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ORIGINAL ARTICLE

Developing a STEAM workbook on Simple Machines to Develop Middle School Students' Problem-Solving Skills

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ABSTRACT

The demands of 21st-century learning encourage education and digitization to equip students with relevant skills, one of which is problem-solving skills. This study aims to develop a Science, Technology, Engineering, Arts, and Mathematics (STEAM) workbook on simple aircraft for junior high school students and to test its effectiveness in improving problem-solving skills. Research and Development with the 4D model is the research method used. The research subjects consisted of 60 eighth-grade students from SMPN 11 Malang. The study design employed a quasi-experimental approach with a pre-test-post-test control group. The t-test results indicated no significant difference in initial ability based on pre-test scores between the experimental and control groups (significance level 0.41), but there was a significant difference in posttest scores (significance level 0.00). The N-Gain value of 0.67 indicates that there was a significant improvement in problem-solving ability in the effectiveness category, and the effect size test yielded a value of 7.227, which also indicates the effectiveness of the STEAM workbook in the significant category. These results show that the developed workbook is valid, feasible, and effective in fostering problem-solving skills. The development of STEAM-based learning resources by integrating other 4C indicators is recommended as an innovation to support students' readiness to face 21st-century challenges.

KEY WORDS: Learning resources, problem-solving skills, Science, Technology, Engineering, Arts, and Mathematics, workbook

INTRODUCTION

Education is a benchmark for a nation's progress as well as a pillar of national awakening. In facing the era of the 5.0 industrial revolution, Indonesian education is required to equip students with the ability to think logically, independently, tolerantly, as well as problem-solving skills and real contributions (Sholikah and Pertiwi, 2021). One of the main subjects that supports this is Natural Sciences (IPA), because it encourages students to understand natural phenomena through observation, experimentation, and scientific reasoning (Kurniasari and Fauziah, 2022). The material on simple machines in IPA is very relevant because it reflects students' daily activities and has the potential to encourage scientific activities (Pratiwi et al., 2022). However, students' understanding of this material is still low, due to the conventional learning approach and the perception that IPA is difficult and less applicable (Febriyani, 2022; Putri et al., 2024). In fact, many student activities involving simple machine principles have not been utilized as learning resources (Fajarwati et al., 2025; Alya et al., 2025).

A contextual, active, and reflective learning approach to student experiences is needed. Problem-solving skills are an important aspect in science because they help students build concepts independently (Tambusai and Rakhmawati, 2023). Unfortunately, PISA results show that this ability is still low; Indonesia's science score is only 383 out of an international average of 485, ranking 67 out of 81 countries (OECD, 2023). This shows students' weak ability to solve problems based on reasoning and connection one approach that can answer this challenge is Science, Technology, Engineering, Arts, and Mathematics (STEAM)-based learning. STEAM has been shown to be effective in improving students' creativity, critical thinking, and problem-solving abilities (Yulianti et al., 2024; Syukri et al., 2022). This approach is in line with the Merdeka Curriculum, which emphasizes student-centered learning and the development of 21st-century skills (Priyantini et al., 2021; Hasballah, 2024). Unfortunately, limited resources and teacher training are obstacles to its optimal implementation in Indonesia (Yulianti et al., 2024; Backfisch et al., 2021). This study aims to develop a STEAM-based workbook on simple aircraft material to improve students' problem-solving skills innovatively and contextually, according to the needs of 21st-century learning.

LITERATURE REVIEW

Learning Resources

Learning media is anything that can be used by educators and learners to enhance learning activities (Dale, 1969). In the Cone of Experience theory, Dale emphasizes that concrete experiences provide a better understanding than abstract experiences. Visualization, simulation, and interaction are forms of media that facilitate such learning experiences. The Association for Educational Communications and Technology (AECT, 1994) defines learning resources as all elements that support the learning process, such as information, people, materials, tools, methods, and the environment. Seels and Richey (1994) add that learning resources include various means of conveying information and skills. Azubuike and Ph (2025) divide educational resources into two main categories, namely human and material, both of which play an important role in ensuring the quality and effectiveness of learning.

