Investigating Secondary School Mathematics Teachers' Proficiency with the Use of Jigsaw Collaborative Method in Tanzania

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Abstract

The study was conducted in the Mtwara region of Tanzania to investigate Mathematics teachers› proficiency in using the jigsaw teaching strategy. An exploratory research approach was employed, focusing on six underperforming schools where 10 specialised mathematics teachers were interviewed. Data analysis was conducted using thematic analysis. The findings indicate that many teachers had a limited understanding of the jigsaw method, hindering their effective implementation. Initiatives such as pre-service training, in-service support, and personal efforts were identified as key factors in improving teachers' proficiency with the jigsaw strategy. The study recommends ongoing in-service training and mentorship to enhance teachers› skills in utilising collaborative teaching strategies like the jigsaw method.

Keywords: *jigsaw, teaching strategies, mathematics learning, cooperative learning strategies*

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Introduction

Tanzania, like many other countries in the world, is striving to achieve the 4th sustainable development goal of quality education. This can be accomplished by enhancing mathematical proficiency at various educational stages in Tanzania, which plays a crucial role in realising the country's industrialisation agenda and overall economic development. Unfortunately, Tanzania has long struggled with widespread underachievement in mathematics among secondary school students. This chronic issue is evident through low pass rates in national examinations compared to other subjects, as shown in the data collected from the report of the National Examination Council of Tanzania (NECTA) for five consecutive years.

This data is summarised in Table 1.

Table 1

CSEE Percentage of Pass and Fail Rates in Basic Mathematics (2018 – 2023)

Year	2018	2019	2020	2021	2022	2023	Average
Pass	20.0	20.0	20.0	19.54	20.08	25.42	20.84
Fail	80.0	80.0	80.0	80.46	79.92	74.58	79.16

Source: National Examination Council of Tanzania (NECTA) (2018; 2022; 2023)

Based on the data in Table 1, it is clear that the average percentage of students failing the mathematics national examination from 2018 to 2023 is remarkably high, at 79.16%. This poor performance hinders many students from pursuing careers in science, as proficiency in mathematics is often a requirement for entry into science-related programs at higher education institutions (Mazana et al., 2020). This raises significant concerns about the quality of mathematics education in Tanzania, posing a threat to both future generations and the nation's efforts towards industrialisation and achieving sustainable development goals.

The poor performance in mathematics across all educational levels is attributed to various factors. Mkenda (2022), Kyaruzi (2023), and Francis (2024) pointed to ineffective teaching strategies and students' anxiety, phobia, or negative attitudes toward the subject as key contributors. Moreover, Kinyota (2020) cites the absence of competent teachers and inadequate teaching and learning resources, such as books, as factors leading to high failure rates. Additionally, Kayombo et al. (2022) highlight insufficient teaching aids and a limited number of mathematics teachers in most schools as further factors impacting performance. In contrast, Mazana et al. (2019) suggest that higher failure rates are linked to low levels of teacher motivation, negative teacher attitudes toward students and mathematics, poor instructional strategies, and teachers' weak content knowledge. In this regard, it is worth noting that teachers' competency including understanding relevant teaching strategies have significant contributions towards improved academic performance.

The government recognises the critical importance of providing strong support for mathematics teachers to enhance mathematics teaching and learning. The Ministry of Education, Science, and Technology, in collaboration with other donors, has initiated various programs to enhance the capacity of science teachers to improve learning outcomes. Two key programs include the Science Education in Secondary Schools (SESS) project and the Science Teacher Improvement Project (STIP). The SESS project was implemented in 29 government secondary schools at the Ordinary level in the Coast, Dodoma, and Iringa regions from 1995 to 2003.

The STIP focused on schools under the Christian Social Services Council (CSSC). Additional strategies include the training of more mathematics teachers and the integration of ICT into teacher education and secondary school curricula, since the early 2010s (Kafyulilo et al., 2015).

Despite these efforts, poor performance in mathematics persists. Available studies in Tanzania have generally investigated the effectiveness of a learner-centred approach in teaching mathematics (Mkimbili, 2018; Mbedule, 2020; Kasuga et al., 2022; Mkenda, 2022; Michael, 2015), factors for poor performance from teachers' perspectives (Mazana et al., 2020), barriers to the use of problem-based learning (Kikomelo, 2024), and mathematics teachers' choice of teaching strategies (Mazana et al., 2023). However, none of these studies specifically focused on investigating mathematics teachers'' understanding of the jigsaw strategy in teaching mathematics. The current study is designed to fill this knowledge gap.

Research questions

The study sought to answer the following specific research questions:

i. How do secondary school mathematics teachers conceptualise the jigsaw teaching strategy?

ii. How do secondary school mathematics teachers acquire knowledge about the jigsaw strategy?

Literature Review

Meaningful mathematics learning

Teaching and learning mathematics have been very challenging at almost all education levels due to the diverse learning needs of students. The inability of students to connect the study of mathematics with solving real-life problems creates anxiety among them (Mazana et al., 2019). This has led to persistent failures in mathematics at various education levels in Tanzania and many other countries worldwide. To ensure effective learning, teachers are constantly striving to implement appropriate strategies tailored to the needs and learning styles of young learners. The available literature indicates that meaningful learning of mathematics requires teaching strategies that provide opportunities for hands-on, collaborative, gamified learning, visual representations, and technology integration (Freeman et al., 2014; Rachmah, 2017). By incorporating these innovative strategies into teaching, educators can create dynamic and enriching mathematics learning experiences that foster curiosity, promote deep understanding, and equip students with essential mathematical skills for success.

In Tanzania, the quality of mathematics education plays a crucial role in shaping students› academic performance and future prospects. Unfortunately, studies indicate a consistent pattern of poor performance in mathematics across all levels of education. Data from the National Examinations Council of Tanzania over five years from 2018 to 2022 reveals an average failure rate of 80% in mathematics among secondary school students. Disparities in academic achievement are evident among regions, districts, and schools, with some consistently outperforming others. These performance gaps are often attributed to differences in learning opportunities, among other factors (Mkenda, 2022). Analysis of Certificate of Secondary Education Examination (CSEE) results highlights regions such as Songwe, Singida, Dodoma, Mtwara, and Lindi as consistently underperforming, while regions like Dar es Salaam, Geita, and Iringa demonstrate strong performance.

