



Development of The STAD Cooperative Learning Model : Enhancing Mathematical Reasoning and Communication Skills in Higher Education

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Abstract: This study aims to develop the STAD cooperative learning model specifically designed for mathematics education in a higher institution to impact students' reasoning and communication skills. The study holds significance in its comprehensive analysis, encompassing (1) Plomp Stage 1 Schematic: Preliminary Study; (2) Plomp Stage 2 Schematic: Development Study; and (3) Plomp Stage 3 Schematic: Assessment Study of the developed STAD learning model. The method employed was Research and Development (R&D), utilizing questionnaires, tests, and observations as data collection techniques. The present research involved students at a university in Padangsidempuan, North Sumatra, Indonesia. The analysis techniques used were inferential statistics and descriptive statistics. The findings indicated that: (1) The preliminary study of the model was conducted based on needs analysis incorporating the curriculum, student, and learning materials; (2) The model's development study, encompassing six phases, yielded a significant validation result of 3.84, categorized as 'Good'; (3) The assessment study, in terms of practicality, obtained a score of 4.60 (considered 'Good'), and effectiveness demonstrated positive significance in affecting students' reasoning and communication skills. The overarching conclusion drawn is that the research and development of the STAD learning model revealed significant positive impacts on students' reasoning and communication skills.

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Introduction

The cooperative learning model, STAD (Student Teams Achievement Division), is one of the numerous learning models that can be utilized in education (Sirait et al., 2024). It is developed by Slavin (1980) at Johns Hopkins University (Abdullah et al., 2018). Several researchers believe the STAD model can significantly encourage student interaction regarding subjects and improve their interpersonal skills (Narzoles, 2015; Khan, 2011). Implementing this learning approach is one method teachers can use to enhance learners' mathematical reasoning abilities (Zakaria & Amidi, 2020).

Many scholars emphasize the definition of mathematical reasoning, which is a process carried out to obtain a conclusion based on mathematical premises, as well as relevant facts and sources whose truth is assumed (Besar, 2018; Hasanah et al., 2019; Kadioglu et al., 2020). Meanwhile, reasoning ability is one of the higher-order thinking skills that is crucial for students to carefully develop and master carefully (Thompson et al., 2017; Thuneberg et al., 2018). However, much of the literature on mathematics education has revealed that both high school and university students exhibit limited mathematical reasoning abilities (Mukuka et al., 2021). In this regard, their difficulties in developing reasoning skills are often caused

by a lack of understanding of concepts and challenges in reasoning abilities (Isnaeni et al., 2018; Astuty et al., 2019).

Researchers found that sixth-grade students at Traimit Pattana Suksa School had limitations in problem-solving and mathematical reasoning skills, attributed to how the teachers organized their learning activities (Seepiwsiw & Seehamongkon, 2023). Likewise, research results in several countries, including Turkey, indicated that the scientific reasoning of eighth-grade students remained notably low (Gunhan, 2014). Despite mathematics playing a crucial role as a foundation for logic, reasoning, and quantitative solutions applicable to other subjects (Pahrudin et al., 2020), the primary goal of its teaching is to help students develop their reasoning abilities (Norqvist et al., 2015). Accordingly, numerous scholars assert that learners' reasoning abilities strongly correlate with their mathematical communication skills (Teledahl, 2017; Otoo, 2018; Palinussa et al., 2021).

The general perception of mathematics is often synonymous with calculating numbers and formulas, leading to the misconception that communication skills cannot be fostered in mathematics learning (Rohid & Rusmawati, 2019). However, such skills play a crucial role as avenues for exchanging ideas and tools to clarify students' understanding and grasp mathematical concepts correctly (Pourdavood & Wachira, 2015; Dewi et al., 2021). One practical approach to enhancing students' mathematical communication skills is implementing a relevant learning approach (Trisnawati et al., 2018). Hence, cooperative learning is believed to be helpful for students in this context (Ardiyani et al., 2018).