STEAM

STEAM-based learning integrates Science, Technology, Engineering, Arts, and Mathematics into a single curriculum to develop students' critical thinking, creativity, and innovation skills. According to Umami et al., (2023), this concept was introduced by Dr. Georgette Yakman in 2006, who combined science and technology with arts and mathematics as a foundation. STEAM encompasses science that encourages curiosity and problem-solving, technology as a human tool, engineering that focuses on system design, arts to create engaging learning processes, and mathematics to understand numerical and structural concepts. Nuragnia et al. (2021) state that integrating arts into STEM to form STEAM is important for holistic and creative education. Liu and Wu (2022) emphasize that STEAM enables students to combine creativity and science in solving real-world problems. (Mariana et al., 2023) add that this method not only enhances academic knowledge but also psychomotor, cognitive, collaborative, and reflective skills. Motimona and Maryatun (2023) state that STEAM fosters students' creativity and logical abilities through hands-on experiences. Thus, STEAM is an effective method that develops soft skills and problem-solving abilities, as well as fostering multidisciplinary skills essential for students' future (Amalia et al., 2021).

Workbook

According to Liana et al., (2023), workbooks are one of the teaching products used in learning. Workbooks contain learning objectives, theory summaries, exercises, assignments, and discussion materials (Aima and Rahima, 2020). Active learning encourages students to engage cognitively to develop complex thinking skills (Martín-Alguacil and Avedillo, 2024). Workbooks support this by providing assignments that encourage critical and creative thinking (Pereira et al., 2023). In problem-based learning (PBL), workbooks are effective in improving higher-order thinking skills and problem-solving (Anbiya et al., 2023). However, the role of the teacher remains crucial in achieving learning objectives (Zeng, 2023), and students demonstrate high levels of active participation (Ulya et al., 2022).

Problem-solving Skills

Problem-solving skills are essential in learning and everyday life. Rusmin and Misrahayu (2024) state that these skills help individuals deal with challenges and uncertain situations. In addition, according to Adeoye and Jimoh (2023), these skills support decision-making, adaptation, and creative problem-solving. Kaya-Capocci et al. (2024) add that problem-solving contributes to academic success, work readiness, and personal development. Therefore, these skills need to be instilled in the learning process. Pólya (1945) developed a systematic approach to problem-solving that includes four steps: Understanding the problem, planning a solution, implementing a strategy, and evaluating the results. This approach trains students to think logically, systematically, and reflectively in solving various problems (Afifah et al., 2019).

METHODOLOGY

This study uses a development method known as Research and Development (R&D). Richey and Klein (2007) describe R&D as design and development research, which is an in-depth investigation into the design, production, and evaluation of products based on empirical evidence. According to Borg and Gall (1983), R&D in education involves the design and validation of educational products. Susanto et al. (2024) added that R&D aims to create and test the effectiveness of learning resources. This study adopts the 4D model by Thiagarajan et al. (1974), which consists of Define, Design, Develop, and Disseminate, with adaptations made to suit the context and needs of the study (Figure 1). The 4D model was chosen due to its clarity, ease of use, and wide application in developing teaching materials (Cahyanto et al., 2020).

Due to limitations in participant randomization, true experiments often cannot be conducted in educational settings. Thus, this study used a quasi-experimental design, specifically where researchers can control who is involved and measured (Cohen et al., 2018). and adopted a non-equivalent pre-test-post-test control group design method. The experimental group received a STEAM-based workbook to improve problem-solving skills, while the control group followed conventional instructions (Setianingsih et al., 2019). The population consisted of all 8th-grade students at SMPN 11 Malang, with purposive sampling used to select class VIII-C (34 students) as the experimental group and class VIII-B (34 students) as the control group. Purposive sampling was chosen due to its ability to target participants who were most relevant to the research topic (Cohen et al., 2018).

The Define stage collects important information for product development and identifies learning needs through: (1) Literature review, (2) Analysis of learning objectives and concepts, and (3) Analysis of teacher and student needs. Literature from books, articles, and journals provides a theoretical basis for learning materials, STEAM approaches, and criteria for quality learning resources, forming the scientific basis for development. Concept and objective analysis ensure curriculum alignment and cohesive content. Teacher and student needs are explored through interviews with 8th-grade students (before studying simple machines), 9th-grade students (after studying), and science teachers. The data obtained reveals media suitability, learning difficulties, and classroom feasibility as qualitative input for development objectives.

