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Scoping the landscape: Comparative review of collaborative learning methods in mathematical problem-solving pedagogy

Nurfirzanah Muhamad Fadzil [1], Sharifah Osman [1*]

[1] Faculty of Educational Sciences and Technology, Universiti Teknologi Malaysia, Johor, MALAYSIA
*Corresponding Author: sharifah.o@utm.my

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ABSTRACT

Collaborative learning is a group learning paradigm in which individuals or students work together to solve problems or complete tasks, exemplifying the essence of collective educational efforts. There are a lot of collaborative learning methods available; however, finding one that is suitable for the complex nature of mathematical problem-solving is a very difficult task. As a result, the goal of this paper is to compare and evaluate three collaborative learning methods that, while similar, serve different goals. These methods include thinking aloud pair problem-solving (TAPPS), the jigsaw method, and the fishbowl method. TAPPS emphasizes metacognition development by providing individuals with problem-solving skills and how to convey their mental processes verbally. The jigsaw method, on the other hand, encourages comprehensive knowledge through cooperative group efforts while working in small groups. Finally, the fishbowl method emphasizes collaborative and observational learning. This paper highlights the unique characteristics of each method by reviewing previous research and considering how each influences student participation, group learning, and mathematical achievement. The evaluation's goal is to assist educators and researchers in making informed decisions about the selection and implementation of teaching methods that suit the specific needs of mathematics classrooms.

Keywords: collaborative learning, fishbowl method, jigsaw method, mathematical problem-solving, thinking aloud pair problem-solving method

INTRODUCTION

The dynamic environment in mathematics classrooms keeps revolving around students' understanding of mathematics, particularly in problem-solving tasks, as an ongoing adaptation to meet the diverse needs of students. Mathematical problem-solving evolved from constructivist learning theory, which emphasizes the need of students to actively develop an understanding of mathematical concepts through hands-on involvement, inquiry, and critical thinking (Makonye, 2019). Constructivism is at the heart of this revolutionary journey, serving as a theoretical basis that has shaped current mathematical instructional approaches. This learning theory provides a key framework that emphasizes the active role of learners in generating knowledge through their interactions with the environment (Rob & Rob, 2018). This theory is a substantial change from the usual teacher-centered models of education because it focuses more on students' ability to comprehend their understanding in the learning process. Kalamas Hedden et al. (2017) found that students' active participation in the learning process has a favorable influence and fosters sustainability in learning.

Students participate in the constructivist learning process by actively generating knowledge rather than simply passively acquiring. As a result, the learning process expanded when students' understandings were examined. The need for interactive learning was suggested to increase the student's interest in the topics studied (Tuma, 2021). Interactive learning can be used in mathematical problem-solving for individual tasks or groups. The goal of interactive learning was to provide a dynamic learning process and encourage students to be actively involved in it. When students became more interested in being involved in the discussion, collaborative learning was seen as one of the strategies to maintain not only their focus and comprehension but also increase students' engagement, learning simulations, and social learning (Aliyu et al., 2021; Gillies, 2019).

According to Stewart (2021), participating in social activities promotes meaningful learning. Vygotsky explicitly highlighted the link between communication and thinking. Mahn and John-Steiner's (2012) discussion emphasized Vygotsky's argument that learning is more effectively facilitated through interactions with others than in solitary environments. Vygotsky's theories provide significant insights into how teaching and learning can be made more effective and engaging, particularly by leveraging social interactions to actively involve students in the learning process (Polly et al., 2017). Social constructivism develops through group discussions and peer dialogues. In addition to challenging students' ideas and developing their critical thinking skills, discussion additionally encourages a positive attitude and a sense of trust (Lenkauskaitė et al., 2020).

The thinking aloud pair problem-solving (TAPPS) method, jigsaw method, and fishbowl method were ingenious approaches to collaborative learning where each method was designed to cultivate engagement and mutual understanding among students. These collaborative learning methods were most likely alike but implemented differently. Firstly, the TAPPS method offers possibilities for individuals to share ideas, recognize errors, and engage in in-depth discussions to find solutions through collaboration. This method integrated cognitive process and social constructivism to facilitate students exchanging ideas and engaging in discourse by asking questions when faced with difficulties with understanding (Bada & Olusegun, 2015). By adapting to real-life problems, students have the opportunity to come up with ideas and investigate difficult problems in collaboration (Sarita, 2017). Through this organized process, students actively connect with each other, creating an environment for collaborative learning that values shared responsibility and hands-on learning.

Social constructivism is a teaching method that promotes collaborative learning among students by encouraging conversation, sharing perspectives, and co-constructing knowledge. The jigsaw method is another example of constructivism practice; using it, students build their own knowledge by focusing on particular subtopics and refining their planning, analysis, and study processes (Alfares, 2020). In the jigsaw method, social constructivism was developed when students collaborated in varied groups, exchanging knowledge, listening to other's perspectives, and developing a holistic understanding as a group. According to Akbar et al. (2018), the fishbowl method further supports the idea that social constructivism and constructivism can be implemented in teaching approaches to foster student collaboration and improve learning. The fishbowl method promotes active learning and reflection by encouraging inner circle students to generate their understanding through conversation, engagement, and link-making. Meanwhile, students in the outer circle observe and learn from the discussion.

