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Impact of the team-assisted individualization learning model on mathematical problem-solving, communication, and self-regulated learning

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Abstract

The importance of mathematics in various aspects of life cannot be ignored. Every discipline, from the natural sciences to the social sciences, has a connection with mathematics. Therefore, understanding mathematics that is relevant to its context is very important. One step in understanding mathematics' implications is through effective learning models in elementary schools. This study aims to analyze the impact of the Cooperative Learning type and Team type-assisted individualization (TAI) learning model on three main aspects of mathematics learning at the elementary school level: mathematical problem-solving, mathematical communication, and self-regulated learning skills (SRLS). Quantitative methods were used in this study, with a quasi-experimental design involving two groups: an experimental group and a control group. A total of 64 students were involved in this study, with each group consisting of 32 evenly distributed students. The data collection instruments comprised mathematical problem-solving, communication tests, and Self-Regulated Learning Skills (SRLS) scale instrument sheets. The results of the data analysis revealed significant differences between the experimental and control groups regarding mathematical problem-solving ability, mathematical communication, and SRLS. This study shows that the Cooperative Learning type Team Assisted Individualization (TAI) learning model has positive implications for improving students' abilities in three key aspects of mathematics learning: students' ability to solve mathematical problems, their ability to communicate in a mathematical context, and their ability to learn independently.

Keywords: Communication, Cooperative learning, Elementary school, Problem-solving, Self-regulated, Team-assisted individualization.

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1. Introduction

One cannot ignore the difficulties students confront when working with mathematics. Mathematics is considered the "king of sciences," which is the basis for advancing science and technology and has practical applications in everyday situations [1, 2]. Each aspect of life is affected by learning mathematics; various disciplines require an understanding of mathematics relevant to their context. Through mathematics, students are taught how to communicate effectively, concisely, and clearly while being given the skills to present information in various forms. Furthermore, mastery of mathematics can enhance students' logical and accurate thinking abilities, shape their understanding of spatial dimensions, and give them satisfaction when tackling complex problem-solving challenges [3, 4]. Additionally, problem-solving and mathematical communication techniques are viewed as instructional tools that may enhance the standard of mathematics instruction in educational settings, including primary schools.

Problem-solving in mathematics involves several important stages, such as understanding the question, planning the solution, and evaluating the work [5]. Although these stages can stand alone, they are closely related. Students who do not have a strong understanding of the material often face difficulties in solving mathematical problems [6]. As an initial effort to address this, several previous studies have focused on improving these aspects [7-9]. However, understanding the material alone is not enough. Students must also have effective mathematical communication skills to overcome challenges in understanding the subject matter. Aspects of mathematical communication include using appropriate terms, converting concepts into language that is easy to understand, switching between verbal language and gestures, and adjusting speaking and behavioural styles [10]. Indicators include discussing clearly with lecturers and classmates, accurately applying mathematical ideas, and evaluating proposed strategies [11]. In a classroom setting, mathematical ideas are often communicated.

Math language can help students become better communicators [12]. Previous studies have shown that group discussions can strengthen this mathematical communication ability [13, 14]. Several studies have explored the issue of weaknesses in mathematical communication ability [15, 16]. The results of previous studies confirm that well-rounded learning is needed to improve both mathematical problem-solving and communication abilities simultaneously.

One of the more effective methods to help students develop their problem-solving and mathematical communication abilities is to use a cooperative learning model. The practice of cooperative learning has many advantages for the development of intellectual and social skills. One of the main aspects emphasized is listening to classmates' opinions and applying logic to conclusions, resulting in more comprehensive thinking for students [17]. In addition, cooperative learning models also have the potential to promote cooperation and collaboration among students with diverse backgrounds. Students are taught to work together to complete tasks and face mathematical challenges in this learning environment. This improves collaboration skills and teaches students to appreciate differences and take advantage of individual expertise within the group [18].

However, besides problem-solving and mathematical communication skills, another important aspect of learning is self-regulated learning (SRL). Self-regulated learning includes students' skills in understanding, applying, and implementing appropriate procedures and strategies to solve mathematical problems. This ability significantly impacts learning outcomes, even before the learning process occurs [19]. Several studies, as described by Eggers, et al. [20], have adopted an empirical approach to understanding students' learning independence. However, most of these studies have focused on the achievement of learning outcomes, and not many have examined the potential for improving the ability to learn independence itself.

