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Developing a Learning Tool Based on the Problem-Based Learning Model to Improve Students' Problem-Solving and Collaboration Skills

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Abstrak

Penelitian ini bertujuan untuk menciptakan produk alat bantu belajar berbasis model pembelajaran berbasis masalah yang realistis, praktis, efektif, dan ditingkatkan untuk meningkatkan kemampuan pemecahan masalah dan kerja tim siswa kelas VIII SMP WR. Supratman 1 Medan. Teknik penelitian ini mengembangkan alat bantu belajar Thiagarajan, Semmel, yaitu model 4-D (pendefenisian, rancangan, pengembangan, penyebaran). Siswa kelas VIIIA SMP WR. Supratman 1 Medan tahun ajaran 2025/2026 menjadi subjek penelitian. Alat bantu belajar berbasis masalah yang valid dan praktis berdasarkan Rencana Alat Bantu Belajar, Lembar Kerja Siswa, Buku Guru, dan Buku Siswa ditemukan dalam penelitian ini. Kemampuan pemecahan masalah matematika siswa meningkat setelah menggunakan pembelajaran berbasis masalah pada sistem persamaan linear dua variabel, seperti yang ditunjukkan oleh rata-rata 86% pencapaian posttest percobaan I dan percobaan II. Pembelajaran berbasis masalah pada sistem persamaan linear dua variabel meningkatkan kemampuan kolaborasi matematika siswa, seperti yang terlihat dari rata-rata skor mereka pada percobaan I dan II.

Kata Kunci: *Pengembangan Kemampuan Pemecahan Masalah, Kolaborasi Siswa.*

Abstract

This study aims to create a learning aid product based on a realistic, practical, effective, and enhanced problem-based learning model to improve the problem-solving and teamwork abilities of eighth-grade students of SMP WR. Supratman 1 Medan. This research technique, developed by Thiagarajan and Semmel, is a learning aid known as the 4-D model (Define, Design, Develop, Disseminate). Class VIIIA students of SMP WR. Supratman 1 Medan in the 2025/2026 academic year became the subject of the study. Valid and practical problem-based learning aids based on the learning aid plan, Student Worksheets, Teacher's Books, and Student Books were found in this study. Students' mathematical problem-solving abilities increased after using problem-based learning on a system of linear equations with two variables, as shown by an average of 86% achievement in the posttest of experiment I and experiment II. Problem-based learning on a system of linear equations with two variables improved students' ability to collaborate mathematically, as evidenced by their average scores in experiments I and II.

Keywords: Developing Students' Problem-Solving and Collaborative Skills.

A. Introduction

Education reflects dynamic, developing human culture. Thus, education should evolve with culture. Improving education at all levels requires ongoing change to anticipate future requirements. Education that supports future development helps students overcome life's problems (Sinaga. C. V. R, 2020). So it's no surprise that every school wants to improve education. Many schools use character education to raise moral youngsters. Elementary (SD/MI), secondary (SMP/MTs), senior high (SMA/MA), and universities perform this function.

To fulfill these educational aims, Indonesia changed the 1975 Curriculum to the 2013 Curriculum (K13) (Shoimin, 2016). Conceptually, curriculum development must be founded in national culture, current life, and future life. The curriculum addresses society's and the nation's youth development needs. The curriculum allows students to develop their potential in a fun learning environment that matches their ability, resulting in the traits society and the nation want. Legally, the curriculum is a public policy based on the nation's education philosophy and law (Hartati, 2021).

The educational objectives aim to instill ideals essential to a better life, underpinned by steps that enhance student learning. Learners engage with all their surroundings. Learning involves goal-setting and action through varied experiences ((Rusman, 2018). Learning involves seeing, observing, and understanding ((Asri, S. A., Syahrul, & Ishak, 2025). Teachers must grasp learning in all its forms and manifestations. Their incorrect or inadequate views on learning and related issues will keep Indonesia's development index low. UNDP's Human Development Index (HDI) statistics, which rank educational attainment, health, and per capita income, show this. Indonesia has the world's lowest human development index (Rismen et al., 2021).

Math is taught and studied from elementary school to university to improve Indonesia's human development index. Mathematics is a universal science that drives technological progress, promotes human thought, and is essential in many fields. Human intellectual thought creates mathematics, according to (Hasratuddin, 2018). This intellectual thinking is prompted by daily life issues. Math is also a tool for life and cognitive training. According to Eviliasani, Hendriana, and (Zakiamani et al., 2020) mathematics is taught to develop students' thinking processes, allowing them to address issues creatively, critically, rationally, analytically, systematically, and collaboratively.