Poor performance in mathematics is often attributed to various factors such as negative attitudes, lack of motivation, insufficient teachers, and ineffective teaching methods (Mkenda, 2022). The limited competence of teachers to implement Problem-Based Learning pedagogy (Kikomelo, 2024) contributes to the persistent poor performance in mathematics. Attitudinal factors also play a significant role, as students often perceive mathematics as difficult and masculine, which hinders their performance (Kinyota, 2020). Teachers²' diverse views on students› aptitude and the teaching-learning environment also impact their instructional behaviour and, consequently, students' learning outcomes (Mazana et al., 2020).

Despite the multifaceted nature of poor performance in mathematics, the choice of teaching methods significantly influences student engagement, comprehension, and retention of mathematical concepts (Hiebert & Morris, 2012). Traditional lecture-based instruction is known for limiting the acquisition of critical thinking skills (Smith & Wang, 2020). In contrast, collaborative and technology-enhanced strategies promote deeper understanding and improve academic performance (Freeman et al., 2014; Rachmah, 2017). However, literature shows that mathematics teachers tend to choose the traditional lecture method in favour of content coverage and time-saving, thereby limiting students' learning (Mazana et al., 2023).

A thorough analysis of the existing literature reveals a significant gap in the research on the subject at hand. For example, Mollel et al. (2022) explored the impact of a collaborative learning approach, particularly computer-supported collaborative learning, on students' understanding of mathematics. Similarly, Kasuga et al. (2022) investigated the effects of a problem-based learning approach on students' motivation in biology education in Tanzanian secondary schools. Furthermore, Michael (2023) studied the outcomes of using a participatory method on students' learning in mathematics and biology in Tanzania. Mbedule

(2020) examined the influence of teaching methods on the academic performance of secondary school students in basic mathematics in Dar es Salaam, Tanzania. Additionally, Mkimbili (2018) looked into learner-centred teaching in community secondary schools throughout Tanzania. While these studies made valuable contributions to the field, they did not specifically address mathematics teachers' understanding of the jigsaw method, which could potentially enhance its effective use and improve mathematics learning and performance among secondary school students. Therefore, reconsidering teachers'' choices of teaching strategies could have a positive impact on mathematics learning outcomes.

Jigsaw teaching strategy and mathematics learning

The literature demonstrates that optimal performance in mathematics can be attained through the implementation of cooperative learning methods (Freeman et al., 2014; Rachmah, 2017). Among the array of cooperative learning techniques available, notable examples include student teams-achievement division, team games-tournament, think-pair-share, Round Robot Brainstorming, Reciprocal Teaching, and the jigsaw method (Dhull & Verma, 2019). There are various methods within a cooperative approach including learner-centred, problem-based learning, and inquiry-based learning. These approaches position every student as an engaged and self-reliant learner, fostering a sense of accountability for their academic progress. However, among the various cooperative learning strategies, available studies have shown that the jigsaw method stands out as particularly impactful on students' learning outcomes compared to others (Rachmah, 2017; Ojekwu & Ogunleye, 2020).

The jigsaw strategy is a cooperative learning strategy that involves breaking a class into small groups, with each group becoming an expert in a specific topic or concept and then sharing their knowledge with the rest of the class (Aronson & Patnoe, 2011). The core components of the strategy, such as the initial formation of expert clusters followed by the reshuffling into mixed-expertise teams, are well known for capturing learners' diversity in learning mathematics. According to Bayraktar (2021), the effectiveness of the jigsaw strategy depends much on adherence to several principles, including having "home groups" of 3-5 students who reflect a range of abilities, determining essential topics or areas for discussion, creating "expert groups" that consist of students across "home groups" who will read the same selection and provide key questions and resources necessary for all students to learn about their topics to become "experts". However, other principles, like monitoring the discussion and guiding the proper way for knowledge sharing, which often guides normal group discussions, remain constant.

Figure 1 provides a framework for understanding how the jigsaw teaching strategy can be used in actual classrooms. Step 1 represents the home groups, which may have students ranging from 3-5 of diverse learning abilities, then step 2 shows the expert groups, which are composed of one member from each home group. However, the actual implementation and effectiveness of the method depend on various factors such as student engagement, the nature of the topics being covered, teacher facilitation, and resource availability.

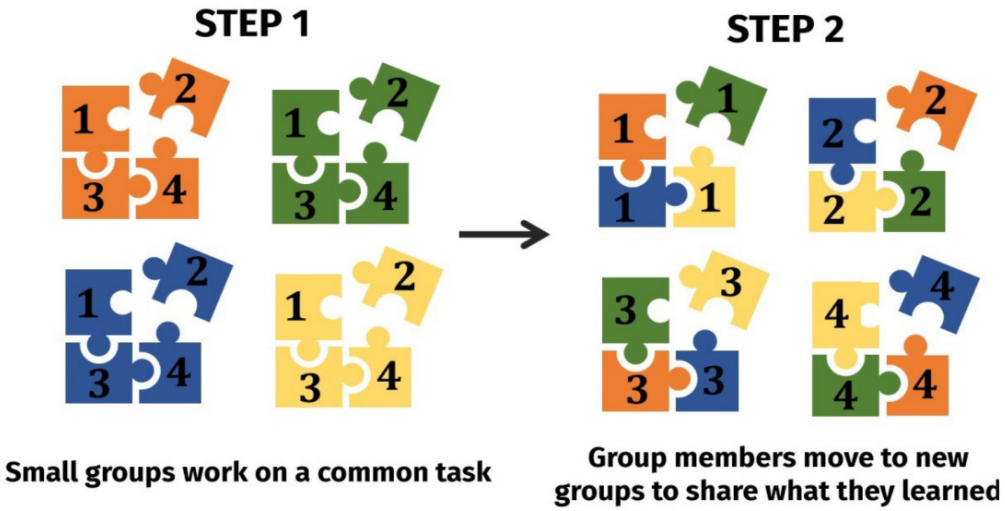

Figure 1: *A framework for the use of jigsaw strategy in teaching*

Source: Bayraktar (2021)