This paper conducts a scoping review to compare and gather information on three different collaborative learning methods: the TAPPS method, the jigsaw method, and the fishbowl method. The results show that there are a wide variety of methods for collaborative learning, each with its own set of advantages and opportunities for interaction. The TAPPS method promotes collaborative critical thinking by guiding students through a structured process of thinking, questioning, partnering, participating, and sharing (Kani & Shahrill, 2015; Rofiqah & Rozaqi, 2020). On the other hand, the jigsaw method prioritizes work splitting and enhancing group understanding (Baken et al., 2022). The review could indicate a knowledge gap, which refers to the insufficient understanding of how the three methods–TAPPS, jigsaw, and fishbowl–differ in their impact on cognitive skills, subtle aspects of student behavior, and students' learning styles and abilities. This gap highlights the lack of detailed evidence on how each method uniquely contributes to fostering critical thinking, collaboration, and adaptability in various classroom settings. Examining these variances may provide teachers with helpful information to help them choose and implement collaborative learning methods based on the goals and scenarios in which they are employed.

RESEARCH METHODOLOGY

This article analyses three learning methods (TAPPS, jigsaw, and fishbowl) using a non-empirical design based on a systematic analysis of articles from databases, including Research Gate, Google Scholar, Science Direct, and other internet sources. The article chosen for review consisted of studies that either compared these methods or evaluated their performance in educational environments. Articles were initially screened based on title and abstract, resulting in the identification of 150 articles, and then subjected to a full-text review to confirm they met the criteria. Out of these, 71 articles were discarded during the full-text review due to insufficient methodological rigor, lack of focus on the methods under study, or irrelevance to the study context. Finally, 79 articles were analyzed for this study. This stage ensures that only the most relevant papers are included in the review, enabling a thorough comparison of the TAPPS, jigsaw, and fishbowl methods.

During selection, each article undergoes a thorough evaluation process focusing on the context and outcomes of the learning methods. This entails retrieving information regarding the study's goals, the approach, participant demographics, educational environments, and main discoveries. The focus will be on how each learning method affects student engagement, knowledge retention, and collaboration skills, as well as other outcomes. Understanding this step is crucial for understanding the nuances of every method and how they affect learning. The comparative analysis expands on the previous master's thesis by evaluating the different effects of methods on educational results to identify their individual strengths and drawbacks.

The analysis identified knowledge gaps in the available research on TAPPS, jigsaw, and fishbowl methods of learning. This review critically evaluates the procedures and findings of chosen studies in order to identify research gaps, such as settings or demographics where specific methods thrive. The gap analysis will guide future research by identifying areas that require further study to improve the optimization of learning processes for better educational results. By employing a rigorous methodology, this paper endeavors to make a substantial scholarly contribution to the field of education by conducting an exhaustive comparison of the TAPPS, jigsaw, and fishbowl strategies and by identifying potential directions for future research.

RESEARCH RESULTS

Thinking Aloud Pair Problem-Solving

TAPPS, additionally referred to as "Whimbey-pairs," was created by Arthur Whimbey. The method used aimed to improve students' understanding of the lesson by maximizing their cognitive thinking processes (Whimbey et al., 2013). TAPPS was

Figure 1. Illustration of TAPPS (Hafizah et al., 2015)

commonly utilized in the education sector, where students are expected to collaborate in groups to solve a series of problems. Whimbey et al. (2013) highlight the use of probing and clarifying questions as the main structures for TAPPS, as they improve the description of the activity conducted. Furthermore, prior to implementing TAPPS, it is imperative that educators rigorously adhere to established procedural standards.

Figure 1 presents a depiction of the TAPPS execution process, where one student took on the role of the problem-solver or the explainer within TAPPS. The problem-solver was expected to discuss the problem statement in detail, explaining the difficulties they encountered, making a presumption, and discussing the method of addressing the problem. Meanwhile, the other one will act as a listener. The listener plays an important role that somehow requires a lot of communication skills to keep the discussion alive. This is because, from the beginning, even if there is a brief pause from the problem-solver, the listener must make sure the problem-solver keeps on talking and expressing the idea to solve the problem (Al Sultan & Alasif, 2021). Conversely, the listener needs to go above and beyond. The listener does not directly provide the answer to the problem discussed, but they must probe the problem-solver to explain the answer. As a result, the listener's primary goal is to fully comprehend and clarify the discussion, as well as any divergence or mistake made by the problem-solver.