Less than 1% of Indonesian students are mathematicians. Students need problem-solving skills to understand this. Analysis, interpretation, reasoning, prediction, evaluation, and reflection are life skills that help solve problems, according to (Hendrikson R Panjaitan, 2023). Higher-order thinking and problem-solving skills adapt previously acquired knowledge to new contexts. Problem-solving helps students apply and integrate concepts, theorems, and skills. Data processing practice is essential for pupils. Unfortunately, math problem-solving skills remain low. In an experimental class, pre-test scores for mathematics problem-solving skills averaged 25.84, 33.56% of the optimal score, according to Priangga (. In Agustina's (2011) study, 18 of 32 students (56.25%) completed the pre-test. Programme for International Student Assessment OECD, 2018) scores indicate low problem-solving ability. Indonesia participates in PISA. Students' mathematical abilities in the 2003 PISA (Page 100) test were level 1 (49.7%), level 2 (25.9%), level 3 (15.5%), level 4 (6.6%), and level 5-6 (2.3%). At level 1, students can only answer one-step math problems. Only 3 Indonesian junior high school students reach levels 5-6 per 100. This matches a preliminary assessment by researchers to assess starting math problem-solving skills at the school.

The pupil couldn't figure out how to tackle the challenge. According to the student's response sheet, the student instantly subtracted the two linear equations without looking at the x and y variables, hence he did not locate the solution set (Mustafa, 2020). The student's response sheet shows that the student answered the linear equation by looking at the x and y variables, hence he found the solution set. Near the end of the solution, the student misplaced the values of the x and y variables, preventing them from restating the concept. According to the analysis of 34 students' problem-solving tests, 21 (61.8%) had low scores, 9 (26.5%) had sufficient scores, and 4 (11.8%) had good scores. The diagnostic test results of one kid who answered the math problem show this (Manyira, M., Saidi, S., & Hamid, 2021).

Math is abstract, therefore problem-solving skills are vital to grasping new concepts. Students who can explain a solution are considered to have understood it. Several factors cause pupils to struggle in arithmetic, according to (Trianto., 2017), who noted that teachers always require kids to learn and rarely teach how they learn. Teachers require pupils to solve problems but rarely teach them how. Ministry of Education and Culture Regulation No. 65 of 2013 on Elementary and Secondary Education Process Standards requires learning planning to integrate material development. Learning planning includes resource development. Learning materials' importance in teaching and learning makes their development difficult for teachers and prospective teachers. Process-based learning begins with a Lesson Implementation Plan, per Minister of Education and Culture Regulation Number 81 A of 2013, Appendix IV on curriculum implementation and general learning requirements. The syllabus-based Lesson Implementation Plan is a complete subject learning plan.

A teacher's lesson plan must be reliable. The lesson plan assessment guidelines (Akbar, P., Hamid, A., Bernard, M., & Sugandi, 2018) define high lesson plan validity as (1) a clear, complete, logically structured learning formulation that encourages students to think at a higher level; (2) a clear material description in accordance with learning objectives, student characteristics, and scientific development; and (3) a clear, systematic organization of the learning material. (4) Learning resources are varied and suited to student growth, teaching materials, and contextual environment; (5) The learning path is comprehensive (beginning, core, and end) and reflects the learning model. (6) Learning steps match aims; (7) The learning steps include learning approaches that support the learning objectives and engage students to participate and think; (8) The RPP's completeness is specified in terms of methods and types of assessment based on learning objectives, including tests, non-tests, and rubrics.

In junior high schools in Medan city, there are no standards for developing lesson plans. Lesson plans have several weaknesses: (1) teachers do not determine minimum completion criteria for the Minimum Completion Criteria (KKM); (2) teachers do not explain and separate teacher and student activities; (3) teachers do not include problem-solving strategies from Student Worksheets (LKPD); (4) lesson plans are outdated and simple; and (5) there are no assessment instruments. Textbooks help students learn. According to Akbar (2013), textbooks are subject-specific reference texts. Good textbooks must be valid and effective. (Wanahari, M., Amry, Z., Simamora, 2022) defines good textbooks as accurate, relevant, communicative, complete, systematic, and student-centered. (6) In accordance with national and state ideology; (7) Correct language rules: textbooks are written with correct spelling, terminology, and sentence structure; (8) Readability: textbooks with high readability have sentence lengths and structures that are easy to understand.