The Team-Assisted Individualization (TAI) cooperative learning model has demonstrated solutions to mathematical problem-solving, communication, and learning obstacles that focus on student self-regulation. TAI can bridge this gap by providing an adaptive and inclusive learning process. This model organizes students in small groups with diverse backgrounds and abilities [21]. Through interactive sessions, learners can understand the learning material better. One of the key elements of TAI is the development of positive interdependence rules among group members. This promotes close collaboration and encourages each individual to actively contribute to learning. In addition, TAI also builds individual responsibility, where each group member has a significant role in achieving the learning objectives. Face-to-face communication is at the core of this process, allowing students to discuss, exchange ideas, and explain mathematical concepts to each other in greater depth [22].

In addition to the positive impact on problem-solving and mathematical communication skills, the TAI model also impacts effective classroom management. Since this model emphasizes interaction between students and their active involvement in the learning process, the teacher needs to be more of a facilitator than an information provider. Thus, the classroom atmosphere becomes more dynamic and focuses on joint exploration and mutual support. Applying the TAI-type cooperative learning model is not only a solution to learning challenges but can also be adapted to students' characteristics and unique needs. This shows the flexibility and adaptability of this model in dealing with various learning situations [23].

Based on the above, this study investigates the potential to improve elementary school students’ mathematical problem-solving, communication, and self-regulated learning skills by applying the Team-Assisted Individualization (TAI) type cooperative learning model. This research fills a gap in the literature by focusing on adding aspects of self-regulated learning, which has not often been the subject of research in the past. The Team-Assisted Individualization (TAI) learning model was chosen as the main learning model in this study because this model is believed to integrate various aspects of learning holistically and effectively. This research uses an experimental method to test the effect of the Team-Assisted Individualization (TAI) learning model in the mathematics subject of elementary school students on mathematical problem-solving ability, mathematical communication, and Self-Regulated Learning. The problem formulations in this study are as follows:

1. Does using the Team-Assisted Individualization (TAI) learning model affect students' problem-solving abilities?

2. Does using the Team-Assisted Individualization (TAI) Learning Model affect students' mathematical communication?
3. Does using the Team-Assisted Individualization (TAI) Learning Model affect students' Self-Regulated Learning Ability?

This research is deemed necessary to fill the literature void by re-analyzing the impact of applying the Team-Assisted Individualization (TAI) learning model to mathematics learning at the elementary school level. In addition, this research has significant relevance for educators and field researchers in providing an overview of learning innovation through the use of the model.

2. Literature Review

2.1. Mathematical Problem Solving

An understanding of mathematical problem-solving encompasses a variety of complementary theoretical approaches. The cognitive process at the core of mathematics learning is problem-solving, which is important in international assessment frameworks such as TIMSS (Trends in International Mathematics and Science Study), PISA (Programme for International Student Assessment), and NAEP (National Assessment of Educational Progress). This focus supports the development of knowledge and skills for dealing with everyday challenges. Mathematical problem-solving ability becomes a very relevant element to achieving optimal learning achievement in the context of learning. The urgency of problem-solving ability is seen in several important aspects: (a) as the main goal in teaching mathematics; (b) as the core of methods, procedures, and strategies integrated into the curriculum; and (c) as a fundamental foundation in mastering this discipline [24]. Consequently, problem-solving skills are essential for all mathematics learners, from the primary to the tertiary level.

The ability to solve mathematical problems involves some important aspects that need to be improved, including (a) understanding mathematical concepts and terms, (b) being able to identify similarities, differences, and analogies, (c) selecting essential elements and appropriate strategies, (d) recognizing unrelated items, (e) exercising critical judgment and analysis, (f) having skills in visualizing and interpreting quantities or spaces, (g) being able to make generalizations based on multiple examples, (h) being flexible in changing familiar methods, and (i) having a sufficient level of confidence and enthusiasm for the material [25]. Following this view, some constructivist approaches also emphasize the importance of preparing students to cope with ambiguous or uncertain problematic situations. In this regard, open-ended exploration of mathematical problems is considered an important activity, which involves developing the problem into a broader and deeper form to explore various possible solutions and issues of a general nature [26].

Evaluation of a student's ability to solve mathematical problems is often done through solving a series of problems. In this framework, the problem-solving and evaluation processes are comprehensive. As a result, students should master this aspects as it is crucial to educational endeavors. The importance of problem-solving skills contributes to developing cognitive and analytical skills and builds the foundation for a deeper understanding of mathematical concepts. In addition, students need to be given adequate opportunities to hone these skills through active interaction with learning materials. By proactively engaging students in the learning process, they can build their analytical and critical abilities in dealing with mathematical challenges. These skills also prepare them to tackle problems in everyday life that require deep understanding, logical reasoning, and perseverance in finding effective solutions [27].