Students' cognitive in mathematical problem-solving

Mathematical problem-solving is a part of mathematics that requires a lot of mathematical skills. Solving a mathematical problem requires the brain's cognitive process to determine the best way to achieve a specific objective. Therefore, students' ability to answer mathematical problems can be measured based on their cognitive level. There are six cognitive levels: remembering, comprehending, applying, analyzing, evaluating, and creating (Subia et al., 2020). At the foundational level, memorizing and applying approaches are essential for basic mathematics. Students made progress as they encountered algebraic problems that required abstract reasoning, as well as geometric and trigonometric problems that required spatial thinking. Next, the peak of mathematics involves complex problem-solving in subjects like calculus, which requires a high level of insight, pattern recognition, and strategic planning. According to Szabo et al. (2020), applying mathematics to real-world problems fosters creativity and adaptability beyond computation. By fostering the critical thinking and problem-solving abilities that are essential for success in the classroom and in industry, this cognitive journey transforms mathematics into an active and dynamic intellectual activity.

TAPPS is a cooperative method that combines cognitive levels and problem-solving techniques to give teachers different views on how their students think (Fuchs et al., 2019). Using this method, two students, one as the speaker and the other as the listener, work together on a mathematical problem while discussing their ideas aloud. Combining and collaborating on these procedures allows for a dynamic exploration of cognitive levels. Verbalization provides teachers with valuable insights into their students' comprehension and problem-solving abilities (Fuchs et al., 2019). Siddiq and Scherer (2017) explored the correlation between cognitive abilities and social skills using thinking-aloud methods. A few indicators were developed for the social and cognitive skill sets to illustrate how the students used collaborative problem-solving (ColPS) techniques in their research. The social skillset has three indicators: participation, perspective-taking, and social regulation, whereas the cognitive skillset has two indicators: task regulation and learning and knowledge building (Siddiq & Scherer, 2017). The research was able to establish that each indication was implemented for each group of students based on the results of the analysis. This result suggests that there are elements within the ColPS assignment that support communication, teamwork, and problem-solving among students.

TAPPS aims to enhance students problem-solving cognitive processes (Widuri et al., 2018). Involving mathematics in problem-solving requires understanding fundamental mathematical concepts, recalling important ideas, and applying effective problem-solving strategies. The study by Widuri et al. (2018) reveals that students may effectively apply their understanding by providing examples of problem-solving techniques and observing others while applying TAPPS. Students who implement TAPPS have better mathematics learning outcomes compared to those who use traditional learning methods (Fauzan et al., 2019; Widuri et al., 2018). The results suggest that TAPPS helps students enhance their knowledge and ability to solve mathematical problems, as well as their cognitive level. When students discuss problems in pairs, they use cognitive processes to recall and combine their information through discussion. Implementing the TAPPS methods requires the listener and problem-solver to keep the discussion going and seek solutions.

To keep the conversation "alive" and more educational, TAPPS needs to have strong communication abilities. Although using TAPPS to solve mathematical problems involved a lot of work, it also helped students comprehend how the problem-solving process works. Kani and Shahrill's (2015) study highlighted that the ability of intermediate and high-achieving students to solve mathematical problems was the highest, followed by the low-ability students. Although the TAPPS strategies provide good indication and feedback, students with moderate achievement struggle to grasp fundamental ideas and are most likely to get confused when trying to solve mathematical problems.

Furthermore, students with poor problem-solving abilities face challenges in using TAPPS strategies due to their lack of prerequisite mathematical knowledge (Fauzan et al., 2019). This situation can hinder effective discussions during the implementation of TAPPS. Hence, it is most likely that students should be equipped with basic mathematical concepts. This is how the cognitive process for mathematical problem-solving could be rotated and delivered successfully.

To sum up, TAPPS is a dynamic and transformative approach that significantly affects students' cognitive abilities during mathematical problem-solving. A basic comprehension of complex synthesis during the TAPPS process offers a special perspective on the cognitive journey that students take as they cooperatively express their ideas. Furthermore, this method encourages students to think critically about how they should solve mathematical problems to assess cognitive functions. TAPPS presents itself not just as a teaching method but also as an engine for overall improvement in education. The TAPPS methods may act as a guide, pointing the path to a more engaging, cooperative, and enhanced mathematics learning environment.

Students' behavior with TAPPS toward mathematical problem-solving

TAPPS significantly influences students' mathematical problem-solving behavior and enhances their problem-solving skills (Simpol et al., 2017). TAPPS encourages teamwork to establish a positive learning environment that allows students to tackle mathematics problems with confidence. Students not only learn from each other but also develop a sense of interaction while dealing with mathematical problems by talking and sharing how they think. This cooperative setting promotes better learning behaviors in mathematics by minimizing anxiety at times related to solving problems independently. Furthermore, TAPPS also fosters an open-minded attitude towards different opinions and problem-solving methods, which helps individuals understand the intricacies of mathematical reasoning (Simpol et al., 2017). As a result of collaborating together to solve problems, students' attitudes towards mathematics shift. This makes them more interested in discovering and embracing mathematical subjects.