The design stage responds to the problems identified earlier. Product design is based on data collected to meet student needs.

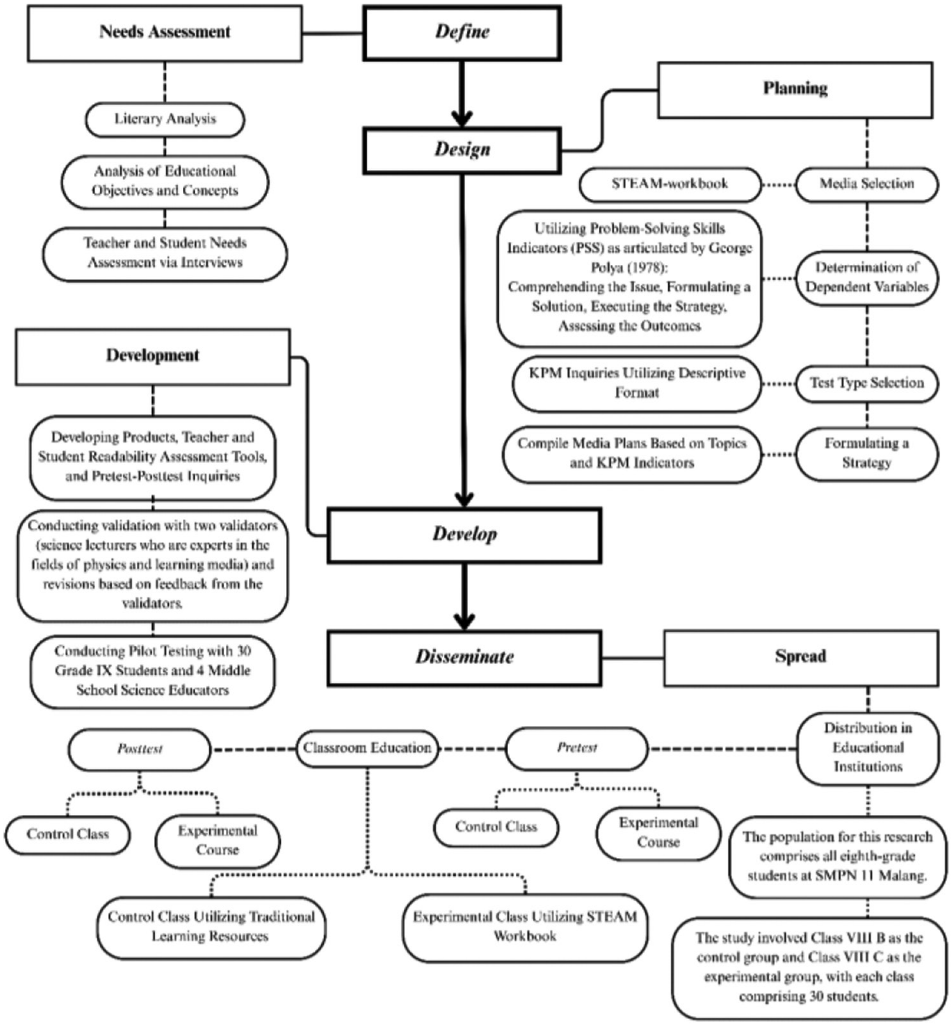

Figure 1: 4D model development procedure/flow

A STEAM-based workbook is chosen to integrate Science, Technology, Engineering, Arts, and Mathematics in the topic of simple machines. Problem-solving skills, an important 21st-century competency, were selected as the dependent variable, using four indicators from Polya (1945), including problem understanding, solution planning, strategy implementation, and result evaluation. This product aims to strengthen STEAM understanding and problem-solving, supported by descriptive questions.