The intricate connection between students' reasoning and communication skills is rooted in regulatory principles. As outlined in the Minister of National Education Regulation Number 22 of 2006, mathematics teachers must be adept at facilitating effective mathematics learning to ensure that students comprehend mathematical concepts, apply reasoning, solve problems, and communicate their ideas (Muthmainnah & Marsigit, 2018; Sa'adiah et al., 2021). Educators who adhere to traditional teaching methods and assign routine tasks when assessing students impede the development of highly desired mathematical competencies, such as conjecturing, justifying, and reasoning (Tejeda & Gallardo, 2017; Mukuka et al., 2021). Therefore, teaching innovations are essential to achieve significant benefits. In addressing the complexity of existing problems, the present research focused on developing the STAD model to positively impact students' cognition and skills, thereby improving their mathematical reasoning and communication skills in the classroom. This innovative role model was based on bibliometric analysis results conducted using VOS Viewers with the keyword "Mathematical learning," referencing 4705 papers through 150 terms for the exact 10 keywords in a paper, as visualized in Figure 1.

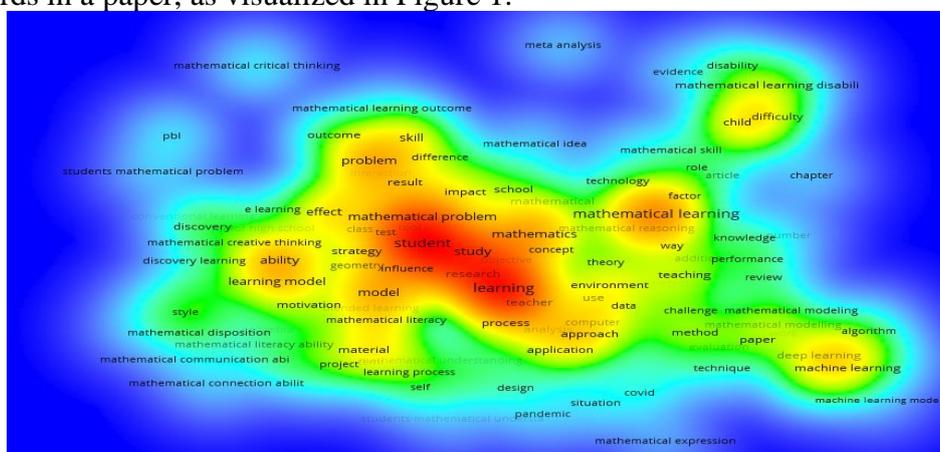


Figure 1. Bibliometric Analysis of "Mathematical Learning"

The analysis results revealed a notable gap in the research landscape spanning a decade (2014-2024), as reflected in publications on *Google Scholar*. Specifically, there appeared to be a limited exploration of communication and reasoning skills, evident in the relative paucity of keywords associated with these focal points. Consequently, this analysis highlighted an opportunity for innovation, proposing the development of the STAD learning model to enhance students' reasoning and communication skills within the context of mathematics learning. The outlined research objectives were structured following the stages of (1) Preliminary Study (Plomp Stage 1 Schematic), (2) Development Study (Plomp Stage 2 Schematic), and (3) Assessment Study (Plomp Stage 3 Schematic). It is hoped that this research can improve Reasoning and Communication Skills through the development of the STAD cooperative model of mathematics learning in higher education.

Research Method

The research employed a Research and Development approach, utilizing a schematic design to develop the Plomp model. This process unfolded through three stages: preliminary study, development study, and assessment study (Van den Akker et al., 2006). The method used in experimental research is to test the development of previously developed models to improve reasoning and communication skills.

As previously explained, the schematic used by the Plomp design was specifically outlined as follows:

- a) Plomp Stage 1 Schematic: The preliminary study marked the initial step, focusing on identifying the significance and alignment of the problem. It involved needs analysis, curriculum assessment, student evaluation, and analysis of the developed materials.
- b) Plomp Stage 2 Schematic: The development study represented the second phase, encompassing the design process of the STAD cooperative learning model. It was subsequently verified by experts who reviewed the theoretical development of the model.
- c) Plomp Stage 3 Schematic: The assessment study constituted the final stage, evaluating the practicality of the model output and its effectiveness in enhancing student communication and reasoning.