In addition, Kotsopoulos (2010) stated that students need to be able to express as well as back up each other's thinking and educational requirements while utilizing TAPPS. This is due to TAPPS rules, which encourage cooperation and teamwork throughout the process (Al Sultan & Alasif, 2021). Therefore, the quality of solutions from the conversation could be improved when the students were able to build deeper relationships and trust. In contrast, even though Sönmez and Sulak (2018) stated that TAPPS has little effect on performance speed, it does assist students in identifying and monitoring their thinking processes. This is because TAPPS encourages people to reflect more thoroughly and from a variety of perspectives on the problems (Al Sultan & Alasif, 2021). Hence, it improved problem-solving skills and gave a deeper understanding of the problem.

Previous studies by Syafitri et al. (2018), examined how TAPPS methods affected students' communication skills when addressing mathematical problems. TAPPS improved students' communication skills by requiring them to address problems and problem-solutions while also capturing mathematical concepts. As students learn to navigate collaborative discussions with complete knowledge, the problem-solving process not only improves their interpersonal skills but also refines their capacity to communicate mathematical reasoning (Fatimah et al., 2023). TAPPS converts mathematical difficulties into group challenges, promoting the development of communication skills through cooperation and shared experiences.

While TAPPS prioritizes individual cognitive processes and verbalization, research has demonstrated that it improves problem-solving skills by concentrating students' attention on their thoughts (Pate & Miller, 2011). Additionally, TAPPS has been shown to enhance students' verbal interactions and performance when solving chemistry problems (Noh et al., 2005). TAPPS usage has been demonstrated to have enhanced critical thinking in mathematics lessons (Salehha et al., 2021), highlighting its diverse advantages and multifaceted benefits.

To summarize, TAPPS encourages a good attitude towards mathematics and a collaborative environment, which improves communication skills. TAPPS has been demonstrated to improve problem-solving abilities and critical thinking in several educational settings, especially in the fields of mathematics and chemistry. The TAPPS setting fosters a comfortable culture that encourages students to share their opinions, challenge assumptions, and collaborate to solve problems. Cooperative behavior in TAPPS methods promotes a positive attitude towards mathematics and enhances interpersonal skills. It aids students in building confidence and developing a deeper understanding of mathematical concepts. TAPPS also encourages a growth mindset, in which problems are seen as opportunities for learning and growth rather than daunting difficulties as students express their thought processes. TAPPS's behavioral influence goes beyond traditional problem-solving, creating a learning environment that prioritizes cooperation, resilience, and a true desire for mathematical inquiry.

Students' learning style and ability to learn mathematics

TAPPS is an innovative method of handling problems that involves working together with others. It has become known as an effective way to improve mathematical abilities that can also be used by people with different learning styles. For their educational development, it is critical to consider how students absorb and digest information from their environment (Sheromova et al., 2020). In their study's results, Rahman and Ahmar (2017), identified and classified three distinct learning styles among mathematics students: visual style, auditory style, and kinesthetic style. According to their findings, teachers were able to create a more inclusive learning environment by using a diversified strategy that included auditory, visual, and kinesthetic learning styles. As a result, teachers were able to fit each student's mathematical skills and preferences.

Mashuri et al. (2018) conducted a study to explore how applying the TAPPS impacted students' learning styles. Their research aims to examine the correlation between students' learning styles and the mathematical problem-solving stage. The mathematical problem-solving stages were segmented into four stages: understanding the problem, devising a plan, carrying out a plan, and looking back. Students with a visual learning style excel at formulating a plan, according to the research. They are capable of accurately drafting and finishing the plan. Kinesthetic students excel at comprehending the problem but tend to be quickly distracted during the TAPPS process. Above all, the auditorial students were the ideal match for the TAPPS methods

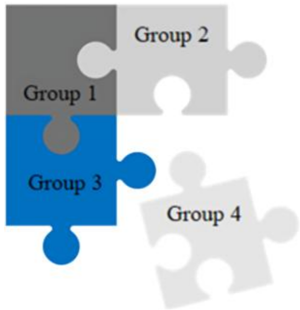

Figure 2. Illustration of jigsaw method (Hafizah et al., 2015)

because of their optimum learning style. Auditorial students could address practically all of the problem-solving stages (Mashuri et al., 2018). Due to the fact that TAPPS necessitates effective communication, the auditorial students demonstrated proficiency in expressing their ideas and expertise throughout the process.

Fauzan et al. (2019) found that students with visual learning styles demonstrate better problem-solving abilities while using TAPPS, in contrast to the findings of Mashuri et al. (2018) on auditorial and kinesthetic learning styles. The result was influenced by the predominant use of visualizing concepts using tables, figures, symbols, and graphics in the problem-solving assessment of this study, as compared to Mashuri et al. (2018), which addressed a range of mathematics topics without emphasizing diagrams and symbols. The results of Fauzan et al. (2019) also suggest that students may observe improvements in their ability to solve mathematical problems when employing TAPPS. However, these results do not necessarily imply a direct correlation between the utilization of TAPPS and learning style. Therefore, these two results indicate that the learning environment influences the behavior of students with diverse learning styles in mathematics classes, which is consistent with the findings of Ozerem and Akkoyunlu's, (2015).