The development phase included creating a STEAM workbook, compiling a readability checklist for students and teachers, and designing pre-test and post-test questions based on Polya's indicators. Validation sheets for subject matter and media experts were prepared to ensure the product's validity. The readability sheets assess how easily students and teachers understand the workbook. Both use a 4-point Likert scale (Likert, 1932) and a 2-point Guttman scale (Guttman, 1944). The pre-test and post-test questions are based on Polya's problem-solving indicators (1978) and are evaluated holistically. Validation was conducted by two expert lecturers, a physics lecturer and a media specialist, whose feedback was used for revisions before limited testing. The trial assessed the readability of the workbook and the effectiveness of the test questions. Data were analyzed qualitatively and quantitatively. The validity and reliability of the instrument were tested using Pearson's product-moment correlation and Cronbach's Alpha in IBM the Statistical Package for the Social Sciences (SPSS) Statistics 23 to ensure consistent and valid measurements (Sundayana, 2018). During the development phase, the workbook was adjusted based on expert advice, which included refining concepts, simplifying instructions, adding illustrations to activities, and restructuring the design along with STEAM icons to facilitate understanding. After these improvements, the material was tested with 30 students and 4 teachers. The notes obtained at this stage, especially those related to the clarity of procedures and text length, were used to make additional adjustments so that the workbook became more functional and suitable for use in the learning process.

The dissemination stage was conducted after the refinement of the instruments and focused on broader implementation using a quasi-experimental pre-test–post-test design with unequal control groups to measure effectiveness. Learning in the experimental and control groups took place over six sessions of 600 min each. The first session was for the pre-test, sessions two to five were for core activities, and the sixth session was for the post-test. The experimental group used STEAM workbooks, while the control group followed traditional lectures, question and answer sessions, and science textbooks without additional intervention. Both groups were taught by the same teacher to ensure uniform treatment. Before starting the intervention, teachers in the control group received a brief orientation on the STEAM workbook to maintain alignment with the research design. The pre-test and post-test were administered in the first and last sessions. The data were analyzed to evaluate the impact of the STEAM workbook compared to conventional methods. Quantitative analysis was performed using IBM SPSS Statistics 23. Before applying parametric tests, pre-requisite tests (normality and homogeneity) were conducted. The Shapiro–Wilk test assessed normality; data were considered normal if the significance value exceeded 0.05. The Levene test determined homogeneity, with significance above 0.05 indicating uniformity (Sundayana, 2018). A significance level of 0.05 was applied in accordance with social science standards. After meeting the prerequisites, the independent sample t-test compared the pre-test and post-test results between groups. The post-test averages were compared to determine improvement. The N-Gain test measured the improvement in problem-solving skills in the experimental group, while the effect size-d test assessed the impact of the STEAM workbook. These tests ensured a systematic analysis of learning effectiveness.

RESULTS

This study produced learning resources in the form of STEAM workbooks on simple aircraft topics to improve junior high school students' problem-solving skills. The study was conducted at SMPN 11 Malang with initial analysis through interviews with students who had and had not studied the material and science teachers. The results of the needs analysis showed that learning resources greatly helped students' understanding, but junior high school students' problem-solving skills were still relatively low, which was confirmed by teachers, students, and literature studies, as shown in Table 1.

Based on the literature review conducted, textbooks remain the primary learning medium in schools, but are often perceived as uninteresting, boring, and lacking in creativity (Febiola, 2020). Many also fail to fully support 21st-century skills, making them less relevant to current learning needs (Soleh and Arifin, 2021). Habibaturrohmah et al. (2022) found that the PBL-STEM approach can enhance students' problem-solving skills but has not fully integrated STEAM elements. Similarly, Atieh et al. (2024) noted that project-based STEM learning is effective but limited by technology, resources, and underutilized artistic components. Meanwhile, Rusmin and Misrahayu (2024) emphasize that problem-solving skills are crucial for future competitiveness. Teachers also note that learning still focuses on mastering concepts, with minimal attention to skill development due to resource constraints. Students need engaging and interactive methods beyond lectures to improve learning outcomes and problem-solving skills, fostering independence, creativity, and readiness to face real-life challenges (Pokhrel et al., 2024). Teachers observed

Table 1: Table of results of needs analysis through literature studies, teacher and student interviews