2.2. Mathematical Communication

Communication is a medium for sharing thoughts and enhancing understanding and requires continuous improvement, dialogue, and adaptation. In education, communication is important in giving identity and significance to ideas and facilitating their dissemination to a wider audience. Effective communication is essential for educators, as they interact with students, colleagues, administrative personnel, parents, and the community [27].

Enhancing the mathematical communication ability of students holds significant importance in their comprehension of mathematics as it empowers them to articulate their thoughts verbally and in writing effectively. This proficiency equips students with the capacity to engage in constructive communication with educators and peers throughout the teaching and learning process [28]. Programs designed for mathematics education should provide students with opportunities to: (a) structure and synthesize their ideas through communication; (b) express their thoughts logically and transparently to peers, instructors, and others; (c) critically assess and appraise the ideas put forth by their peers; and (d) employ mathematical terminology to convey concepts accurately [29].

The significance of mathematical communication is grounded in two primary rationales [30]. Firstly, mathematics serves as a language that facilitates thought processes, pattern recognition, problem-solving, and conclusions. It is also an essential tool for articulating ideas precisely and clearly. Mathematical language comprises personally crafted and meaningful assertions, while mathematical symbols derive their significance only after being defined. Secondly, mathematics learning possesses a social dimension, serving as an arena for interaction between students and educators. Consequently, the development and enhancement of mathematical communication, both as a social activity (oral expression) and as a cognitive tool (written communication), are continuously emphasized within the learning environment.

According to the National Council of Teachers of Mathematics, the indicators of mathematical communication include: (1) the capacity to effectively communicate mathematical ideas through oral, written, and visual means; (2) the ability to comprehend, interpret, and assess these ideas in both oral and visual formats; and (3) proficiency in using mathematical terminology, notations, and structures to convey concepts, describe relationships, and model situations [31]. Another perspective presented by Szabo, et al. [32] underscores the significance of communication skills, particularly within student discussions. Students are expected to be able to convey, elucidate, describe, actively listen, pose inquiries, and collaborate to gain a deeper comprehension of the subject matter. This encompasses fostering students' competence in elucidating specific concepts or ideas, including their ability to express themselves using visual imagery and symbols, and training them to relate mathematical concepts to everyday scenarios.

2.3. Self-Regulated Learning Skills

Self-regulation refers to an individual's ability to control and organize personal learning processes. This ability is important for assisting students in comprehending and assimilating the topic matter [20]. Self-regulation makes learning more purposeful and helps students reach their learning objectives more effectively. Self-regulation abilities are essential for learning mathematics in primary school. Students may need to self-regulate their learning process to comprehend the subject because mathematics incorporates abstract concepts. In managing their knowledge of mathematics learning, self-regulated learning skills (SRLS) become the major support [33].

Creating SRLS is essential, especially when instructing a high abstraction level of arithmetic. Identifying and applying the strategies required to meet their learning objectives aids students in having a good learning experience. Additionally, it lays the groundwork for students to thrive in their subsequent educational endeavors. Students learn to organize themselves, manage their time, identify effective learning strategies, and monitor their learning progress. This process provides students with powerful tools to face complex learning challenges. Overall, self-regulation plays an important role in learning mathematics, and the development of SRLS is a key factor in students' success in understanding abstract concepts [34].

2.4. Team-Assisted Individualization Learning Model (TAI)

The application of the cooperative learning model in practice prioritizes the formation of student groups. The fundamental principle underlying these group formations is to ensure a diverse range of abilities among group members. In certain instances, these groups should also encompass students from diverse racial, cultural, and ethnic backgrounds, all while ensuring gender equality is maintained [35]. This cooperative learning approach instills the importance of cooperation and collaboration, leading to a positive impact on the development of students' social skills. According to Arrahim, et al. [21], this model not only aids in comprehending intricate concepts but also fosters critical thinking skills and the ability to work collaboratively, benefiting classmates. This methodology has the potential to enhance students' problem-solving in mathematics, communication, and self-reliance abilities.

The team-assisted individualization (TAI) model represents a form of cooperative learning. Within the TAI approach, proficient students take on the role of mentors for their peers who may be encountering difficulties in group settings. In this method, the teacher assumes the role of a facilitator and mediator, creating a conducive learning environment [36]. The TAI model promotes peer assistance within groups and cultivates a healthy sense of competition while also highlighting the significance of individual contributions alongside collaborative elements.