The data collection techniques employed in this research encompassed:

- a) Observation: Utilized to gather primary and secondary data, such as observation sheets assessing student communication skills.
- b) Test Instruments: Employed to collect primary data, specifically focusing on identifying students' reasoning abilities.
- c) Questionnaire: Distributed to gather primary data, including validity assessments from experts regarding model evaluation, student responsiveness, and the practicality of model use.

The development of research instruments served as a validation of the tools employed in data collection, such as test instruments conducted using SPSS to assess the criteria and validity of an instrument designed for measuring students' reasoning abilities, as presented in Table 1.

Table 1. Test Instrument Development

Item	Validity			Cronbach's Alpha		Question Difficulty		Question Differentiation	
	r-count	r-table	Criteria	Result	Criteria	Result	Criteria	Result	Criteria
1	0.695	0.444	Valid	.652	Reliability (Moderate)	0.9	High	0.3	Adequate
2	0.663	0.444	Valid			0.5	Moderate	0.4	Good

3	0.528	0.444	Valid	0.7	Moderate	0.3	Adequate
4	0.692	0.444	Valid	0.6	Moderate	0.4	Good
5	0.648	0.444	Valid	0.5	Moderate	0.4	Good

The data analysis techniques used are specifically presented in Table 2.

Table 2. Research Data Analysis Techniques

Stages	Activities	Data Analysis Techniques	Respondents	Data Analysis
Preliminary Study	Needs Analysis	Observation Sheet	Lecturer	Qualitative Descriptive
	Curriculum Analysis	Documentation	-	
	Student Perspective Analysis	Observation Sheet	Students	
	Material Analysis	Documentation	-	
Development Study	Model Design	Literature Review	-	Descriptive Statistics
	Validate with Experts	Questionnaire Sheet	Lecturer	
Assessment Study	Model Practicality	Questionnaire Sheet	Students	Descriptive Statistics
	Model Effectiveness	Test	Students	Inferential Statistics (t-test)

Results and Discussion

1) Plomp Stage 1 Schematic: Preliminary Study

In the first stage, several schemes were implemented to collect data, including needs analysis incorporating educators, curriculum evaluation, student perspectives, and material analysis.

Analysis of Educator Needs

The analysis of educator needs obtained from field observations revealed that current mathematics learning still relied on conventional method. Specifically, basic mathematics learning centered on lecturer merely imparting knowledge to students. Moreover, the learning process deviated from the formulated stages despite lecturers preparing SAP per the *KKNI* Curriculum.

Observations further indicated that the learning resources utilized consisted of several books from lecturers. However, they could not effectively activate students' reasoning, communication, and critical thinking abilities. Considering these findings, there was recognized importance in developing a learning model to guide lecturers in implementing processes to foster the construction of students' basic mathematical knowledge, enabling them to think logically, critically, and systematically.

Curriculum Analysis

The objective at this stage was to identify the curriculum used as a reference for implementing basic mathematics learning in the Chemistry Study Program at UIN Syahada Padangsidempuan. The curriculum employed was the *KKNI* curriculum, which encompassed eight stages, including (1) Determining the graduation profile; (2) Formulating learning outcomes; (3) Formulating competencies for study materials; (4) Mapping learning outcomes of study materials; (5) Packaging courses; (6) Preparing curriculum framework; (7) Preparing curriculum lecture plans, serving as the primary reference for lecturers to design and formulate lecture units; and (8) Carrying out learning process and evaluations. Regardless, basic mathematics learning activities in the classroom did not entirely align with the *KKNI*

Curriculum. Specifically, in-group learning and the STAD cooperative learning approach implementation to master skills in reasoning and communication were not fully applied.