Literature study	Teacher interview	Student interview
Print media is still the main choice in schools, but is often considered less interesting and boring and less creative (Febiola, 2020)	Students generally understand the basic concepts but still have difficulty applying them.	If the learning media is more interesting, has a connection with everyday life and lots of varied activities, it will help students to understand the material more easily.
The textbooks used do not yet integrate 21st-century skills into them, so they are less suited to classroom needs (Soleh and Arifin, 2021)	The media used is still limited and cannot facilitate students in developing skills, especially problem-solving.	The STEAM learning model attracts students' attention because it provides a new and non-monotonous learning experience.
Habibaturrohmah et al., 2022) showed that approaches such as PBL-STEM can improve students' problem-solving skills. However, this study has shortcomings such as the lack of STEAM integration.	The STEAM approach and problem-solving skills are considered important to improve students' skills according to the needs of the times.	Demonstrations or experiments are preferred because students can see and try directly, and they are not boring like just reading.
Atieh et al. (2023) showed that STEM-integrated project-based learning is effective in improving students' problem-solving skills. However, this strategy still has weaknesses, such as limited technology, resources, and lack of comprehensive STEAM integration.	If learning activities are increasingly varied, it may increase students' interest in learning while providing space for exploring ideas and solutions.	Even though they have studied the material, some students still do not fully understand certain concepts, so they suggest using fun learning models such as projects, experiments, and educational games to reinforce the material.
Rusmin and Misrahayu (2024) emphasized that learning problem-solving skills is very important, because these skills help someone to be able to face everyday challenges and uncertain situations better, which is very important to remain competitive in the 21st century.	Real-life applications in the Ministry of Education and Culture's books already exist, but they are not often found in everyday life problems, so students sometimes still have difficulty applying them in their surroundings.	Many students feel more engaged and excited when they can participate directly in learning activities, especially when working in groups or on projects.

PBL: Problem-based learning, STEAM: Science, Technology, Engineering, Arts, and Mathematics that students are more motivated when lessons are linked to real-life contexts using interactive media. However, existing media do not sufficiently support this need. Although the STEAM approach is relevant, examples in MOEC textbooks are often not sufficiently contextual (Fricticarani et al., 2023).

The results of interviews with junior high school students showed that conventional methods such as lectures, demonstrations, and pictures were less interesting. Students preferred experiments, projects, and interactive activities because they were more fun, easy to understand, and encouraged creativity. They were attracted to the varied, contextual, and collaborative STEAM approach. Therefore, the development of STEAM-based workbooks is important to replace conventional textbooks with media that are more interesting, creative, and support critical thinking and problem-solving skills.

After analyzing needs and initial results, the next step is designing interactive learning media to support learning and develop students' problem-solving skills. This involves selecting simple machine subtopics, defining learning outcomes and objectives, determining problem-solving indicators, and designing questions that foster these skills. Validation sheets for material and media experts, along with readability questionnaires for teachers and students, are also prepared. The next phase is developing the STEAM workbook based on the design. It includes a cover, CP and TP, usage instructions, practice questions, simple experiments, bibliography, and developer profiles. The workbook integrates Science, Technology, Engineering, Art, and Mathematics to enhance students' understanding and problem-solving skills.

This workbook refers to Polya's (1945) problem-solving indicators which include four main aspects: problem understanding, solution planning, plan implementation, and outcome evaluation. Each aspect is presented in the form of icons with explanations to facilitate understanding (Figure 2a). For example, in Figure 2b and c, students are asked to understand the problem, discuss, and answer questions in the column equipped with problem-solving indicator icons. This activity supports the development of students' problem-solving skills.

The developed media not only contain aspects of problem-solving skills, but also STEAM elements packaged in the form of special icons. For example, the test tube icon in "activity 3" shows the science element (Figure 3a). The blue light bulb icon indicates technology, such as the barcode scan activity for videos related to the observed problem. The calculator icon in the let's count activity indicates the mathematical aspect to calculate force (Figure 3b). Meanwhile, the colored palm and bicycle gear icons in other activities indicate the art and engineering aspects (Figure 3c). In addition, many students feel more involved and enthusiastic when participating directly in learning, especially through group work or projects. After the product was developed, validation was carried out by media experts and material experts to measure the validity and feasibility of the product. The validation results showed that the STEAM-workbook obtained a validity value of 86.8% from media experts (very valid) and 83.5% from material experts (valid) and was suitable for use (Akbar, 2013). Validation of the pre-test and post-test questions used an open-ended question instrument, with 10 descriptive questions that were in accordance with the problem-solving indicators. The validator suggested adding images to the questions to make it easier for students to understand, and all input has been accommodated to improve the product.