In addition, the measure of students' reactions to the challenges given in the problem can be referred to as the adversity quotient. Students in the adversity quotient were classified into three categories: quitters, campers, and climbers (Damastuti et al., 2023). Students who tend to quit when learning mathematics find the subject difficult, confusing, and frustrating. They give up and stop attempting to solve mathematics problems when they find difficulties due to a lack of motivation. Next, students who were labeled as "campers" were satisfied with the position they were in and did not want to take big risks. When it comes to learning, these students usually give up earlier and put in less effort. Students classified as climbers were goal-oriented. They could work assiduously to achieve their objectives. They exhibit extraordinary discipline and courage. These students continually strive to achieve superiority (Darmawan et al., 2019).

Dewanto et al. (2019) conducted a study on students with adversity quotients to investigate the impact of cooperative learning on students' mathematical achievements. They worked on three forms of cooperative learning: TAPPS, two stay, two stray (TSTS), and discovery learning (DL). The study shows that climbers with a higher adversity quotient showed better mathematics achievement than campers and quitters with lower adversity quotients. Students with the climber type were characterized by their strong discipline and persistent focus on their goals (Darmawan et al., 2019). TSTS techniques were considered more dependable than TAPPS and DL in this study. The study emphasized that the tactics employed depend on the student's learning environment (Dewanto et al., 2019).

Jigsaw Method

The jigsaw method is another form of cooperative learning method. According to Karacop (2017), the jigsaw method is an instructional strategy designed to foster student interdependence through teamwork in mastering a specific subject matter and knowledge sharing with peers; it facilitates cooperative learning and in-depth understanding of concepts. This approach divides students into smaller groups, each of which is tasked with understanding a particular subtopic. Members of these expert groups acquire a thorough understanding of the topic and become experts in the field to which they have been assigned. The jigsaw method follows a sequence of events, such as a book with chapters (Garcia et al., 2017). In this method, students are required to understand only their part or the group task was assigned; after completing the task in their group, students need to teach or assist another group about the task they get, like completing the jigsaw puzzle separately and combined in the end. **Figure 2** shows the illustrations of the jigsaw method.

To successfully implement the jigsaw method, key factors such as positive interdependence, individual accountability, face-to-face interaction, social skills, and group processing need consideration (Alfaruqy, 2021). Positive interdependence develops when students depend on their teammates for ideas (Garcia et al., 2017). Consequently, the group learns to trust each member, understanding that individual success is vital for the group's overall success. As a result, students will grow in their sense of personal accountability since they will feel that actions taken by the main group will contribute to their achievement.

Other than that, face-to-face engagement through the exchange of questions and explanations will promote a feeling of respect by appreciating their team members' views (Garcia et al., 2017). The jigsaw method has the potential to facilitate the interpersonal and social development of students, given the criticality and difficulty of fostering social skills (Cochon Drouet et al., 2023). Finally, group processing by reflecting on their collaboration during the project will enhance the quality of their work as they strive towards a common goal (Garcia et al., 2017).

Students' cognitive in mathematical problem-solving

The jigsaw method transforms how students interact intellectually with mathematical problems, improving their comprehension, analytical skills, and collaboration. Jigsaw has been extensively utilized for teaching problem-solving skills and has been proven to enhance students' comprehension and problem-solving capabilities (Oakes et al., 2018). Dewi and Harahap (2016) found that students become experts by exploring specific subtopics, necessitating an in-depth knowledge of the content they are assigned. Post-learning tests reveal that more than 80% of students demonstrated comprehension and active involvement, confirming the instructional materials' impact in improving mathematical thinking. Furthermore, improvements in syllogism, generalization, analogies, and conditional reasoning abilities were shown to meet the average standards. The in-depth study helps students think around them, analyze, and internalize mathematics material. This makes them ready to teach their peers what they have learned (Olaoye, 2019; Sari & Haji, 2021).

Spatial ability is a cognitive skill. The research findings and analysis by Sari and Haji (2021) present significant findings about students' spatial skills in solving mathematical problems through the implementation of the jigsaw method. The study found that the jigsaw method provided opportunities for students to collaborate, discuss, and explain their reasoning, which enhanced their spatial abilities. It also encouraged students to refine their understanding by learning from peers. The students' spatial ability was categorized into three distinct categories in this research: high, intermediate, and low. Students with high spatial ability think in an abstract and systematic fashion, whereas those at the intermediate level think in a structured but semi-abstract fashion. Conversely, students with inadequate spatial skills demonstrate fragmented, concrete thought processes, an inability to concentrate, and a dearth of alternative problem-solving strategies.

The jigsaw method fosters critical thinking. By incorporating knowledge from diverse expert groups, students are encouraged to engage in critical assessment of their peers' contributions, question assumptions, and synthesize multiple perspectives (Saputra et al., 2019). This method prompts students to assess the dependability and suitability of various problem-solving methods, enhancing their critical thinking skills (Olaoye, 2019). This study also found that students who learned the jigsaw method did better than those who learned more traditional ways to solve problems.