Student Perspective Analysis

The student analysis examined the characteristics of learners with diverse backgrounds, mathematical knowledge, and reasoning and communication abilities. In this regard, the Chemistry Study Program students exhibited varying levels of knowledge: high, medium, and low. Additionally, their ability to reason and communicate was generally considered low. It was evident when solving problems, expressing opinions, and asking questions, as these activities were not consistently performed accurately and comprehensively.

Material Analysis

At this stage, the researchers analyzed teaching materials, specifically equations, inequalities, and logic, considering they were related to basic statistics courses and directly applicable to everyday life. While studying basic mathematics necessitates logical thinking and the ability to make informed decisions, the analyzed materials did not facilitate a relevant, in-depth understanding. Consequently, students were perceived to lack proficiency in logical and systematic thinking.

2) Plomp Stage 2 Schematic: Development Study

Several stages in the schematic model development were carried out, such as designing the output model and subsequently validating it with experts. The process is explained as follows.

Development Study: Design of the STAD Cooperative Learning Model

At this development stage, greater emphasis was placed on designing the STAD cooperative learning model. This design comprised six stages based on specific considerations, as visualized in Figure 2.

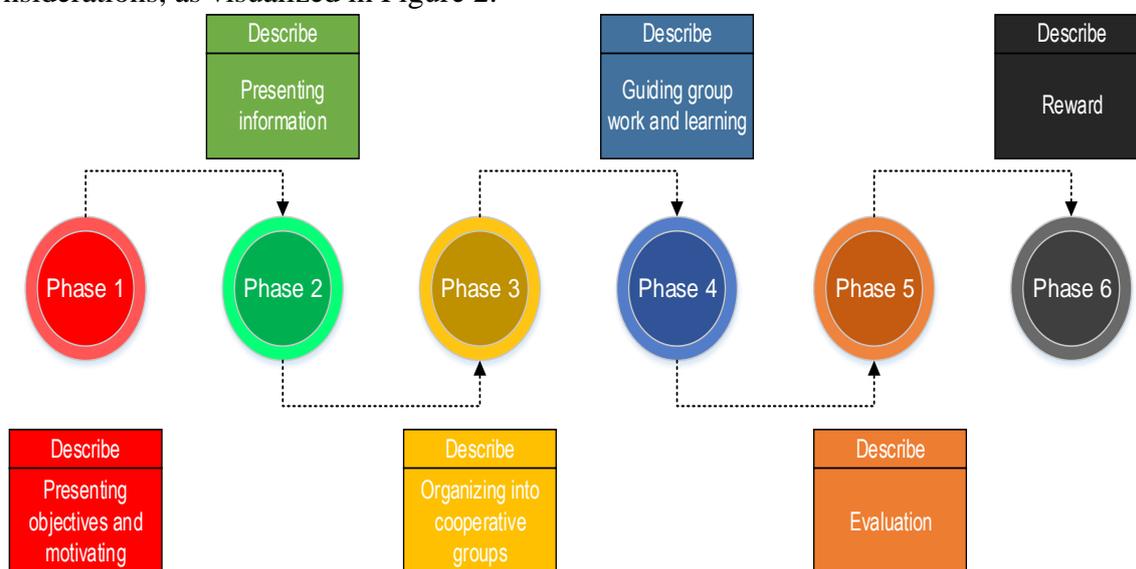


Figure 2. STAD Cooperative Learning Model

Development Study: Validation of the STAD Cooperative Learning Model

During this stage, development was executed through the review of expert validation, which assessed various indicators, including linguistic and pedagogical aspects, suitability of the STAD model materials, alignment with basic competencies, and aspects of the STAD model design. The results obtained are illustrated in Figure 3.