The viability of the product was determined through expert validation, readability tests, and assessments of the instrument's validity and reliability. A product is considered viable if it obtains at least 61% (Akbar, 2013). The workbook developed achieved scores of 86.8% in the assessment by media experts and 83.5% in the assessment by content experts, placing it in the viable to very viable category. Likewise, the readability test conducted on 28 students and four teachers yielded results

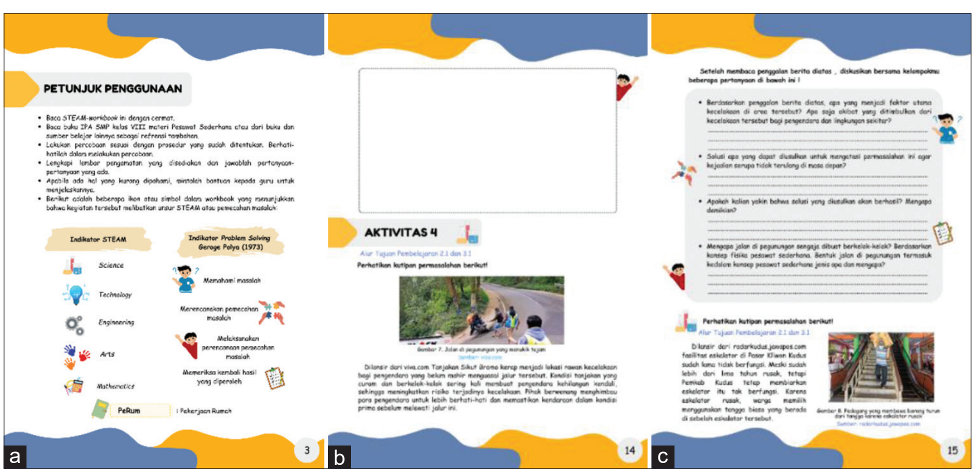

Figure 2: STEAM View-workbooks that contain aspects of problem-solving skills. (a) Display of instructions for using the STEAM-workbook; (b) Display of learning activities in the STEAM-workbook; (c) Display of answer sheets in the STEAM-workbook containing 4 indicators of problem-solving skills. STEAM: Science, Technology, Engineering, Arts, and Mathematics

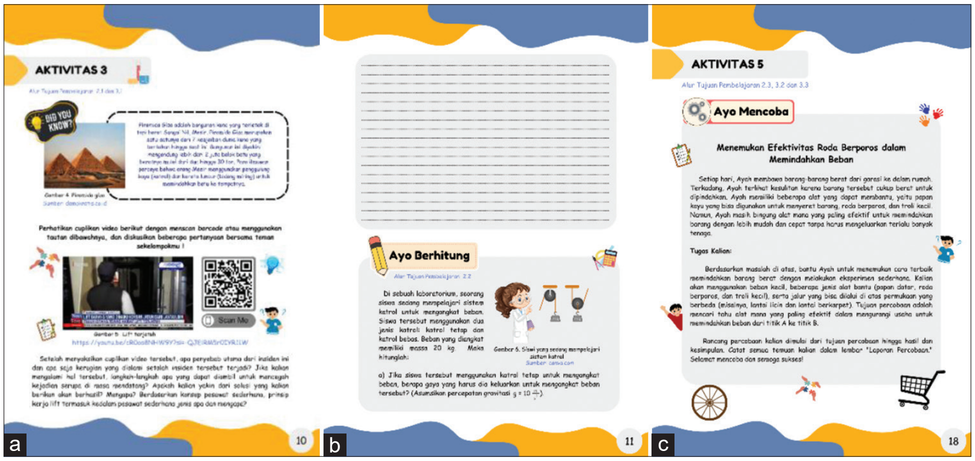

Figure 3: STEAM View-workbooks containing Science, Technology, Engineering, Art, and Mathematics elements. (a) Display of learning activities in STEAM-workbooks with Science and Technology indicators; (b) Display of learning activities in STEAM-workbooks with Mathematics indicators; (c) Display of learning activities in STEAM-workbooks with Engineering and Art indicators. STEAM: Science, Technology, Engineering, Arts, and Mathematics

of 77.08% and 84.92%, respectively, both classified as valid (Akbar, 2013). The pre-test and post-test instruments included 10 items with various indicators of problem-solving skills. The initial application to 30 students showed that all items were valid and had a reliability of 0.746, considered high (Nunnally and Bernstein, 1994). Taken together, these results show that the workbook and assessment instruments meet the feasibility criteria for sustained implementation.