Students' behavior with jigsaw method toward mathematical problem-solving

Students exhibited increased involvement, cooperation, and a positive shift in problem-solving behavior while utilizing the jigsaw method. The study by Putra et al. (2022) found that students who got integrated math instruction that included teaching for sustainable development did better than those who got traditional instruction. This was evident in the fact that these students got higher average scores on the final exam for mathematical problem-solving skills. From the perspective of education for sustainable development, the jigsaw method helps students understand mathematical ideas and come up with theories when solving math problems (Putra et al., 2022; Putri & Syahputra, 2019; Saputra et al., 2019).

Integrated mathematical learning motivates real growth by combining guided interactions with teachers and peers with independent work. Student-teacher and student-to-student interactions are critical for encouraging students' development and improving their ability to solve problems and understand mathematics. Yeubun et al. (2020) found that improving communication skills within a jigsaw method group significantly impacts student behavior. Extroverted students benefit more from jigsaw cooperative learning for enhancing mathematical communication abilities compared to introverted students (Sudin et al., 2021; Yeubun et al., 2020).

The jigsaw method develops a feeling of collective accountability through the necessity of effective coordination and communication among group members. Students learn to articulate themselves clearly, listen to their peers, and collaborate to find solutions, all of which foster more cooperative problem-solving strategies (Bau et al., 2023; Prasetyo, 2019). In addition, employing the jigsaw method resulted in a significant enhancement in the mathematical self-perception of students, according to this study (Prasetyo, 2019). As a result, students who used the jigsaw method's scientific approach to cooperative learning excelled over those who used the conventional method in terms of self-concept, mathematical communication, connection skills, and overall achievement (Prasetyo, 2019).

Overall, the jigsaw method changes how students solve mathematics problems by encouraging them to be actively involved, work as a team, communicate clearly, and have a good attitude concerning cooperating to solve problems (Hiltrimartin & Hartono, 2020). Students enhance their ability to express their ideas and boost their enthusiasm through the jigsaw method (BK & Hamna, 2021). By creating a safe space that encourages students to try new things and take calculated risks, the method changes the way students think about math problems for the better.

Students' learning style and ability to learn mathematics

Research by Virgana (2019) on students' learning styles found that using two group learning methods–the student team achievement division (STAD) and the jigsaw method–produced clear differences in how well students learned math ideas. The types of learners were visual, auditory, and kinesthetic. The STAD method helped students understand math ideas more on average (76.17%) than the jigsaw method (56.83%). STAD's exceptional performance can be ascribed to its all-encompassing framework, as elaborated by Virgana (2019). These results show that STAD's structured method works better than the jigsaw method at helping people understand mathematical ideas. The STAD model's broad applicability and effectiveness are also supported by Virgana's (2019) results that learning styles have little effect on mathematical idea acquisition.

On the other hand, K urniawati et al. (2017) discovered that the jigsaw method was more effective in boosting mathematics achievement and it helped kinesthetic learners more than visual and auditory learners. This is because kinesthetic learners benefit most from hands-on experiences and physical exercises. While the method may not be kinesthetic by nature, the interactive nature

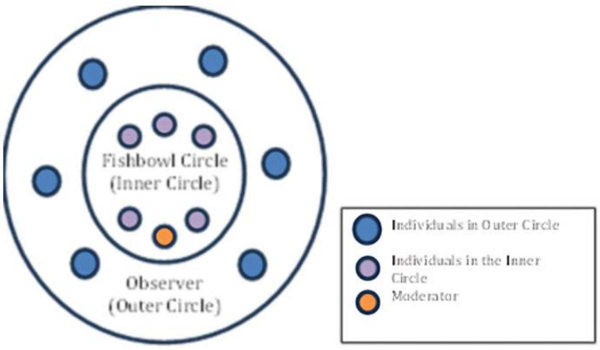

Figure 3. Illustration of fishbowl method (Flor et al.., 2013)

of group activities, talks, and problem-solving could lead to chances to be physically involved. For example, students may use manipulatives or construct tangible models to represent mathematical ideas.

Fishbowl Method

The fishbowl method is an engaging and participatory approach to education that encourages students to actively participate in class discussions. In the fishbowl method, the classroom will be divided into two groups, called the inner circle and the outer circle, with a moderator, usually the teacher, facilitating the discussion. Effendi (2018) stated that the inner circle was called a fishbowl circle, while the outer circle acted as the observer. The inner circle, which is typically made up of a smaller group of students, will actively take part in a role-play, group discussion, or cooperative activity at the center. The interactions occurring within the inner circle are observed and analyzed by the outer circle concurrently. Students in the outer circle may join the discussion later if the positions are reversed (Andika, 2019). **Figure 3** is an illustration of how the fishbowl method was conducted.

Other than that, this method gives students the chance to simulate or observe how individuals interact in a discussion context as a group, as well as to give structure for in-depth conversations (Brookfield & Preskill, 2012). The fishbowl method serves dual purposes: it facilitates brainstorming sessions and allows for structured observation of group dynamics (Kagan, 2002 as cited in Nisa, 2016). During brainstorming sessions, students select a topic of interest, and those keen on discussing it sit in the central circle. Inside the fishbowl, participants can ask questions, reply, share information, or comment. On the other hand, in structured observation of a group process, students will be given a specific task to complete together in the inner circle, while the outer group will act as observers and note specific behavior (Kagan, 2002, as cited in Nisa, 2016).