This educational process can be delineated into eight stages: (a) initial assessment; (b) group formation; (c) study clusters; (d) students with innovative insights; (e) group-based learning; (f) objective evaluations; (g) team evaluations and acknowledgments; and (h) lesson modules. Each phase within the TAI model can elicit aspects of mathematical problem-solving, communication skills, and self-regulated learning in all students across the class. The team-assisted individualization learning model boasts advantages for both teachers and students who collaborate on academic tasks. Those who grasp concepts more swiftly than their peers are encouraged to assist those progressing at a slower pace, thus enabling all students to fully nurture their talents and competencies.

3. Methodology

3.1. Research Design

This study uses quantitative methodology by applying a quasi-experimental approach involving two groups, namely the Experimental Group (EG) and the Control Group (CG). A quasi-experimental design is a research approach that does not rely on random assignment but rather utilizes pre-existing groups as research subjects [37]. Specifically, this study focused on three main variables, namely mathematical problem-solving ability, ability to communicate in a mathematical context, and self-regulated learning skills (SRLS). As a starting point for this study, a quasi-experimental method was used to look at how the Team-Assisted Individualization (TAI) Cooperative Learning model affected the three factors in primary school math learning.

3.2. Participant

Purposive sampling was chosen as the sample method for the research, keeping a set of criteria in mind [38]. A total of 64 students participated in the study in an elementary school in Tomohon City, North Sulawesi Province, with 32 of them divided equally between the Experimental Group (EG) and the Control Group (CG). Cluster random sampling was used to choose the participants for the EG and CG. While the control group received training using conventional teaching techniques, the experimental group used the Team-Assisted Individualization (TAI) learning model. In order to undertake team-assisted individualization, small research groups of six students each were formed.

3.3. Data Collection Tools

In this study, data collection involved the utilization of a testing instrument designed to evaluate proficiency in "mathematical problem-solving," "mathematical communication," and the "Self-regulated learning skill (SLRS)."

Assessment of Problem-Solving Proficiency. To evaluate the problem-solving ability of elementary school students in mathematics, a problem-solving proficiency assessment was administered. This assessment comprised a set of 10 essay-style questions, with each question allocated a maximum score of 10 points. The total score for the assessment could range from

0 to 100. Prior to utilization in data collection, the questions underwent rigorous testing for validation. Initially, a draft containing 15 problem-solving questions was subjected to review by grammar and mathematics educators, along with assessment and evaluation specialists. Following expert input, the set was refined to ten problem-solving questions deemed adequate and suitable for generating meaningful results. Subsequently, these questions underwent validation and reliability testing. The validation process was employed to ensure the precision and accuracy of the measurement instrument in fulfilling its intended function. Additionally, a reliability assessment was conducted to gauge the consistency of measurement outcomes [39, 40].

Assessment of Mathematical Communication Proficiency. An assessment focusing on the mathematical communication skills of elementary school students was implemented to gauge their proficiency in this domain. Evaluations of mathematical communication ability hold significance in assessing students' grasp of mathematical concepts, their ability to tackle real-world problems, and their application of mathematical principles across various disciplines. This particular assessment included 5 essay-style questions, each carrying a point value of 20. Prior to implementation, these questions were subjected to validation and reliability testing, involving a sample of 15 students, to ensure the credibility and consistency of the assessment instrument.

Self-regulated learning scale. The Self-regulated learning scale instrument was developed by Eryılmaz and Mammadov [41], drawing inspiration from Zimmerman's self-regulation model. This measurement tool encompasses three dimensions: Foresight, Performance, and Self-reflection. Scoring is executed via a Likert scale, with ratings ranging from 1 = very inappropriate, 2 = inappropriate, 3 = appropriate, and 4 = highly appropriate. The reliability of this instrument, as assessed by Cronbach's Alpha, yielded coefficients of 0.76 for the foresight dimension, 0.82 for the performance dimension, and 0.71 for the self-reflection dimension. These findings affirm the instrument's high level of reliability. Elevated scores on the scale are indicative of students possessing a strong proficiency in Self-Regulated Learning Skills (SRLS)."