After going through initial trials and validity, and reliability tests, the next stage is the implementation of the product in learning. The implementation involved 30 grade IX students at one of the junior high schools in Malang City. The pre-test was conducted to measure students' initial understanding, while the post-test was to measure learning outcomes after all the materials were delivered. A summary of the results of students' problem-solving skills is presented in Table 2.

The STEAM workbook was only used in the experimental class, while the control class used conventional methods. Table 2 shows the improvement of problem-solving skills in students after using the STEAM workbook, as seen from the difference in the mean of pre-test and post-test in both groups. Before the t-test was conducted, a prerequisite test was first conducted to ensure that the data met the requirements of the statistical test.

Test the Normality of Problem-solving Skills Data

The normality test using Shapiro–Wilk was conducted because the number of samples was <50 students. The results in Table 3 show that the significance values of the pre-test and post-test in both classes exceed the limit of 0.05, so the data are normally distributed.

Test the Homogeneity of Problem-solving Skills Data

If the data are normally distributed, the next step is the homogeneity test to determine the similarity of variance between groups. Table 4 shows the test results on the pre-test and post-test of the control and experimental classes, with a significance value above 0.05. This indicates that the data are homogeneous.

Table 2: Recapitulation of results pre-test and post-test

Class	Number of students	Average	Max	Min	Standard deviation
Pre					
Ex	30	31.43	39	25	3.821
Con	30	30.50	38	18	4.953
Post					
Ex	30	77.47	85	71	2.945
Con	30	40.30	50	28	4.557

Table 3: The results of the pre-test and post-test normality test

Class	Df	Sig (2-tailed)
Pre		
Ex	30	0.121
Con	30	0.107
Post		
Ex	30	0.331
Con	30	0.283

Table 4: Results of the homogeneity test of the questions pre-test and post-test

Class	Sig
Pre	
Ex	0.243
Con	
Post	
Ex	0.154
Con	

T-test of Problem-solving Skills Data

The difference test was used to determine whether the observed differences between the experimental and control groups were caused by the treatment or were simply random. The results of the normality and homogeneity tests showed that the pre-test and post-test data were valid, so it was continued with a t-test for independent samples. Table 5 shows a pre-test significance value of 0.41 (Sig >0.05), indicating that there was no significant initial difference between the two groups. However, the post-test significance value of 0.00 (Sig <0.05) indicates a significant difference after the treatment. Analysis of the average post-test score showed that the experimental class (mean = 77.47) was superior to the control class (mean = 40.30). This proves that the use of STEAM workbooks is effective in improving junior high school students' problem-solving skills on the topic of simple machines.

N-Gain test of Problem-solving Skills Data

After the research results showed that the problem-solving skills of the experimental class students were superior to the control class, the next step was analysis using the N-Gain test. This test compares the results of the pre-test and post-test to assess the increase in student understanding. The average N-Gain of the experimental class was 0.67, which is included in the fairly effective category (Hake, 1999).

Test d-Effect Size Data on Problem-solving Skills

Cohen's effect size test was used to measure the effect of using the STEAM workbook on students' problem-solving skills. Based on the calculation, a value of 7.227 was obtained, which is considered high (Cohen, 1988), indicating that the STEAM workbook has a positive impact compared to conventional methods.

Comparison of Pre-test – Post-test Results per Problem-solving Skills Indicator

Comparison of pre-test and post-test results per problem-solving skill indicator shows the extent to which students' abilities have improved after using learning media. This analysis also identifies indicators with significant improvements as well as parts that still need improvement. Figure 4 shows the highest increase of 203.47% in the indicator evaluating results.

Figure 4 clearly shows that problem solving skills (PSS) on each indicator in the experimental class increased after learning. The largest increase was seen in the "Evaluating Results" indicator, with an average score of 4.03 on the pre-test and 12.23 on the post-test, an increase of 203.47%. These results indicate that students' problem-solving skills improved significantly after using the STEAM workbook.