Students' cognitive in mathematical problem-solving

The fishbowl method, a technique involving a select group of students engaging in discussion as their peers observe, is employed to enhance cognitive and metacognitive skills in math problem-solving. It enables the analysis of processes used in solving math problems and aims to improve students' oral communication skills, Observation, and participation dynamics (Ermiwin, 2019). Previous findings showed that this method is a highly effective strategy for conducting discussion since it is an instructional approach. The method assists students in learning how to discuss and think critically about the discussion (de Sam Lazaro & Riley, 2019). Metacognitive reflection was enhanced during the inner circle conversation. Participants in the fishbowl group increased their analytical abilities and demonstrated critical thinking as the circle debated, evaluated, and responded to the discussion. This expands their understanding and provides valuable information to those in the outer circle.

The active sharing of concepts and problem-solving solutions inside the inner circle exemplifies the fishbowl method's cognitive element in mathematics. Students demonstrate their understanding of mathematical concepts and reflect on their problem-solving strategies by verbalizing their thought processes in rotation (Schmitz, 2016). Through this process, students enhance their cognitive flexibility and develop the skill to evaluate many perspectives, leading to a more comprehensive and dynamic problem-solving approach in mathematics.

The study conducted by Siagian and Surya (2017) provided evidence that implementing the fishbowl method substantially improved the mathematical problem-solving abilities of students. Specifically, a structured three-stage fishbowl choice approach, which includes problem analysis, group discussion, and solution synthesis, was responsible for a 35.77% enhancement in the student's abilities. Other factors caused the last 64.23% of performance outcomes. These results also support research by Siagian and Surya (2017), who states that students in the inner circle have to solve difficult problems and then analyze, evaluate, and put together different pieces of knowledge. As observers, those in the outer circle see different ways to solve problems. This helps them think critically about the solutions and adds to the group's knowledge of mathematical topics.

Although several studies have shown the benefits of the fishbowl method on students' mathematics study, its use in current math education research is still limited. The fishbowl method was considered more advantageous for enhancing social skills and improving communication abilities in language, as indicated by Adoum and Nemouchi (2018), Ameen and Ahmed (2023), and Ermiwin (2019). This method effectively creates an environment that encourages students to engage in meaningful discussions, enhancing their skills in articulating ideas, active listening, and making significant contributions to group learning.

Students' behavior with fishbowl method toward mathematical problem-solving

The fishbowl method has a strong positive behavioral influence on students' mathematics learning, resulting in increases in attitude, participation, and collaborative skills (Pellas et al., 2017). Learning activities that encourage more active student participation in the classroom helped to create an inclusive learning environment. When students rotate in the inner circle to debate and solve mathematical problems, there is a noticeable rise in active participation, resulting in active learning. This promotes positive behavior modification and encourages a feeling of shared responsibility and involvement among students.

Additionally, through mathematical problem-solving, the fishbowl method promotes the development of effective communication skills among students (Ningsih & Nurseha, 2018). The method's structured style involves an inner circle discussing problems and an outer circle observing, requiring clear articulation of concepts and ideas. Students collaborated in a team to analyze the mathematical concept in relation to a real-life scenario. This communication-centered strategy contributes to improved behavior by teaching students to explain their mathematical reasoning with precision and clarity.

Rashid and Khan's (2023) findings show that collaborative learning including the fishbowl method, has a positive impact on students' collaborative skills. Working together in a team when solving mathematical problems improves teamwork and peer collaboration among the students. The method creates a platform for students to share their problem-solving strategies, discuss different approaches, and collectively arrive at solutions. This collaborative aspect enhances students' interpersonal skills and positively influences their behavior towards teamwork and group problem-solving.

Lastly, the fishbowl method's previous findings on attitude and behavior for mathematical problem-solving are still not actively discussed. Overall, although the fishbowl method demonstrates a significant impact on students' behavior, fostering active participation, effective communication, and collaborative skills there was still a lack of findings that focused on mathematical problem-solving.

Students' learning style and ability to learn mathematics

According to Ningsih and Nurseha (2018), students' ability in mathematical problem-solving improved when using the fishbowl method compared to the conventional method that focused on teachers. In their findings, at the stage used in the collaborative fishbowl method, students were trained to complete mathematical problems in the real world in mathematical language, and students were trained to be able to solve mathematical problems related to everyday life situations. These improvements align with the four phases of Polya's problem-solving model, as reflected in the students' problem-solving abilities in experimental and control classes obtained from the results of students' mathematical problem-solving achievement tests.

By referring to the Polya model, students were able to identify known elements and create mathematical models. They could carry out problem-solving plans, implement strategies for solving problems, solve mathematical models and real problems, and use mathematics meaningfully. They were also able to explain and interpret the results. Variations in interpreting results between experimental and control groups were impacted by the learning process (Ningsih & Nurseha, 2018).