Here is an example of how the jigsaw method could be applied to teach a Form Two class of 16 students about simultaneous equations using four different methods. The students will learn how to solve simultaneous equations through substitution, elimination, graphical, and matrix methods. The teacher will divide the students into four groups, each consisting of four-members. Each group will be given the same set of simultaneous equations to solve using one of the mentioned methods. After solving the equations, the groups will be reshuffled into expert groups, with each group containing one member from the original groups (A, B, C, D). Each expert will then teach their method to the other members, ensuring that everyone gains knowledge of all four methods of solving simultaneous equations. The jigsaw strategy has been regarded as a powerful tool in helping students grasp challenging concepts in mathematics and other subjects (Costouros, 2020). Research shows that using the jigsaw method can improve students' achievement, motivation, social relations, and academic self-esteem (Drouet et al., 2022). Ural et al. (2017) also found that the jigsaw method can enhance students' motivation to learn.

Berger and Hänze (2015) demonstrated that the jigsaw method can significantly impact the quality of teaching and intrinsic motivation to learn-in the field of physics. They found that the jigsaw method helps learners grasp complex content more easily compared to other strategies. Furthermore, Blajvaz et al. (2022) reported a significant improvement in students' physics achievement, metacognitive awareness, and motivation after implementing the Jigsaw technique. This suggests that integrating the jigsaw method into daily school practices at the lower secondary level could be highly beneficial for education. Studies indicate a favourable influence of the jigsaw method on students' social relations (Oakes et al., 2019; Costouros, 2020). Similarly, Theobald et al. (2017) observed that effective implementation of the jigsaw method resulted in enhanced interpersonal attitudes and empathy among students. Additionally, Mohamadlou et al. (2021) reported a significant influence of the jigsaw method on students' sense of social skills and their connectedness to school.

The jigsaw strategy in mathematics has been shown to enhance self-esteem and academic achievement. A study by Berger and Hänze (2009) in secondary schools found that students with lower academic self-concepts felt more competent with the jigsaw method compared to traditional instruction. Direct engagement in group activities allows students to freely exchange ideas (Drouet et al., 2023) learning communities and collaborative groups in the classroom (Mbacho, 2013). The jigsaw approach promotes creativity and critical thinking, leading to improved academic performance (Aprili & Amelia, 2022; Turgut & Turgut, 2018). Mbacho (2013) observed significant improvements in students' math scores after teachers'' were trained in the jigsaw method. However, the benefits of the jigsaw strategy can be influenced by factors such as teachers' readiness, availability of resources, classroom conditions, content complexity, and students' educational levels (Smith & Wang, 2020; Inan & Dogan, 2016; Wei et al., 2023). Teachers' positive attitudes towards cooperative teaching strategies may be hindered by limited knowledge, affecting effective implementation (Gillies & Boyle, 2010). Ineffective implementation can have negative effects, especially for students with lower abilities. Group composition is crucial, as students of varied abilities can support each other. O'Leary et al. (2019) noted that students with low abilities may feel isolated and confused when using the jigsaw method. Studies have also shown negative effects on social self-esteem (Roseth et al., 2019) and insignificant impacts on intrinsic motivation (Costouros, 2020).

Based on these diverse findings, it can be argued that a significant portion of the surveyed studies indicates the effectiveness of the jigsaw method in enhancing students' social relations and fostering connections not only among peers but also within the broader school community. Nevertheless, careful consideration is

warranted regarding challenges related to students' ability to effectively engage with others when utilizing the jigsaw method, ensuring that all students have equitable opportunities to grow socially and academically.

Methodology

Study approach and design

The study utilised a qualitative research approach with a case study design to explore mathematics teachers› comprehension of the jigsaw method in teaching and learning mathematics. This approach was deemed valuable as it considers teachers' real-life experiences to establish a profound understanding of their proficiency in using the jigsaw strategy effectively in mathematics education. Specifically, the study employed a case study design, focusing on individual mathematics teachers and the schools where they work. The research investigated their proficiency in utilising the jigsaw collaborative method and how they acquired this proficiency. By treating individual teachers and their schools as cases, the study captured the complex nature of teachers' proficiency in using the jigsaw method. This approach ensured a comprehensive understanding of teachers' proficiency in the jigsaw strategy and how they acquired the necessary skills to enhance mathematics performance in Tanzania.

Participants and sampling procedures

The study utilised a purposive sampling technique to select six secondary schools within Mtwara municipality based on their performance in national secondary education examinations. Consequently, the poorly performing schools were sampled. All mathematics teachers from the selected schools were purposively included in the study. Ethical standards were adhered to by obtaining a permit letter from the Vice Chancellor to connect with the regional administrative office in Mtwara and the selected school management. Pseudonyms were used for schools and participants to maintain confidentiality. Participants are identified by their school and a corresponding number in the findings. As such, information on the socio-demographic characteristics of the participants, including sex, level of education, and teaching experience was captured. In total 10 mathematics teachers were engaged in the study. The majority of participants were males (8) while only two (2) were females, highlighting the prevailing gender bias towards mathematics. Furthermore, seven (7) teachers held bachelor's degrees, whereas only three (3) had a Diploma in education. The teachers also had varying years of experience in teaching mathematics, with the highest experience falling within the 13-15 years range, represented by a single teacher. The majority of teachers (3 each) had

experience in the 4-6 – and 7-9-years range. In addition, two (2) teachers had taught mathematics for 1-3 years, and only one teacher had experience in the 10-12 years range.

