling-Hammond, L. (2020). Accountability in teacher education. *Action in Teacher Education, 42*(1), 60-71.

DeJonckheere, M., & Vaughn, L. M. (2019). Semi-structured interviewing in primary care research: a balance of relationship and rigour. *Family Medicine and Community Health, 7*(2).

Dekker, S., Lee, N. C., Howard-Jones, P., & Jolles, J. (2012). Neuromyths in education: Prevalence and predictors of misconceptions among teachers. *Frontiers in Psychology, 3*, 33784.

Dunn, R., Griggs, S. A., Olson, J., Beasley, M., & Gorman, B. S. (1995). A meta-analytic validation of the Dunn and Dunn model of learning-style preferences. *The Journal of Educational Research, 88*(6), 353-362.

Dunn, W. (2007). Supporting children to participate successfully in everyday life by using sensory processing knowledge. *Infants & Young Children, 20*(2), 84-101.

Fischer, A., Sananbenesi, F., Wang, X., Dobbin, M., & Tsai, L.-H. (2007). Recovery of learning and memory is associated with chromatin remodelling. *Nature, 447*(7141), 178-182.

Fisher, D., & Frey, N. (2014). *Checking for understanding: formative assessment techniques for your classroom*. ASCD.

Fullan, M. (2015). *The new meaning of educational change*. Teachers college press.

Godec, S., King, H., Archer, L., Dawson, E., & Seakins, A. (2018). Examining student engagement with science through a Bourdieusian notion of field. *Science & Education, 27*, 501-521.

Hattie, J. (2016). Know thy impact. *On Formative assessment: readings from educational leadership (EL Essentials), 36*.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of educational research, 77*(1), 81-112.

Howard-Jones, P. (2008). Potential educational developments involving neuroscience that may arrive by 2025. *Beyond Current Horizons*, 1-25.

Howard-Jones, P. A. (2014). Neuroscience and education: myths and messages. *Nature Reviews Neuroscience, 15*(12), 817-824.

Immordino□Yang, M. H., & Damasio, A. (2007). We feel, therefore, we learn: the relevance of affective and social neuroscience to education. *Mind, brain, and education, 1*(1), 3-10.

Jensen, E. (2008). *Brain-based learning: The new paradigm of teaching*. Corwin Press.

Kalu, F. A., & Bwalya, J. C. (2017). What makes qualitative research good research? An exploratory analysis of critical elements. *International Journal of Social Science Research, 5*(2), 43-56.

Kestel, E., Drouhard, J.-P., Forgasz, H. J., & Choi, S.-K. (2012). Investigation of a targeted intervention program delivered by personal videoconferencing for primary and middle school students with mathematical learning difficulties. *International Congress on Mathematical Education 2012*.

Kyaruzi, F., Strijbos, J.-W., Ufer, S., & Brown, G. T. (2019). Students' formative assessment perceptions, feedback use and mathematics performance in secondary schools in Tanzania. *Assessment in Education: Principles, Policy & Practice, 26*(3), 278-302.

Mazana, M. Y., Montero, C. S., & Casmir, R. O. (2020). Assessing students' performance in mathematics in Tanzania: the teacher's perspective. *International Electronic Journal of Mathematics Education, 15*(3), em0589.

Pekrun, R., Goetz, T., Frenzel, A. C., Barchfeld, P., & Perry, R. P. (2011). Measuring emotions in students' learning and performance: the achievement emotions questionnaire (AEQ). *Contemporary Educational Psychology, 36*(1), 36-48.

Reeve, J. (2016). Autonomy-supportive teaching: what it is, how to do it. In: *Building Autonomous Learners: Perspectives from Research and Practice Using Self-Determination Theory* (pp. 129-152). Springer.

Stein, Z., & Fischer, K. W. (2011). Directions for mind, brain, and education: methods, models, and morality. *Educational Philosophy and Theory, 43*(1), 56-66.

Taljaard, J. (2016). A review of multi-sensory technologies in a science, technology, engineering, arts and mathematics (STEAM) classroom. *Journal of Learning Design, 9*(2), 46-55.

Thomas, G. (2021). *How to do your case study: a guide for students and researchers* (3rd ed.). SAGE Publications.

Tokuhama-Espinosa, T. (2010). *Mind, brain, and education science: a comprehensive guide to the new brain-based teaching*. WW Norton & Company.

Wang, M. T., & Eccles, J. S. (2012). Social support matters: longitudinal effects of social support on three dimensions of school engagement from middle to high school. *Child development, 83*(3), 877-895.

Wisniewski, B., Zierer, K., & Hattie, J. (2020). The power of feedback revisited: a meta-analysis of educational feedback research. *Frontiers in Psychology, 10*, 487662.

Yates, M. (2022). *Understanding the perceptions of neuroeducation training for lay counsellors in South Africa*. The Chicago School of Professional Psychology.

Yin, R. K. (2009). *Case study research: design and methods* (Vol. 5). SAGE.