3.4. Data Analysis

In this study, the mathematical problem-solving ability (MPSA), mathematical communication ability (MCA), and self-learning ability (SLRS) of students in the Experimental Group (EG) and Control Group (CG) were examined before the experiment through a pre-test. Furthermore, a post-test was conducted after the treatment was given to both groups. To evaluate significant differences between the two groups, analysis of covariance (ANCOVA) was used. A study using ANCOVA was done to see if there was a noteworthy distinction between the post-test scores of the Experimental Group (EG) and the Control Group (CG) in a design with a pre-test and post-test control group [42].

4. Result and Discussion

4.1. Result

4.1.1. Mathematical Problem-Solving Ability (MPSA)

The first objective of this study is to answer the problem formulation, namely, "Does using the Team-Assisted Individualization (TAI) learning model affect students' problem-solving ability?" The results of the data analysis resulted in the mean and standard deviation of the scores in both classes, detailed in Table 1.

Table 1.
The statistical result for students' problem-solving ability.

Group	Pre-test			Post-test		
	N	$\bar{x}$	SD	N	$\bar{x}$	SD
Experimental (EG)	32	46.75	8.43	32	85.38	15.43
Control (CG)	32	43.29	11.29	32	73.40	12.54

From the results of Table 1, it can be seen that there was an increase in the average problem-solving ability in both groups, namely the experimental group (EG) and the control group (CG). In the EG group, the ability to understand problems has increased, with an average pre-test of 46.75 and increasing to 85.38 in the post-test. Similarly, the CG group experienced an increase in problem-solving ability, where the pre-test average of 43.29 increased to 73.40 in the post-test. The findings also indicated that students taught using the Team-Assisted Individualization learning paradigm demonstrated greater improvement in their ability to solve problems. An analysis of covariance was conducted to test the significant difference between the pre-test and post-test problem-solving ability scores in both groups. Information about statistical data and covariance analysis results can be seen in Table 2.

Table 2.
ANCOVA results for students' problem-solving ability.

Source of variance	Sum of square	Degree of freedom (df)	Mean square	F	Significance level (P)
Pre-test	88.402	1	88.402	15.345	0.000
Group	42.723	1	42.723	9.175	0.007
Error	141.250	61	2.316		
Total	3,486.400	64			

Table 2 presents the outcomes derived from the Analysis of Covariance (ANCOVA) investigation conducted in this research. This data analysis method involved the adjustment of students' pre-test scores in problem-solving abilities. The p-value serves as a crucial indicator to ascertain the presence of a significant disparity in the post-test results for problem-solving abilities within the respective groups. The analysis results reveal a notable discrepancy in the post-test performance concerning students' problem-solving abilities. An F statistic value of 9.175, with a significance level of 0.007, surpasses the predetermined threshold of 0.050 and further supports this observation. The F value, utilized in ANCOVA analysis, quantifies the disparity between groups after controlling for pre-test scores. With the robust statistical analysis affirming the substantial difference, it can be concluded that the Team-Assisted Individualization learning model has effectively contributed to enhancing students' problem-solving abilities, even after accounting for pre-test scores.

4.1.2. Mathematical Communication Ability (MCA)

The second objective of this study is to answer the problem formulation, namely, "Does using the Team-Assisted Individualization (TAI) Learning Model affect students' mathematical communication?" The results of the data analysis resulted in the mean and standard deviation of the scores in both classes, detailed in Table 3.

Table 3.
The statistical result for students' math communication ability.

Group	Pre-test			Post-test		
	N	$\bar{x}$	SD	N	$\bar{x}$	SD
Experimental (EG)	32	39.19	21.21	32	76.43	15.81
Control (CG)	32	42.11	18.87	32	64.21	23.74

From the results of Table 3, it can be seen that there was an increase in the average mathematical communication ability in both groups. In the EG group, mathematical communication ability increased, with an average pre-test of 39.19, which increased to 76.43 in the post-test. Similarly, the CG group experienced increased mathematical communication ability, where the pre-test average of 42.11 increased to 64.21 in the post-test. The results also revealed that students who used the Team-Assisted Individualization learning approach experienced a greater improvement in their mathematical communication abilities. An analysis of covariance was conducted to test for significant differences between the pre-test and post-test mathematical communication ability scores in both groups. Information regarding statistical data related to the covariance analysis results can be seen in Table 4.

Table 4.
ANCOVA results for students' mathematical communication ability.