The SMP WR texts were observed. Supratman 1 Medan still has several weaknesses, including a lack of concept maps, textbooks that present concepts such as theorems and formulas without a scientific discovery process, and unfamiliar language. Students need more than textbooks and teaching materials to understand the content. Textbook assistance includes Student Activity Sheets (LKPD). LKPD uses structured activities with difficulties to assist students in learning. Activity sheets assist students in learning skills through diverse exercises, according to (Fardani, Z., Surya, 2021).

According to the argument above, learning tools improve learning. No matter the situation, learning tools are essential for improving student knowledge, motivation, excitement, and classroom engagement. Learning tools can assist teachers in anticipating the many possibilities that develop during the complex learning process. In the learning process, teachers can be creative, inventive, proactive, and innovative (Herdiansyah, 2025).

The description above shows that learning tools improve learning. Developing learning tools improves existing products and creates new ones. No single learning resource can cover all learning demands, it attempts to provide learning tools that solve classroom difficulties. Thus, learning tools must be related to learning objectives, particularly boosting students' comprehension, problem-solving, and cooperation skills (Wismath., 2018).

In the problem-based learning model, small groups of students address issues agreed upon by the teacher and students, according to (Abdul Rahman, N. A. A., & Abdullah, 2024) Students apply several skills when teachers adopt this learning paradigm. Problem-based learning starts with math problems. Students must answer mathematically complex issues using their skills. Problem-based learning allows students to investigate their own options for interpreting, explaining, and understanding phenomena. Learning is based on students' talents, conditioning, and the control of teacher-student and student-student interactions.

A different way to boost self-confidence, make math fun, and improve problem-solving and teamwork is problem-based learning (PBL). (Kotto, M. A., Babys, U., dan Gella, 2022) found that the PBL-B3 model improves students' mathematical problem-solving, mastery of mathematical learning, active learning, and teachers' abilities. (Sinaga, 2007) research, Development of a Mathematics Learning Model Based on Problems Based on Batak Culture (PBM-B3), found that (i) students' learning mastery is achieved classically; (ii) ideal time for each category of student and teacher activities is met; (iii) the average teacher's ability to manage learning is 3.51, which is fairly good; and (iv) teachers have an average of. The author wants to study "Development of Learning Tools Based on the Problem-Based Learning Model in Improving Student Problem-Solving and Collaboration Skills at SMP WR Supratman 1 Medan" because of the above issues.

B. Research Method

This study is classified as Development Research (DR) using the Thiagarajan, Semmel, and Semmel Four-D model based on issue formulation and research aims. Thus, this research yields problem-based learning techniques and essential instruments (Sugiyono, 2018). The learning materials produced include lesson plans (RPP), teachers' books (BG), students' books (BS), student activity sheets (LKPD), problem-solving ability assessments (TKPM), and student cooperation questionnaires. SMP WR.

Supratman 1 Medan, a junior high school in Medan City, North Sumatra, undertook this investigation. During the odd semester of the 2025/2026 academic year, grades VIIIA and VIIIB will study systems of linear equations in two variables with a modified mathematics lesson schedule. This study includes 2025/2026 grade VIIIA students from SMP WR. Supratman 1 Medan. This research focuses on a problem-based learning device for two-variable linear equation systems, problem-solving, and cooperation. This learning device's development model includes define, design, create, and disseminate. The learning tool development process is as follows:

Define

This stage defines learning requirements by examining material objectives and limits. In the Define stage, five phases are performed: Preliminary-Postfinal Analysis, Student Analysis, Concept Analysis, Task Analysis, and Learning Objective Specification.

Design

This step designs learning aids to create a PBL prototype for systems of linear equations in two variables. This stage includes test development, media and format selection, and the creation of learning tools.

a. Construction of Test and Non-Test Criteria Task and idea analysis from the learning objective
   Specifications underpin test development.
b. Format Choice
   Development of learning tools involves choosing a format for designing information, strategies/models, approaches, learning methods, and resources.
c. The First Design
   This research refers to the initial planning of all pre-trial activities.

Development

Experts will review the first draft to ensure a strong final draft. Piloting the problem-solving ability test and student collaborative attitude questionnaire in a non-sample class follows. Development steps are as follows:

a. Expert Verification/Evaluation
   Expert validation or evaluation provides feedback on learning tools designed during the design stage.
b. Trial of Research Instruments
   This study used the problem-solving ability test and the student collaborative attitude questionnaire.
c. Trial in the field
d. The field experiment provided direct input on the learning aids, culminating in the final tool.