Data collection methods

The study primarily utilised semi-structured interviews to gather data from mathematics teachers. A set of questions was designed to probe teachers' understanding of the jigsaw strategy in teaching mathematics. In total, 10 face-to-face interview sessions were conducted, one with each mathematics teacher. These interviews took place within the school premises during regular working hours. Each session lasted between 20 to 30 minutes, allowing for a comprehensive exploration of the topic. Here are some of the questions asked during interviews: have you ever heard about the jigsaw collaborative teaching strategy? And please, can you explain what you know about the jigsaw collaborative teaching strategy?

Data analysis process

The researcher utilised a thematic analysis technique involving inductive-deductive coding to analyse the data. The process was conducted manually by reading the transcripts multiple times to become familiar with and understand the emerging themes from the data. Initially, the process resulted in 12 codes, as shown in Table 3, which were then analysed deductively based on the existing categories of understanding. According to Braun and Clarke (2006), the inductively identified codes must be interpreted and assigned to deductively developed themes. Therefore, related codes with their respective voices were grouped to inform each pre-established theme, as presented in the study findings. Table 2 displays the themes generated along with their corresponding codes observed from the data.

Table 2

Criteria for Data Analysis and Themes Development

Themes	Codes	No. participants
1. Good understanding of the jigsaw	▪ Teachers never heard about it. ▪ Teachers clearly illustrate a step-by-step implementation of the Jigsaw strategy. ▪ Teachers clearly describe the advantages and disadvantages of the Jigsaw strategy. ▪ Teachers have employed it in teaching but not regularly.	3

Themes	Codes	No. participants
2. Partial Understanding of the jigsaw	▪ Teachers are aware of the jigsaw strategy. ▪ Teachers fail to articulate the basic principles guiding the strategy such as the role of different group dynamics and interdependence. ▪ Teachers have misconceptions about the strategy confusing it with other collaborative approaches. ▪ Teachers try to describe but confuse the steps for the implementation of the Jigsaw strategy. ▪ Lack of confidence to employ the strategy in teaching mathematics.	5
3. Lack of understanding of the jigsaw	▪ Teachers never heard about the strategy ▪ Teachers knew nothing about the strategy ▪ Teachers never thought of employing the strategy in teaching.	2

Findings and Discussion

This section presents the findings based on the established research questions. The research questions focus on teachers' comprehension of the jigsaw cooperative learning strategy and how they gained this knowledge. The premise was that teachers' grasp of the jigsaw strategy in teaching mathematics has implications for its implementation and, ultimately, students' comprehension of mathematical concepts and enhanced student academic performance.

Mathematics teachers' understanding of the jigsaw teaching strategy

This section discusses mathematics teachers' comprehension of the jigsaw cooperative teaching strategy in mathematics instruction. Understanding the strategy is crucial as it determines whether teachers can effectively utilize it to maximize its benefits for mathematics learning. An analysis of interview data revealed three themes regarding teachers' understanding of the jigsaw strategy: a majority (5) had limited understanding, some (3) had a good understanding, and a minority (2) did not understand anything. The findings are presented below along with relevant quotes.

Good understanding of the jigsaw method

The study findings highlight that only three (3) participants demonstrated a thorough understanding of the jigsaw strategy. This particular group of participants confidently articulated a step-by-step implementation of the strategy without hesitation. The following quotes substantiate the argument:

> The method is being done in steps. First, you need to have tasks on a certain topic, say some questions; For example, Mathematics

> questions which need to be solved by different methods. Then you create home groups by asking students to count numbers say one up to three. Thereafter, members from the home group are asked to create an expert group in which they are asked to employ one of the methods to solve the same questions. Every member of the expert is required to understand and become an expert in that method. Then the members from the expert group are asked to go back to the home group and teach the rest members of the home group what they learned. The tasks are displayed around the classroom for others to view and learn more (MT1, School E).

Another participant had this to say concerning the jigsaw method:

> In jigsaw, two groups are created, first the home and the second the expert group. You may have several questions and each of these questions will be solved in the expert group. Then members of the expert group joined back to the home group with their expertise and shared with their fellows. Thereafter they can share with the rest of the classroom members (MT 2, School E).

The findings show that some mathematics teachers possess a good understanding of implementing the jigsaw method, highlighting several key impressions. Mathematics teachers who demonstrate proficiency in implementing the jigsaw method likely exhibit strong planning skills. Teachers with a thorough understanding can effectively organise content into manageable segments and select appropriate materials to facilitate student learning. Hobson et al. (2009) suggest that the level of teachers' pedagogical knowledge is an important determinant of quality teaching in the classroom. Teachers with a good understanding of the jigsaw collaborative strategy are adept at guiding student discussions and fostering productive group interactions during jigsaw activities. Their facilitation skills enable them to address misconceptions, clarify complex concepts, and maintain a supportive learning environment. A good understanding of the jigsaw collaborative teaching strategy can also lead to its effective implementation, promoting collaboration and active engagement among students while fostering a sense of ownership for their learning.

Literature shows that, teachers who understand the jigsaw strategy can easily design and facilitate collaborative learning experiences that promote student engagement and achievement in mathematics (Drouet et al., 2023). The benefits of teachers' understanding in realising the benefits of collaborative strategies were also evident in Turgut and Turgut's (2018) study, which reported that competent teachers in collaborative techniques managed to help students develop interpersonal

and intrapersonal intelligence to have productive groups, thus having a significant impact on students' mathematics achievement in Turkey. It is difficult to experience the benefits of the jigsaw collaborative strategy on students' attitudes towards learning mathematics, academic achievement, and acquisition of collaborative skills if teachers are not proficient. Teachers with a good understanding of the jigsaw collaborative strategy can easily enhance mutual respect, cooperation, and support among students, which in turn will yield positive results in academic performance. Theobald et al. (2017) suggest that teachers' expertise in effectively structuring and managing group processes could enhance jigsaw collaborative groups, increase learning, cultivate positive attitudes toward science, and enhance social identity as a scientist in classrooms. Therefore, teachers with a good understanding of a jigsaw collaborative strategy hold promise for a bright future in mathematics learning and students' academic performance.