Source of variance	Sum of square	Degree of freedom (Df)	Mean square	F	Significance level (P)
Pre-test	103.251	1	103.251	24.190	0.000
Group	152.498	1	152.498	12.966	0.010
Error	274.167	61	4.495		
Total	6,358.992	64			

Table 4 presents the results of the analysis of covariance (ANCOVA) related to students' ability in mathematical communication. ANCOVA was conducted by considering the pre-test scores to check for statistically significant differences in the post-test results. The data results in Table 4 show that the significance values recorded were below the 0.05 threshold. As indicated by [$F(1,61) = 12.996$; $p = 0.010 < 0.05$], there was a statistically significant difference in the post-test results between the two groups. The obtained F statistic of 12.996 measures the extent of the influence of the pre-test scores on this difference, with a significance level of 0.010, further reinforcing the conclusion that this difference is statistically significant. Therefore, it can be concluded that the Team-Assisted Individualization learning model effectively improved students' mathematical communication skills after considering the pre-test scores, in accordance with the findings of the analysis of covariance documented in Table 4.

4.1.3. Self-Regulated Learning Skill (SRLS)

The third objective of this study is to answer the problem formulation, namely, "Does using the Team-Assisted Individualization (TAI) Learning Model affect students' Self-Regulated Learning Ability?" The results of the data analysis resulted in the mean and standard deviation of the scores in both classes, detailed in Table 5.

Table 5.
The statistical result for students' self-regulated learning skills.

Group	Pre-test			Post-test		
	N	$\bar{x}$	SD	N	$\bar{x}$	SD
Experimental (EG)	32	119.84	21.48	32	132.11	25.81
Control (CG)	32	123.04	24.90	32	109.43	27.34

Table 5 displays data illustrating the mean scores of Self-Regulated Learning Skills (SRLS) within the experimental group (EG) and the control group (CG). Notably, the initial average pre-test SRLS score for EG students was 119.84, and this score rose to 132.11 following their exposure to the Team-Assisted Individualization learning model. Conversely, in the control group, the initial average of 123.04 declined to 109.43.

Moreover, when comparing the average SRLS scores between the two groups during the pre-test phase, it becomes evident that the SRLS averages were nearly identical. However, during the post-test phase, more pronounced disparities emerged. While the experimental group exhibited an increase in their average SRLS score, the control group's average score experienced a decline. This phenomenon underscores the positive influence of the Team-Assisted Individualization learning model on SRLS within the experimental group, whereas conventional learning led to a decrease in the average score for the control group.

To examine the SRLS scores of both groups, an analysis of covariance was employed, with pre-test results as a controlling factor. A comprehensive presentation of the results from this analysis of covariance, which plays a pivotal role in establishing the significance of the SRLS score differences between the two groups, is provided in Table 6."

Table 6.
ANCOVA results for students' self-regulated learning skill.

Source of variance	Sum of square	Degree of freedom (Df)	Mean square	F	Significance level (P)
Pre-test	9678.211	1	9678.211	23.010	0.000
Group	5287.439	1	5287.439	11.572	0.007
Error	13,148.787	61	215.554		
Total	30,402.521	64			

The data presented in Table 6 has been further analyzed to evaluate whether there is a difference in post-test scores between students in the experimental group (EG) who received instruction using the Team-Assisted Individualization learning model and students in the control group (CG) who followed conventional instruction. By conducting the ANCOVA test, we can gain a deeper understanding of the effectiveness of these two learning models in improving students' SRLS.

The results of the analysis showed that the calculated significance values were below the set significance level of 0.05. When considering the effect of the pre-test scores on the SRLS scale, a significant difference in the post-test scores between the two groups became apparent [$F(1.61) = 11.572$; $p = 0.007 < 0.05$]. This confirmed that the Team-Assisted Individualization learning model significantly improved students' SRLS in the experimental group, exceeding the impact of the conventional learning model used in the control group. The findings from this analysis provide strong evidence that a learning model that emphasizes individualization can effectively promote the development of students' independent learning skills.

4.2. Discussion

The main objective of this study was to evaluate the impact of the Team-Assisted Individualization (TAI) Cooperative Learning model on three important dimensions, namely problem-solving ability, mathematical communication, and self-learning skills, among elementary school students. To achieve this objective, a quasi-experimental research design was used. The results showed that applying the TAI learning model in mathematics significantly improved all three abilities in elementary school students: problem-solving ability, mathematical communication ability, and self-regulated learning skills.

A number of studies in the literature have also investigated the impact of the TAI learning model in mathematics. However, most of these studies have not comprehensively investigated specific aspects. For example, Argianti, et al. [17] showed in their study that the application of the TAI learning model improved mathematical reasoning ability in junior high school students, outperforming the results obtained from the direct learning model. Similar conclusions were also found by Arrahim, et al. [21], who highlighted the improvement of students' conceptual understanding at the elementary school level through the application of the TAI model.