Disseminate

After positive expert assessments and the development test, learning tool development is complete. The learning resources are packaged and distributed. This study distributed learning tools only to class VIII of SMP WR. Supratman 1 Medan. The tools were distributed to educational studios and MGMP teachers for follow-up and development during the diffusion process.

C. Result and Discussion

The Four-D Model by Thiagarajan and Semmel is used to design learning devices. First comes definition, then design, then development, and finally diffusion. The results for each stage are listed below.

Define

After conducting observations and conducting an analysis of the learning materials at SMP WR. Supratman 1 Medan: it was discovered that teachers lacked access to appropriate learning resources and frequently did not use them in the learning process. There were a few revisions to the methodologies employed in the existing lesson plan. In accordance with the 2013 Curriculum, the approaches that were utilized and developed by the teachers were appropriate. The current Student Worksheets were not linked to the RPP, which meant the learning objectives were not fully reflected in the RPP. Additionally, the students' disengagement was a direct result of the disengaging learning they were experiencing. Furthermore, students were not involved in the process of discovering new information; rather, the instructor directly supplied it to them.

Based on the information presented above, it is evident that there are issues with how mathematics is taught at SMP WR. Supratman 1 Medan. It is necessary to implement a problem-based learning design in order to overcome these challenges. The purpose of this strategy is to improve the method's effectiveness by incorporating a pre-post analysis that includes student analysis, curriculum analysis, learning process analysis, learning outcomes analysis, problem-solving analysis, and collaborative learning analysis.

Design

Task and idea analysis from learning objectives specifications informs test development. A student collaboration questionnaire and a two-variable linear-equation system math problem-solving test are included. The math problem-solving ability test has four descriptive questions. The test lasts 60 minutes. The initial design stage included a lesson plan for four field-trial sessions and a student learning results test. This design stage produces the Initial Draft. The initial design results are generally: The student book contains real-world issues to tackle individually and in groups. This book provides crucial information on fundamental ideas. The student's book cover is presented for clarity.

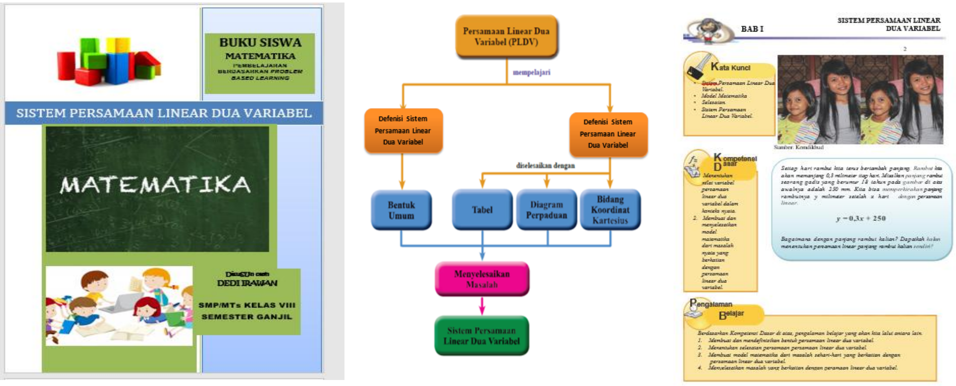


Figure 1. Student Book

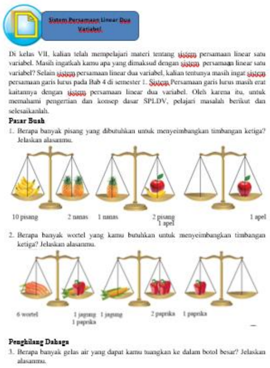
As shown in the image above, the learning materials align with the core and basic competencies of the 2013 Curriculum. The first page of the student's textbook contains keywords and core competencies.

The next page contains the algebra program material and instructions that students will follow during the lesson.

Develop

The resulting Initial Draft was validated by experts. The expert validation covered all developed tools, including lesson plans (RPP), student worksheets (LKPD), teacher's books, and student books. The validators' assessment of the student's textbook included format, language, illustrations, and content. In making the revisions, the researchers referred to the discussion results and followed the validators' suggestions and instructions. Based on the validation calculations for the textbook, the average score for each assessed aspect across the five validators was greater than or equal to 4, meeting the "valid" criteria. The overall average score for the student's textbook assessment met the "valid" criteria, at 4.7. The five validators concluded that the student's textbook could be used with minor revisions. The revisions to the student's textbook were aligned with the revisions to the Student Activity Sheet (LKPD). Other revisions involved typographical/spelling errors in the text, which were corrected according to the validators' observations. For suggestions for improvement, several writing/spelling errors in the manuscript have been corrected in accordance with the validator's notes, while other revisions can be seen as follows.