Partial understanding of the jigsaw strategy

The interview data shows that many interviewed mathematics teachers (5) demonstrated a limited understanding of the jigsaw teaching strategy. This was reflected in their responses, which showed awareness of the jigsaw strategy but a deficiency in understanding what it is and how it could be used in the teaching and learning process. Participants in this category admitted having heard about the method but had little understanding, which affected their confidence in using it in teaching. This is noted in the following quotes:

> I once heard this strategy, mh! I don't even remember at what occasion but the thing is I don't know what it entails and how it is used (MT1, School B).

> Ooh! I remember, by then when taking a diploma in education, mmh! We were exposed to many teaching strategies including jigsaw but for sure I did not understand it and since then I have never heard again about it. So, I cannot say what exactly it means (MT1, School C).

Similarly, another participant confirmed that she once heard about the strategy a long time ago. However, by then she thought it was meant for classes with few students. Therefore, she does not even remember what the strategy is all about. Here is her quote;

> …Well! About the Jigsaw method, I heard about it a long time ago. Based on what I heard is a good method of teaching mathematics however, I found it suitable for a few students thus I didn't bother

> understanding it as I am working with a large number of students (MT 2, School A).

She further added "*To be honest I don't know what is it and how to employ it because I don't normally use the method in my teaching of Mathematics* (MT 2, School A).

However, there were some participants (3) who went beyond mere awareness by demonstrating a limited understanding of the strategy. This group of participants indicated that they were familiar with the method and offered some explanation of what it is and how it could be used in teaching mathematics. However, their step-by-step explanations of the method lacked clarity, as seen in the following quotes.

> When conducting a jigsaw, several steps need to be followed. If I remember well first, you form some groups in the classroom during the questions. Then you give them different questions to solve in their groups. Thereafter, one member from each group is asked to solve the question in front of the others (MT1, School D).Top of Form

Other participants added

> From what I know the use of the jigsaw method, first of all, requires a teacher to divide the students into expert groups where you give them questions to be solved. It can be three, four or five questions. Then you ask them to solve the questions. From there, you create what we call home groups from which students from expert groups will go and share their solutions with each of the home groups created (MT 2, School B).

> In my understanding, the Jigsaw method is not that much different to group discussion as it is done by creating groups of a few students and giving them questions or some mathematical problems, then each group is assigned a leader who will then present in front of others what they have discussed (MT 2, School D).

The quotes suggest that most teachers are aware of the jigsaw teaching strategy, but lack a comprehensive understanding of its implementation, potential uses, and benefits in teaching mathematics. This lack of understanding may hinder their readiness to utilise the strategy effectively to enhance students' understanding of mathematics. Consequently, teachers may continue to rely on traditional teacher-centred approaches, leading to persistent poor performance in mathematics. This aligns with the findings of Gillies and Boyle (2010), who highlighted the challenges associated with implementing collaborative teaching approaches due to insufficient knowledge. Teachers with incomplete knowledge may struggle to design

and structure jigsaw activities that align with the specific learning objectives and content standards of the mathematics curriculum. Without a thorough understanding of how to adapt the method to suit mathematical concepts and skills, teachers may implement the strategy superficially or in a disjointed manner, diminishing its effectiveness as a pedagogical tool.

Similarly, O'Leary et al. (2019) found that teachers with limited knowledge of the jigsaw strategy may ineffectively implement it, leading to students feeling isolated, confused, and struggling to navigate assigned tasks. This ineffective implementation can result in superficial learning, missed opportunities for meaningful interaction, and limited conceptual understanding of mathematical concepts. As a result, students may not develop the necessary skills associated with collaborative strategies like jigsaw, contributing to persistent academic struggles. The findings also support Mkenda's (2022) assertion that the use of ineffective teaching methods can lead to ongoing poor performance. Therefore, the mathematics teachers' limited understanding of the jigsaw strategy can have a detrimental impact on student learning outcomes, affecting both individual students and broader national and international goals related to mathematics achievement.

Lack of understanding of the jigsaw

The findings also revealed that two participants were completely unfamiliar with the jigsaw collaborative teaching strategy. These individuals had more than 10 years of teaching experience. Participants in this category confirmed that they had never encountered the method before and were not aware of its practice. Here are the quotes to support the argument; "uuuh! Jigsaw. (*silent*)…. you said a teaching strategy? *I don't think to have ever heard about it. Honestly, I know nothing about it*. (MT1, School F).

Similarly, a teacher from school A had this to share which reflects a lack of understanding of the jigsaw collaborative teaching strategy;

> mmh! Jigsaw aaah! A teaching strategy? I remember learning different teaching strategies during my teacher education programme like lectures, discussions, projects, problem solving etc but this was not among them, so frankly speaking I don't think I can tell what is it (MT1, School A).

Research studies have consistently shown that the jigsaw cooperative strategy is more beneficial than other learner-centred strategies (Aprili & Amelia, 2022; Mohamadlou et al., 2021; Theobald et al., 2017). The absence of mathematics teachers who are knowledgeable about this strategy may have led them to use

ineffective teaching methods, resulting in persistently poor performance. Hiebert and Morris (2012) suggest that the failure to select and implement relevant and effective strategies for mathematics learning can impact students' understanding and ultimately lead to poor performance. Therefore, the poor performance in mathematics in the sampled schools can be partly attributed to the lack of understanding of the jigsaw strategy among mathematics teachers.

The findings indicate that many mathematics teachers do not have a thorough understanding of the jigsaw method. Teachers who lack comprehension of the jigsaw method may encounter challenges in effectively implementing it in their classrooms. This could result in activities that are disjointed or poorly structured, reducing the potential benefits of cooperative learning for students. Cooperative learning strategies like the jigsaw method aim to promote the development of crucial skills such as communication, teamwork, and problem-solving. Mbacho (2013) argues that by employing the jigsaw approach, learning communities and collaborative groups can be nurtured within the classroom, creating a more conducive environment for students to grasp mathematical concepts. In addition, Smith and Wang (2020) put forward that teachers' limited understanding of teaching strategies including jigsaw that can suit students' intellectual levels and enhance the understanding of the subject has enormously contributed to underachievement in mathematics examinations. Thus, when teachers lack understanding of how to leverage these methods, students may not have the opportunity to fully develop these skills, impacting their overall academic growth and preparedness for future challenges.