The experimental group engaged in learning exercises with worksheets focused on solving questions relating to internal problems in daily life, while the control group did not get this form of treatment. Therefore, these circumstances led to a greater ability to evaluate the results in the experimental class compared to the control class (Ningsih & Nurseha, 2018). The analysis of students' mathematics problem-solving ability test answers indicates that the experimental class has a higher mathematical problem-solving ability than the control class, consistent with Siagian and Surya's (2017) findings.

DISCUSSION

The three collaborative methods presented are similar but differ significantly in their implementation. Each method emphasizes a distinct focus, whether in cognitive, behavioral, or learning style aspects in students' mathematical problem-solving. Furthermore, these methods vary in their impact on student's cognitive development, reflecting each method's unique approaches.

TAPPS is a method used in the education field. It requires students to pair and work together to solve problems (Whimbey et al., 2013). This method emphasizes the development of metacognitive skills by encouraging students to verbalize their cognitive process. TAPPS also enhances an individual's problem-solving abilities through structured collaboration (Pate & Miller, 2011). This suggests that the impact of TAPPS makes it an excellent strategy for improving students' critical thinking and problem-solving abilities, including the translation of mathematical concepts into operations (Pate & Miller, 2011). Additionally, it enables teachers to focus on the talent development of each individual student. Besides, having students explain their thoughts and logic verbally may be quite challenging. Therefore, it was suggested to document or write the process in solving mathematical problems which can also lead to deeper understanding as well as allows students to track, analyze and identify area for improvement (Albay, 2019).

In all other respects, the jigsaw method emphasizes knowledge consolidation through small-group competence development and collaboration while emphasizing mastery of particular subtopics (Garcia et al., 2017). It focused on cooperative learning and knowledge sharing (Kade et al., 2019). Besides, this method, as emphasized in various research, has proven to be successful in improving student comprehension and problem-solving abilities in diverse educational settings (Akbar & Akhtar, 2021; Amin et al., 2020; Kiuk et al., 2021). Additionally, the jigsaw method fosters students' critical thinking skills by encouraging them to engage deeply with the material and collaborate effectively (Kade et al., 2019). For instance, Nnamani et al. (2023) discovered that students with visual impairment were more interested in basic science when using the jigsaw method. This finding highlights the method's capability to captivate students and cultivate a constructive learning environment. However, defining the roles of each group is the most critical part. Hence, it was recommended that teachers organize frequent feedback periods when students share their taught from their expert groups, strengthening their metacognitive abilities and advancing their overall comprehension of the subject matter.

On the other hand, the fishbowl method places a significant emphasis on observation and participation dynamics in group discussions. In this method, the classroom will be divided into two groups: the inner and outer circles. One person, usually the teacher, will act as a moderator (Effendi, 2018). It helps students grasp mathematical concepts more deeply as the possibility of analyzing mathematical problem-solving processes has been acknowledged (Hartmann et al., 2022). This suggests that the fishbowl method impacts students by improving their cognitive and metacognitive processes (Abdu Babaji, 2020).

Each method has a distinct emphasis, which leads to unique strengths and potential gaps in their application. TAPPS emphasizes individual problem-solving performance, jigsaw focuses on group expertise and critical thinking skills, and fishbowl highlights observational learning in group conversations while improving cognitive and metacognitive processes. However, evaluation methodologies may limit the direct comparison of the efficacy of these methods in different educational environments (Akbar & Akhtar, 2021). To select and implement the appropriate method for the particular learning objectives and classroom dynamics, teachers should possess a comprehensive understanding of these distinctions. Furthermore, emphasizing how students engage with Polya's problem-solving process is essential, as it helps them focus on and overcome the challenging steps they often face in solving mathematical problems.

CONCLUSION

Ultimately, the analysis of the TAPPS, jigsaw, and fishbowl methods shows both similarities and unique variations in their way of collaborative learning. TAPPS focuses on developing individual metacognitive skills and individual problem-solving to improve critical thinking and the application of mathematical principles. The jigsaw method enhances understanding and teamwork by concentrating on comprehending specific related topics, hence fostering inclusive and enjoyable learning. The fishbowl method promotes mathematical comprehension and provides a unique problem-solving approach by utilizing observation and discussion.

The approaches provide various benefits based on their specific focuses: TAPPS enhances individual problem-solving skills. Educators should use this method to develop students' independent problem-solving skills or refine their reasoning. Meanwhile, jigsaw is the most effective method in the classroom, emphasizing independence and teamwork. It can be suggested to implement it in complex topics. Lastly, the fishbowl is ideal for observational learning and active discussion. However, educators should avoid the jigsaw method if students lack foundation knowledge. Additionally, the fishbowl method may be less effective in large classroom settings. Future research should explore learning strategies that combine elements of these methods and investigate the impact on mathematics achievement. Hence, by recognizing and focusing on the particular aspects of each cooperative learning method, educators may build personalized teaching methods that promote a dynamic and inclusive educational environment, fostering individualized assistance and collaborative engagement among students.

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