Table 1. Student Book Revision Based on Correction Results from Validator

No.	Before Revision	After Revision
1.	Validator Use words that are easy for students to understand. Use appropriate and engaging images.	
	 Sistem Persamaan Linear Dua Variabel Di kelas VII, kalian telah mempelajari materi tentang sistem persamaan linear satu variabel. Masih ingatkah kamu apa yang dimaksud dengan sistem persamaan linear satu variabel? Selain sistem persamaan linear dua variabel, kalian tentunya masih ingat sistem persamaan garis lurus pada Bab 4 di semester 1. Sistem Persamaan garis lurus masih erat kaitannya dengan sistem persamaan linear dua variabel. Oleh karena itu, untuk memahami pengertian dan konsep dasar SPLDV, pelajari masalah berikut dan selesaikanlah. **Pasar Buah** 1. Berapa banyak pisang yang dibutuhkan untuk menyeimbangkan timbangan ketiga? Jelaskan alasanmu. 2. Berapa banyak wortel yang kamu butuhkan untuk menyeimbangkan timbangan ketiga? Jelaskan alasanmu. **Penghilang Dahaga** 3. Berapa banyak gelas air yang dapat kamu tuangkan ke dalam botol besar? Jelaskan alasanmu.	 Sistem Persamaan Linear Dua Variabel Di kelas VII, kalian telah mempelajari materi tentang sistem persamaan linear satu variabel. Masih ingatkah kamu apa yang dimaksud dengan sistem persamaan linear satu variabel? Selain sistem persamaan linear dua variabel, kalian tentunya masih ingat sistem persamaan garis lurus pada Bab 4 di semester 1. Sistem Persamaan garis lurus masih erat kaitannya dengan sistem persamaan linear dua variabel. Oleh karena itu, untuk memahami pengertian dan konsep dasar SPLDV, pelajari masalah berikut dan selesaikanlah. **Pasar Buah** 1. Berapa banyak pisang yang dibutuhkan untuk menyeimbangkan timbangan ketiga? Jelaskan alasanmu. 10 pisang, 2 nanas, 1 nanas, 2 pisang 1 apel, 1 apel 2. Berapa banyak wortel yang kamu butuhkan untuk menyeimbangkan timbangan ketiga? Jelaskan alasanmu. 6 wortel, 1 jagung 1 paprika, 1 jagung, 2 paprika, 1 paprika **Penghilang Dahaga** 3. Berapa banyak gelas air yang dapat kamu tuangkan ke dalam botol besar? Jelaskan alasanmu.

The research development stages demonstrate the validity of the test results. The findings of the research instrument data analysis.

Table 2. Validation Results

No	Aspect	Average	Category
1	Student book	4,5	Valid
2	Student Worksheets	4,6	Valid
3	Lesson Plan	4,6	Valid
4	Problem-Solving Ability Test	4,7	Valid
5	Student Collaboration	4,5	Valid

According to Table 2, the learning gadget has a "valid" average score of 4.5 or higher. For this investigation, descriptive statistics were utilized. Descriptive statistics are recommended by Sheskin (2004) for the purpose of data analysis that does not include judgment or prediction. In the data centre and spread, descriptive statistics are used through tables, graphs, diagrams, and calculations.

Learning Device Effectiveness Data

In this study, students' mastery levels were assessed based on their mathematical problem-solving abilities using a newly developed test. The results of students' mathematical problem-solving abilities in trial II are shown in Table 3.

Table 3. Description of Students' Mathematical Problem-Solving Ability Results

Description	Mathematical Problem Solving Ability Pretest	Posttest of Mathematical Problem Solving Ability
Highest Score	80	100
Lowest Score	50	60
Average	63,5	80

According to Table 3, students' pretest mathematical problem-solving ability is 63.5 and their posttest is 80. Table 4 shows students' mathematical problem-solving skill in pretest and posttest trial results.