Sources of jigsaw understanding among mathematics teachers

The researchers were also curious to know how individuals with a good and partial understanding of the method learned about the jigsaw strategy. This information is valuable as it can guide future efforts to ensure that all mathematics teachers are familiar with collaborative strategies, including the jigsaw method. Participants shared various sources of their understanding, with some having multiple sources contributing to their knowledge. Here are the sources of jigsaw understanding among mathematics teachers:

Pre-service training

Analysis of the interviews shows that five (5) out of eight participants with a good and partial understanding of the jigsaw strategy confirm to have learned it during their pre-service teacher training. The following quotes explain:

> During my teacher education programme, I was taught about it,

> then I got to know it better as one of my tutors who was teaching Physics used it frequently. He used to keep us in groups with diverse tasks (MT2, School B).

> I remember when I was taking my degree in education our methodology teacher mentioned the jigsaw as one of the leaner-centred strategies The problem is he did not get into the details of how the method is being implemented (MT1, School D).

In-service training

On the other hand, a total of five participants also mentioned that they had heard about the jigsaw method during their in-service training. Two types of in-service training were confirmed by teachers to have exposed them to the jigsaw strategy: one was out-of-school training, and the other was in-school training or mentorship. Those who had the opportunity for out-of-school training mentioned that jigsaw was one of the topics covered during a training session organised for science teachers within the district with the aim of building capacity to teach science subjects and improve performance. Here are the quotes to support this argument:

> I once attended a seminar that was organised by one of the NGOs. The seminar was for all science subject teachers. During that seminar, we were taught about how to employ learner-centred strategies including the jigsaw method and the gallery work (MT2, School E).

Another participant added,

> I got to know about the jigsaw method during the seminar that was organised by the municipal council. The seminar was organised for capacity building among mathematics and physics teachers During that seminar among other issues we were exposed to different potential teaching strategies including jigsaw that can enhance learning (MT2, School D).

In addition to that, two participants confirm to have gained an understanding of the jigsaw collaborative method through school-based in-service training. For instance, during a visit to one of the schools, a teacher mentioned that they regularly engage in discussions with their colleagues about effective methods for teaching mathematics and other science subjects. This is exemplified by the following quote:

> We have created our own culture here in our school. Every Friday because it is a short working day we spare like an hour and have to assess what we have done during the week and explore some

> challenges we encountered and how to mitigate them. It was during one of the meetings that one teacher shared about the use of jigsaw and how it worked in her lessons, I was interested and keen to understand it better (MT1, School B).

Self-study

The research findings show that two out of eight participants are self-motivated to grow professionally resulting in understanding the jigsaw method. One participant expressed that he was very disappointed seeing a persistent poor performance in mathematics for almost three years consistently so he had to find how to address the problem. The specific teacher had this to share:

> After being employed I noticed poor performance in mathematics at my school, this was a great disappointment and I was curious to know why and how I could change the situation. I started reading and updating myself on issues relating to the proper teaching of mathematics and one day I visited a certain website which had issues related to the effective use of jigsaw for better learning, it showed step-by-step how to implement the jigsaw method (MT1, School E).

The other participant shared that she once found a fellow mathematics teacher teaching using an interesting strategy. She was attracted and interested in the way the students were busy engaging in the lesson. Therefore, she was curious to know the method and asked a colleague to help her understand it. Here is the quote to substantiate the argument;

> I had no idea about the Jigsaw method until one day when I was just passing outside the class where my colleague was teaching and found him teaching using a very interesting strategy with high student engagement in the lesson. Then I asked my fellow teacher about the strategy and how I could utilise it in classrooms… (MT1, School C).

It is evident from the findings that teachers' understanding of the jigsaw collaborative teaching strategy is directly linked to what they learn during pre-service teacher training, in-service training, and self-study. Pre-service teacher education serves as the foundation for teachers' classroom practices. However, the knowledge gained during pre-service teacher education may not be effective in a changing world without continuous in-service training and personal efforts. Therefore, there is a significant need for teachers to update their knowledge of teaching strategies through in-service training and personal initiatives. Collaboration among educators, such as

through lesson study, co-teaching, and professional learning communities, enables teachers to share best practices, reflect on teaching experiences, and address common challenges (Abbas, 2024). School-based in-service training offers opportunities for peer learning and professional growth. Workshops for mathematics teachers can enhance understanding of the jigsaw strategy, leading to improved student performance. Due to financial constraints, the focus is on organising school-based in-service seminars rather than larger training programs, allowing experts to share experiences, discuss problems, and collaborate on solutions.

In a study in India, Grover (2023) found that in-service training significantly improved teachers' professional capacities, competencies, and teaching skills, leading to better student academic performance. However, Hobson et al. (2009) warned that school-based mentoring may not always be effective for new teachers, as some mentors may promote outdated teaching methods. It is important to balance out-of-school training with school-based and individual efforts for optimal learning outcomes. Teachers who are motivated to improve their teaching practices can engage in self-directed learning, such as exploring new teaching strategies like the jigsaw method. This intrinsic motivation to grow professionally is linked to better decision-making, career exploration, and goal-setting. By actively seeking opportunities to enhance their skills, teachers contribute to a culture of continuous improvement and ultimately improve students' mathematics performance in their schools and districts.

Conclusion and Recommendations

In conclusion, the study reveals a significant disparity in mathematics education with many teachers lacking a strong grasp of the jigsaw method. This highlights the urgent need for targeted interventions and support to enhance teachers' cooperative learning skills. The implications are profound, as students may miss out on collaborative learning opportunities and a deep understanding of mathematics concepts. Misconceptions may persist, and achievement gaps could widen without the effective use of cooperation. The study shows the importance of various initiatives, such as pre-service training, in-service support, and personal efforts, in improving teaching proficiency with jigsaw strategy and student performance in mathematics.