Expert Validation Assessment Results

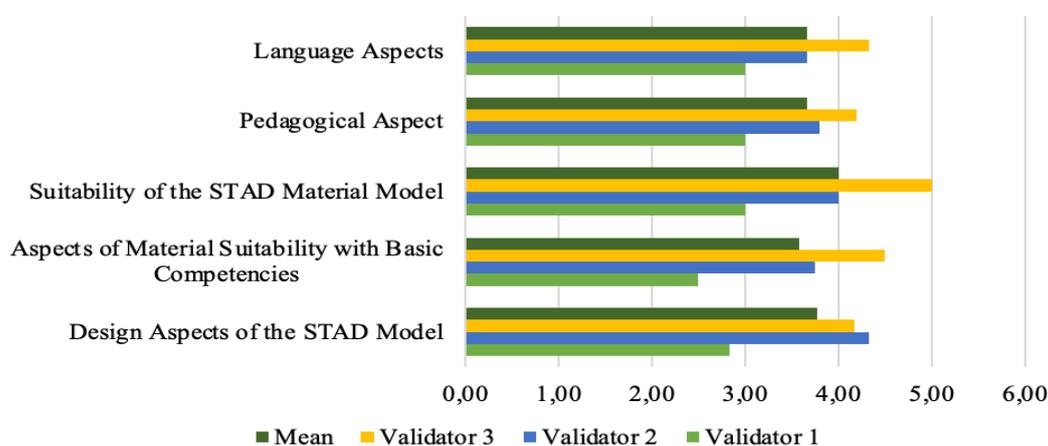


Figure 3. Expert Validation of the STAD Cooperative Learning Model

Based on the recapitulation of model validation results in the table above, each assessment aspect demonstrated an average value falling within the 'good' category. The overall average score for the validator assessment was 3.84, placing the developed model within the 'good' category, thereby validating its effectiveness. Moreover, the collective conclusion reached by the three validators affirmed the model's validity, albeit with minor revisions, and recommended its progression to the subsequent validation stage, classifying the model as 'very good.' The evaluation of the STAD cooperative learning model by the validators indicated that the developed learning model fell within the valid category. However, certain revisions were required in alignment with the suggestions provided. The following summarizes the recommendations from each validator and outlines the necessary improvements for the subsequent revision of the STAD cooperative learning model.

Recommendations for Improvements 1:

"....The presentation cover of the model should incorporate attractive colors and align the theoretical basis with the STAD..." This improvement can be achieved by creating an appealing cover design and ensuring alignment with the theoretical basis.

Recommendations for Improvements 2:

"....Enhance the readability of the model by diversifying the writing style and correlating STAD steps with the materials being taught..." To address this recommendation, it was suggested to (1) enhance the writing style for increased interest and readability and (2) incorporate STAD stages closely linked to the relevant materials.

3) Plomp Stage 3 Schematic: Assessment Study

The assessment stage was conducted during the product trial using the STAD learning model across four sessions. This trial aimed to ascertain the practicality and effectiveness of the developed model.

Assessment Study: Practicality of the STAD Cooperative Learning Model

The average results for each indicator measured with the STAD learning model consistently fell within the 'good' category. The mean score across four meetings with students after learning was 4.6, indicating a successful implementation. Additionally, the practicality of the model was evidenced by the positive response from students, with a satisfaction rate of 88.9%, classified as 'good.' In conclusion, the learning model demonstrated practicality, aligning with previous research findings highlighting the Student Teams Achievement Division (STAD) as a widely adopted, practical, and straightforward cooperative learning model in educational settings (Van Wyk, 2013; Supratman et al., 2021).

Assessment Study: Effectiveness of the STAD Cooperative Learning Model

The effectiveness of the learning model provided to students was evaluated through learning tests in basic mathematics courses, focusing on identifying dependent variables such as reasoning ability (Y1) and communication ability (Y2). Figure 4 and Table 3 provide a comprehensive overview of the data.