Furthermore, Wilujeng, et al. [43], in their research, reported that the TAI model equipped with Ludo media was effective in improving learning outcomes in fraction materials. The results of Putri and Fitria [22] also showed a positive impact on student learning outcomes through the TAI learning model. In addition, Yarmasi, et al. [44] highlighted the positive effect of TAI cooperative learning equipped with interactive media compared to conventional learning methods. Although a large number of studies have illustrated the potential efficacy of the Team-Assisted Individualization learning model, further, more in-depth investigations are needed to explore specific dimensions such as problem-solving ability, mathematical communication, and self-learning skills.

4.2.1. Team-Assisted Individualization Learning Model Affects the Problem-Solving Ability of Elementary School Students

In the first sub-objective, the Team-Assisted Individualization (TAI) learning model is a practical approach to improving problem-solving skills in elementary school students. This improvement can be noted from the research results in Table 2, where there is a significant difference between the experimental and control classes' post-test results, which have been controlled with the pre-test results. Furthermore, Table 1 also shows an increase in the pre-test and post-test results of students who follow the Team-Assisted Individualization learning model. This model significantly benefits developing problem-solving skills by emphasizing individual-centered learning while promoting group work. Through collaboration in small groups, students can support and interact with each other, strengthen their understanding of mathematical concepts, and develop analytical and problem-solving skills to deal with various mathematical challenges [45, 46]. This approach also provides opportunities for teachers to provide more focused guidance and assistance to each student according to their learning needs [47, 48].

Several studies have shown the potential of the Team-Assisted Individualization (TAI) Cooperative Learning model in improving problem-solving skills. For example, research conducted by Arrahim, et al. [21] focused on the problem-solving skills of 4th grade students. The results revealed that about 89% of students experienced increased problem-solving skills after being treated with the Team Assisted Individualization learning model. Furthermore, Neka, et al. [49], in a study that examined the effectiveness of the Team Assisted Individualization learning model in improving the mathematical problem-solving skills of elementary school students, noted that students who learned through TAI-type cooperative learning had better mathematical problem-solving skills than students who followed the conventional approach, without considering students' learning motivation.

Tauran [50] also applied the Team Assisted Individualization learning model to improve high school students' "reasoning" ability, which is an important aspect of problem-solving ability. Furthermore, Marasabessy, et al. [51], in a study involving fourth-semester students in a mathematics education study program, found a significant increase in students' mathematical critical thinking skills after applying the Team Assisted Individualization type cooperative learning model.

Although some studies show that applying the Team Assisted Individualization learning model can improve problem-solving skills, differences in the research context need to be noted. The studies reviewed in this literature involve subjects with educational levels ranging from high school to university. Although some studies involved elementary school students, it should be noted that they mostly focused on one variable, namely problem-solving ability. The research results and literature review concluded that the Team-Assisted Individualization learning model can enhance problem-solving ability by creating an inclusive and interactive learning environment, facilitating the development of crucial problem-solving skills.

4.2.2. Team-Assisted Individualization Learning Model Affects the Mathematics Communication Ability

The implementation of the Team-Assisted Individualization (TAI) learning model has proven to have a significant positive impact on students' mathematical communication skills. This can be observed through the data in Table 3, which shows increased students' communication skills when learning with the TAI model. In addition, Table 4 provides additional information that the ANCOVA statistical test results show a significant difference between the experimental class that received learning with the TAI model and the control class. Noticeable improvements were made in students' mathematical communication through this learning model, including their ability to convey mathematical ideas orally and in writing in a clear and organized manner and demonstrate mathematical concepts visually.

In addition, students also progressed in understanding, interpreting, and evaluating mathematical ideas more effectively in oral communication. The Team-Assisted Individualization learning model provides opportunities for students to become more proficient in using mathematical terms and notation and utilizing mathematical structures in presenting ideas and describing relationships and situations from the models they study [52]. The more dominant interaction in this learning, especially through forming small groups, encourages students to communicate mathematically when solving challenging mathematical problems. This is particularly beneficial for students with lower communication skills, as they can learn from interactions with peers with higher communication skills. Conversely, students who are more adept at communicating can further hone their skills by helping their group mates [53, 54].