Table 4. Students' Mathematical Problem-Solving Skills Mastery Level Based on Pretest and Posttest Results

No.	Value Interval	Pretest		Posttest		Category
		Number of Students	Percentage	Number of Students	Percentage	
1	0≤ SKPM <45	0	0%	0	0%	Very Poor
2	45≤ SKPM <65	10	33%	0	0%	Poor
3	65≤ SKPM <75	12	40%	6	20%	Fair
4	75≤SKPM <90	8	26%	9	30%	Good
5	90≤SKPM ≤100	0	0%	15	50%	Very Good

Description:

SKPM: Problem Solving Ability Score

The table shows that in the pretest, no students scored very poor, 10 scored poor, 12 scored sufficient, 8 scored good, and 0 scored very good. However, in the posttest, 6 pupils (20%) scored sufficient, 9 (30%) good, and 15 (50%) very good.

Students' Mathematical Collaboration Achievement

The mathematical collaboration scale administered in the pilot test was the same as that used in pilot test I. The questionnaire used in pilot test II was also the same as that used in pilot test I. Data from the student mathematical collaboration questionnaire were collected and analyzed to determine students' mathematical collaboration abilities before the learning intervention. The answer choices for the mathematical collaboration questionnaire items used a Likert scale. The data obtained from the questionnaire responses were on an ordinal scale. The complete analysis results are in the appendix. The results of the descriptive analysis of students' mathematical collaboration after using the learning tools in pilot test II are presented in Table 5.

Table 5. Description of Students' Mathematical Collaboration Data After Using Learning Tools

Interval	Category	Pretest		Posttest	
		Number of Students	Percentage	Number of Students	Percentage
76-100	Excellent	7	23 %	12	40%
51-75	Good	13	43%	14	46 %
26-50	Fair	10	33%	4	13 %
0-25	Poor	0	0%	0	0%
Total		30	100%	30	100%

According to the table, 5 students (23%), 13 students (43%), and 10 students (33%), respectively, scored very good on the pretest, and 12 students (40%) and 14 students (46%) scored good on the posttest. The Problem-Based Learning module improves student learning and collaboration.

Disseminate

After the second experiment met the validity and effectiveness criteria, the final toolkit (draft) was obtained. The finished toolkit was distributed to the MGMP forum at SMP WR. Supratman 1 Medan. This was marked by submitting the learning toolkit to the MGMP forum in hopes that mathematics teachers will use it in future lessons. Sharing the development outcomes with the study population was the key step following the submission of the final toolkit.

Discussion

Trials I and II post-test findings showed an increase in students' problem-solving abilities. Problem-based learning methods naturally improve problem-solving. Problem-based learning promotes arithmetic problem-solving because students identify challenges and concepts. The teacher helps pupils think freely and uncover basic concepts based on their instructions/questions. Guidance varies on ability and subject matter. (Wismath., 2018) found that problem-based learning increased mathematical problem-solving skills more than conventional learning. This shows that problem-based learning improves mathematical problem-solving skills. This study concludes that problem-based learning instructional materials improve students' mathematics problem-solving. In Trials I and II, average student scores for mathematical collaboration increased. On average, student mathematical collaboration in trial II was better than in trial I. (Herdiansyah, 2025) revealed that questionnaire data on student mathematical collaboration rose with each cycle. The average questionnaire score pre-cycle was 64.24, cycle I 72.57, and cycle II 77.91, all good. These findings imply that e-learning-based problem-based learning can improve grade XI MIPA 2 students' mathematical collaboration skills in arithmetic and geometric sequences and series. Another study by Jufri (2017) found that problem-based learning improves student mathematical collaboration. This study and earlier research show that problem-based learning tools improve students' teamwork skills in mathematics.

D. Conclusion

Based on the lesson plan, student worksheets, teacher's book, and student workbook, PBL is valid, practical, and effective in improving students' problem-solving and collaboration skills. Students demonstrated very good mathematical collaboration. Problem-based learning on systems of linear equations in two variables improved students' collaborative mathematical problem-solving skills, as evidenced by the average post-test results from trials I and II. Furthermore, over 85% of students responded positively to PBL.

To ensure high-quality learning, other schools should pilot the PBL learning tools in different settings. Teachers should first become more proficient with PBL learning tools before implementing them as alternative learning resources, particularly for systems of linear equations in two variables. Before developing PBL learning tools, teachers and other stakeholders need to assess their school's specific conditions. Problem-based learning can help students solve mathematical problems. Therefore, teachers can use this method to enhance students' mathematical problem-solving skills by providing real world scenarios that require critical thinking and collaboration.

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