Graph of Student Ability Development

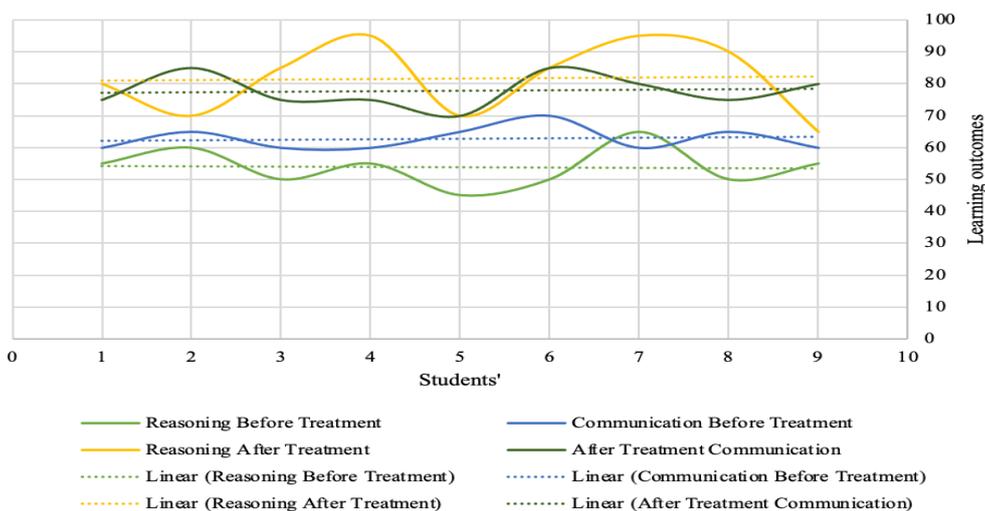


Figure 4. Graph of Student Ability Development
Table 3. Overview of General Impact Analysis

Group Statistics					
	Skills	N	Mean	Std. Deviation	Std. Error of the Mean
Pretest	Reasoning Skill	9	53.89	6.009	2.003
	Communication Skill	9	62.78	3.632	1.211
Posttest	Reasoning Skill	9	81.67	11.180	3.727
	Communication Skill	9	77.78	5.069	1.690

Based on the data above, the effectiveness of the developed model could be gauged through the observable development of students' reasoning and communication skills. This assessment was derived from an examination of the graphical representations and the significance of mean scores associated with each treatment. These findings align with numerous empirical research results emphasizing the positive impact of implementing the STAD model on students' reasoning and communication abilities. This assertion is further substantiated by the outcomes of prior research, presented as follows:

Significance of Reasoning Skill

The impact on students' reasoning skills was evident through the development and implementation of the learning model. In this regard, descriptive analysis revealed a noteworthy increase of 27.78, measured from the pretest to the posttest. The inferential statistics further confirmed this impact, as presented in Table 4.

Table 4. Significance of the Learning Model on Reasoning Skill

One-Sample Test						
Test Value = 0						
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Pretest	26.903	8	.000	53.889	49.27	58.51
Posttest	21.913	8	.000	81.667	73.07	90.26

Interpreting the statistical findings in Table 1 suggests a discernible impact of the application of the developed STAD learning model on students' reasoning skills. The Sig (2-tailed) value of 0.000 (<0.05) underscored the significance of this impact. Furthermore, these results align with previous research, as highlighted by Suyanto (2021), who demonstrated a significant impact of cooperative learning methods on mathematical reasoning abilities.

This correlation is also consistent with the findings of other researchers. For instance, studies by Ramadhani et al. (2019), Benavides-Varela et al. (2020), Klingenberg et al. (2020), Li et al. (2021), and Hidayat et al. (2022) emphasized that the use of self-teaching modules and similar approaches contributed to the enhancement of high-level thinking abilities, including mathematical reasoning.

Significance of Communication Skill

The findings related to another variable suggested an improvement in students' communication skills when utilizing the STAD cooperative learning model. Specifically, there was a significant increase, reaching 15.00, from pretest to posttest activities, as indicated in Table 5. It was also reinforced by inferential statistical analysis conducted using SPSS.