To address this issue effectively, school management, educational leaders at ward and district levels, and the Ministry of Education Science and Technology should provide regular in-service training for mathematics teachers on collaborative teaching methods, focusing on the jigsaw technique. This training will enhance teachers' skills and confidence in using collaborative approaches, leading to increased motivation for both teachers and students in mathematics instruction.

Mathematics teachers can also engage in peer collaboration activities like lesson study groups and collaborative planning sessions to share ideas, and best practices, and receive feedback on implementing the jigsaw method. Additionally, the teachers' continuous professional development (TCPD) programmes can be enhanced to support teachers in fostering a culture of reflection and improvement through an online learning management system. This will enable teachers to collaboratively address challenges, explore new teaching approaches, and continuously update their knowledge. On the other hand, further research is needed to explore the implementation and impact of the jigsaw strategy on mathematics performance and also assess students' collaborative skills for effective use of the jigsaw method in Tanzania.

References

Abbas, A. (2024). *Enhancing teacher education: strategies for effective instruction and professional development*. University of South Alabama.

Al Mutawah, M. A. (2015). The influence of mathematics anxiety in middle and high school students' math achievement. *International Education Studies, 8*(11), 239–252.

Aprili, B., & Amelia, C. (2022). The effect of jigsaw-type cooperative learning strategy to improve students' critical thinking patterns. *Journal of Elementary School Education, 27–32*. https://journal.berpusi.co.id/index.php/joese/article/view/12.

Aronson, E., & Patnoe, S. (2011). *Cooperation in the classroom: the Jigsaw method*. Pinter & Martin.

Bayraktar, B. (2021). *Tip: using a jigsaw activity: a cooperative learning activity with roots in anti-racist and inclusive pedagogy*. Retrieved December 13, 2024, from https://higheredpraxis.substack.com/p/tip-using-a-jigsaw-activity.

Berger, R., & Hänze, M. (2009). Comparison of two small-group learning methods in 12th-grade physics classes focusing on intrinsic motivation and academic performance. *International Journal of Science Education, 31*, 1511–1527. https://doi.org/10.1080/09500690802116289.

Berger, R., & Hänze, M. (2015). Impact of expert teaching quality on novice academic performance in the jigsaw cooperative learning method. *International Journal of Science Education, 37*, 294–320. https://doi.org/10.1080/09500693.2014.985757.

Blajvaz, B. K., Bogdanović, I. Z., Jovanović, T. S., Stanisavljević, J. D., & Pavkov-Hrvojević, M. V. (2022). The jigsaw technique in lower secondary physics education: students' achievement, metacognition, and motivation. *Journal of Baltic Science Education, 21*(4), 545–557. https://www.ceeol.com/search/article-detail?id=1061075.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101.

Costouros, T. (2020). Jigsaw cooperative learning versus traditional lectures: Impact on student grades and learning experience. *Teach. Learn. Inquiry, 8*, 154–172. https://doi.org/10.20343/teachlearninqu.8.1.11.

Dhull, P., & Verma, G. (2019). Jigsaw teaching technique for teaching science. *IJRAR, 6*(2), 809–815.

Drouet, C. O., Lentillon-Kaestner, V., & Margas, N. (2023). Effects of the jigsaw method on student educational outcomes: systematic review and meta-analyses. *Frontiers in Psychology, 14*, 1216437. https://doi.org/10.3389/fpsyg.2023.1216437

Francis, J. S. (2024). Anxiety's impact on mathematics ability in Tanzanian secondary school students: a Singida district case study. *Valley International Journal Digital Library*, 457–466.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences of the United States of America, 111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111.

Gillies, R. M., & Boyle, M. (2010). Teachers' reflections on cooperative learning: Issues of implementation. *Teaching and Teacher Education, 26*(4), 933–940. https://doi.org/10.1016/j.tate.2009.10.034.

Grover, N. (2023). Relevance of in-service teacher training programmes in the present scenario. *International Journal of Humanities and Social Science Invention, 12*(4), 1–5.

Hiebert, J., & Morris, A. (2012). Teaching, rather than teachers, as a path toward improving classroom instruction. *Journal of Teacher Education, 63*(2), 92–102. https://doi.org/10.1177/0022487111433636.

Hobson, A. J., et al. (2009). Mentoring beginning teachers: what we know and what we don't. *Teaching and Teacher Education, 25*(1), 207–216. https://doi.org/10.1016/j.tate.2008.09.001.

Inan, C., & Dogan, Y. (2016). Professional development of mathematics teachers: how do teachers learn to integrate technology into their teaching? *Journal of Mathematics Teacher Education, 19*(2-3), 171–197. https://doi.org/10.1007/s10857-015-9316-7.

Kafyulilo, A., Fisser, P., Pieters, J., & Voogt, J. (2015). ICT use in science and mathematics teacher education in Tanzania: developing technological pedagogical content knowledge. *Australasian Journal of Educational Technology, 31*(4). https://doi.org/10.14742/ajet.1240

Kasuga, W., Maro, W., & Pangani, I. (2022). Effect of problem-based learning approach on developing students' science process skills on the topic of safety in our environment. *Journal of Turkish Science Education, 19*(3). https://www.tused.org/index.php/tused/article/view/1315

Kayombo, A., Salema, V., & Chidyau, A. (2022). Extensiveness of e-learning platform in secondary schools towards improving science and mathematics performance in Moshi District, Tanzania. *British Journal of Education, 10*(13), 119. https://d1wqtxts1xzle7.cloudfront.net/95580025/Extensiveness-of-E-Learning-Platform-libre.pdf?1670779842

Kikomelo, S. (2024). Exploring barriers to the implementation of problem-based learning pedagogy in ordinary secondary school mathematics in Tanzania. *The Accountancy and Business Review, 16*(2), 148–165.