A number of other studies also provide support for these findings. For example, Tinungki, et al. [23], in their research, reported that the application of the Team-Assisted Individualization learning model specifically improved students' mathematical communication skills, including those with high, medium, or low initial mathematical abilities. Similar findings were also revealed in a study by Saputra [55], who found that the TAI learning model approach with a scientific approach provided more positive results in the development of students' mathematical communication compared to the direct learning approach.

Furthermore, research by Marasabessy and Qohar [56] highlighted the advantages of students' mathematical communication in cooperative learning (TAI) in the Introduction to Algebra course. Their findings show that this learning model effectively improves students' ability to convey and interact with mathematical concepts in a clear and structured manner. This learning model's active and collaborative small group interactions encourage students to share mathematical understanding and solutions and enrich their communication skills.

Overall, based on the various results of this study, it is clear that applying the Team-Assisted Individualization learning model significantly improves students' mathematical communication skills. However, it is important to note that these studies were mainly conducted on college- or university-level students. This model still provides opportunities for students to participate more actively in the learning process, interact with each other, and hone communication skills, which are very important in expressing and understanding mathematical concepts. Therefore, TAI positively contributes to developing students' mathematical communication skills by providing a supportive and interactive learning environment [57].

4.2.3. Team-Assisted Individualization Learning Model Affects the Self-Regulated Learning Skills

The application of the Cooperative Learning model type, Team-Assisted Individualization (TAI), proved to have a significant impact on improving students' Self-Regulated Learning Skills (SRLS), as seen in the data in Table 5, which reflects the increase in pre-test and post-test results in the experimental class. On the other hand, the control class experienced a decrease in Self-Regulated Learning Skills (SRLS). The lack of opportunities for students to engage in self-exploration in conventional learning may be at the root of this decline in SRLS abilities.

Table 6 provides additional information that the ANCOVA test results show a significant difference between the class that applied the TAI model and the class that followed conventional learning. This significant difference arises because, in small groups, students can be actively involved in the learning process, thus encouraging them to organize and manage their own learning. Collaboration in small groups allows students to plan, monitor, and evaluate their learning progress more effectively while helping them overcome learning challenges and obstacles. As a result, students can develop important skills such as time management, self-motivation, and effective learning strategies.

Then, if we look at the results of previous literature studies, research on the impact of the Team-Assisted Individualization learning model on students' SRLS is still limited. For example, research conducted by Yoon, et al. [58] noted the positive impact of the Self-Regulated Learning model on undergraduate students. They found that the flipped classroom model significantly improved aspects of SRLS compared to the classical learning model. Although the Team-Assisted Individualization learning model can improve Self-Regulated Learning ability, there is a need for further research that is more comprehensive and in-depth, especially in elementary school students, to better understand the impact of the Team-Assisted Individualization learning model on the development of students' Self-Regulated Learning ability as a whole. This further research will provide a deeper understanding of the potential of TAI implementation in improving students' SRLS at various levels of education.

5. Conclusion

This study successfully tested the impact of the Team-Assisted Individualization (TAI) Cooperative Learning Model on three aspects of mathematics learning at the primary school level, namely mathematical problem solving (MPSA), mathematical communication ability (MCA), and Self-Regulated Learning Skills (SLRS). The results of the data analysis concluded that the TAI learning model significantly improved mathematical problem-solving skills in the experimental group compared to the control group. This occurs through collaboration in small groups where students support each other, interact, strengthen their understanding of mathematical concepts, and develop analytical and problem-solving skills in facing mathematical challenges.

The improvement in mathematical communication skills in the experimental group was also more striking when compared to the control group. Collaboration in small groups allowed students to convey mathematical ideas orally and in writing, which improved their mathematical communication skills. In addition, the results showed that the Self-Regulated Learning Skill (SRLS) of the experimental group was far superior compared to the control group. Collaboration in small groups allows students to plan, monitor, and evaluate their learning progress more effectively while helping them overcome learning challenges and obstacles. As a result, students can develop important skills such as time management, self-motivation, and effective learning strategies.

These findings confirm that the Cooperative Learning Model with the Team-Assisted Individualization approach has great potential for developing three aspects: mathematical problem-solving ability, mathematical communication, and Self-Regulated Learning Skills. Therefore, the results of this study provide an overview for further research on the Team-Assisted Individualization learning model as one of the interesting alternatives to improve the quality of mathematics learning in elementary schools. By understanding more deeply how this model can be implemented more widely and effectively, educators and researchers can better utilize its potential to help students progress in mathematical problem-solving, communication skills, and the ability to manage learning independently.

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