Table 5. Significance of the Learning Model on Communication Skill

	One-Sample Test					
	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
				Lower	Upper	
Pretest	51.848	8	.000	62.778	59.99	65.57
Posttest	46.032	8	.000	77.778	73.88	81.67

The statistical results in Table 2 infer that the scores exhibited positive significance, with the Sig (2-tailed) value being 0.000 or <0.05 . It suggests that employing the STAD cooperative model effectively enhanced students' communication skills, particularly in the context of learning mathematics in the classroom. It aligns with previous research findings, such as Kim (2018), who asserted that the STAD cooperative learning method fostered interaction among students, enabling them to discuss and question each other comfortably, thus naturally motivating them to improve their learning abilities. Similarly, Lee (2015) emphasized that when students articulated their thoughts orally or in writing, it enhanced their understanding of mathematics. Hence, learners' mathematical reasoning could be developed through carefully structured interactions and dialogue (Jensen & Skott, 2022). Building on the study by Serdyukov (2017), a strong understanding of mathematical problems promoted well-developed communication between students, removing limitations. Additional investigations indicated that students comprehended mathematics more easily when their reasoning skills were strong, allowing them to communicate mathematically and give meaning to mathematical symbols (Sumpter & Hedefalk, 2015).

Hayati et al. (2019) discovered that students' mathematical communication contributed to a clearer understanding when addressing mathematical problems. Hence, it is crucial to recognize that an effective communication process in mathematics learning occurs when students can construct knowledge and integrate it into their existing understanding (Trisnawati et al., 2018). It aligns with Mayer (1999), who emphasizes meaningful learning as constructing understanding and integrating mathematical concepts with prior knowledge. Thus, an effective communication process fosters meaningful learning in the classroom teaching and learning process.



The STAD Learning Model: Correlation between Mathematical Reasoning and Communication Skills

The analysis results, indicating the significance between students' reasoning and communication skills, demonstrated a notable correlation. This finding aligns with prior research, which emphasized the importance of classroom interaction, enabling students to collaborate, motivate, and assist each other in comprehending the learning materials to achieve learning goals (Zubaidah, 2013; Supratman et al., 2021). Furthermore, previous studies have shown that students were more likely to articulate their arguments in mathematical problem-solving when they possessed strong mathematical reasoning abilities (Wahyuni et al., 2019; Khainingsih et al., 2020).

Cervantes-Barraza and Sánchez (2022) further highlight that reasoning ability serves as a transversal competency in mathematics learning, supporting the communication of answers through justifying conclusions and linking prior concepts with new ones. It also includes the ability to refute, as students' reasoning is confronted to persuade others of the validity of collectively presented conclusions. Trisnawati et al. (2018) corroborated this idea in their research, stressing the significance of developing students' mathematical communication skills, encompassing the ability to communicate an understanding of concepts, reasoning, and problem-solving known as essential goals in the realm of mathematics learning. Based on the discussion that has been presented, the conceptual implications of the research are to strengthen previous research and/or theory if the development and use of the STAD cooperative model can improve reasoning and communication skills. Meanwhile, practically, the development of this modeling is a reference for dissemination of the outcomes that have been produced for practitioners (lecturers) in implementing learning in higher education.

Conclusion

The result conclude that: (1) The preliminary study of the model was conducted based on needs analysis incorporating the curriculum, student, and learning materials; (2) The model's development study, encompassing six phases, yielded a significant validation result of 3.84, categorized as 'Good'; (3) The assessment study, in terms of practicality, obtained a score of 4.60 (considered 'Good'), and effectiveness demonstrated positive significance in affecting students' reasoning and communication skills.

Recommendation

This research exclusively focused on enhancing students' reasoning and communication skills. Therefore, the researchers recommend that future research endeavors should innovate methodologies, particularly about the dependent variable, incorporating more than two variables. Such an approach seeks to introduce groundbreaking innovations that can significantly impact the realm of research. Meanwhile, the recommendation is for educators (lecturers) to be able to use the model that has been developed as a dissemination activity for the output of research products, to improve students' abilities in their reasoning and communication in class. On the other hand, recommendations for students provide input and suggestions for the resulting model if the context is in terms of the practicality of the model.

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