Kinyota, M. (2020). The status of and challenges facing secondary science teaching in Tanzania: a focus on inquiry-based science teaching and the nature of science. *International Journal of Science Education, 42*(13), 2126–2144. https://doi.org/10.1080/09500693.2020.1813348

Kyaruzi, F. (2023). Impact of gender on sources of students' self-efficacy in mathematics in Tanzanian secondary schools. *International Journal of School & Educational Psychology, 11*(1), 72–85. https://doi.org/10.1080/21683603.2021.1945512

Mazana, M. Y., Montero, C. S., & Njotto, L. L. (2023). Exploring mathematics teaching approaches in Tanzanian higher education institutions: Lecturers' perspectives. *International Journal of Research in Undergraduate Mathematics Education, 9*, 269–294.

Mazana, Y. M., Montero, C., & Casmir, R. C. (2019). Investigating students' attitude towards learning mathematics. *University of Eastern Finland Repository*. https://erepo.uef.fi/handle/123456789/7398.

Mazana, Y. M., Montero, C., & Casmir, R. C. (2020). Assessing students' performance in mathematics in Tanzania: the teacher's perspective. *International Electronic Journal of Mathematics Education, 15*(3), 1306–1330.

Mbacho, N. W. (2013). Effects of jigsaw cooperative learning strategy on students' achievement in secondary school mathematics in Laikipia East District, Kenya (Doctoral dissertation, Egerton University). http://41.89.96.81:8080/xmlui/handle/123456789/1157.

Mbedule, N. L. (2020). The influence of teaching methods on students' academic performance in secondary school basic mathematics, Dar es Salaam, Tanzania (Doctoral dissertation, The Open University of Tanzania). http://repository.out.ac.tz/3136/.

Michael, M. (2023). Effects of participatory teaching methods on students' learning of mathematics and biology subjects in Tanzania. *Asian Journal of Education and Social Studies, 49*(4), 306–316. https://doi.org/10.9734/ajess/2023/v49i41209.

Mkenda, T. B. (2022). Effective classroom practices for unlocking students' potential in mathematics. https://doi.org/10.21203/rs.3.rs-1536613/v2.

Mkimbili, S. T. (2018). Learner-centred science teaching in community secondary schools in Tanzania. *University Repository*. http://urn.nb.no/URN:NBN:no-62939.

Mohamadlou, A., Mohamadlou, M., & Morovati, Z. (2021). Effect of the jigsaw-based cooperative learning method on a sense of connectedness with school and social skills in sixth-grade elementary students. *Iranian Evolutionary Educational Psychology Journal, 3*(4), 564–573. http://dx.doi.org/10.52547/ieepj.3.4.564.

Mollel, A. D., Minani, E., Munezero, V., & Ngayinteranya, J. (2022). Computer-supported collaborative learning and students' electricity concepts: a case of secondary schools in Arusha, Tanzania. *East African Journal of Education and Social Sciences (EAJESS), 3*(2), 139–145. https://www.ajol.info/index.php/eajess/article/view/225257.

O'Leary, N., Barber, A., & Keane, H. (2019). Physical education undergraduate students' perceptions of their learning using the jigsaw learning method. *European Physical Education Review, 25*, 713–730. https://doi.org/10.1177/1356336X1876730.

Oakes, D. J., Hegedus, E. M., Ollerenshaw, S. L., Drury, H., & Ritchie, H. E. (2019). Using the jigsaw method to teach abdominal anatomy. *Anatomical Sciences Education, 12*, 272–283. https://doi.org/10.1002/ase.1802.

Ojekwu, I. N., & Ogunleye, B. O. (2020). Effects of jigsaw learning strategy on science students' performance and interest in biology in selected schools in Rivers State, Nigeria. *Sapientia Foundation Journal of Education, Sciences and Gender Studies, 2*(3). https://www.sfjesgs.com/index.php/SFJESGS/article/view/80.

Rachmah, D. N. (2017). Effects of jigsaw learning method on students' self-efficacy and motivation to learn. *Journal of Educational, Health and Community Psychology, 6*(3), 1–9. https://smartlib.umri.ac.id/assets/uploads/files/836c7-8314-18725-1-sm.pdf.

Roseth, C. J., Lee, Y. K., & Saltarelli, W. A. (2019). Reconsidering jigsaw social psychology: longitudinal effects on social interdependence, sociocognitive conflict regulation, motivation, and achievement. *Journal of Educational Psychology, 111*(1), 149. https://doi.org/10.1037/edu0000257.

Smith, T. M., & Wang, H. (2020). Teacher beliefs and practices in the implementation of cooperative learning. *Journal of the Scholarship of Teaching and Learning, 20*(2), 44–59. https://www.proquest.com/openview/980b633049be8c05f0f77a3a586faba0/1?pq-origsite=gscholar&cbl=44156.

Theobald, E. J., Eddy, S. L., Grunspan, D. Z., Wiggins, B. L., & Crowe, A. J. (2017). Student perception of group dynamics predicts individual performance: comfort and equity matter. PLoS ONE, 12(1), 1–16. https://doi.org/10.1371/journal.pone.0181336

Turgut, S., & Turgut, I. G. (2018). The effects of cooperative learning on mathematics achievement in Turkey: a meta-analysis study. *International Journal of Instruction, 11*(3), 663–680. https://doi.org/10.12973/iji.2018.11345a

Ural, E., Ercan, O., & Gençoglan, D. M. (2017). The effect of the jigsaw technique on 6th graders' learning of the force and motion unit and their science attitudes and motivation. *Asia-Pacific Forum on Science Learning and Teaching, 18*(2), 1–21.

Wei, C., Li, C. Z., Löschel, A., Managi, S., & Lundgren, T. (2023). Digital technology and energy sustainability: recent advances, challenges, and opportunities. *Resources, Conservation and Recycling*, 190, 106803. https://doi.org/10.1016/j.resconrec.2022.106803.