Analysis of Problem-solving Skills per PSS Indicator per Meeting

Each indicator of problem-solving skills was analyzed in every learning activity to monitor student progress. This analysis aimed to determine the impact of the media used and identify which indicators showed improvement and which still needed enhancement. The results revealed consistent growth across all indicators from session to session, supporting the assumption that the STEAM-workbook contributed to the improvements observed throughout the learning process. Comparing each session helped identify the most effective learning units and areas for further optimization.

Figure 5 illustrates that the average student scores on all PSS indicators increased after using the STEAM workbook. The highest improvement was seen in the "Evaluation of Results" indicator, which rose from 50 to 120 points, followed by "Problem Understanding," which increased from 42 to 114 points. Overall, the positive trend across all indicators demonstrates the STEAM workbook's effectiveness in enhancing students' problem-solving skills.

Table 5: Test results independent sample t-test

Class	N	Sig
Pre-test		
Ex-Con	30	0.417
Post-test		
Ex-Con	30	0.000

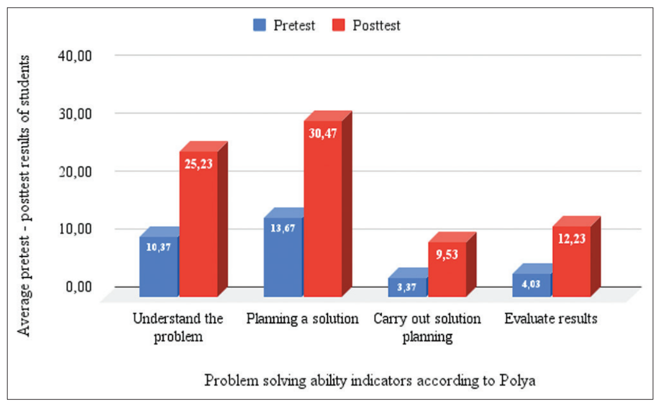

Figure 4: Comparison bar chart of results pre-test-post-test experimental class per problem-solving skills indicator

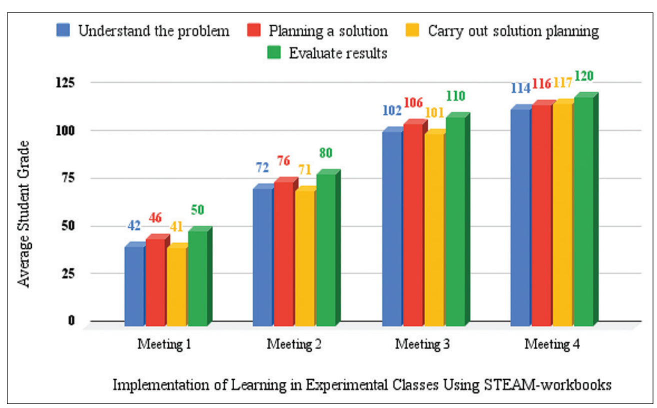

Figure 5: Comparison bar chart of the results of the STEAM workbook of the experimental class per problem solving skills (PSS) indicator per meeting. STEAM: Science, Technology, Engineering, Arts, and Mathematics

DISCUSSION

The use of STEAM workbooks effectively develops students' problem-solving skills. This study is in line with the findings Erol et al., (2023), which showed significant improvements in these skills through STEAM-based science education, as well as Akuba et al., (2022), which confirms the effectiveness of the interdisciplinary STEAM approach in encouraging critical and creative thinking. In the classroom, interactions between students, teachers, and learning resources create an active learning environment, where teachers act as facilitators and learning media increase student motivation. High learning motivation has a positive effect on student participation in class and the quality of learning (Fahri, 2022). According to Asma et al. (2022) stated that the lecture method is often considered monotonous, so interesting learning resources are needed to increase interest and problem-solving skills. The Industrial Revolution 5.0 requires students to master logical, independent, tolerant thinking skills, and be able to solve problems and make real contributions (Sholikah and Pertiwi, 2021). 21st-century education emphasizes integrated critical thinking, creativity, collaboration, communication, and problem-solving skills (Mardhiyah et al., 2021).

The improvement of problem-solving skills can be seen after the pre-test and post-test. The results showed that the mean pre-test of the experimental class was 31.43 and the control class was 30.50, while the post-test of the experimental class was 77.47 and the control class was 40.30. These data indicate that the STEAM-workbook intervention provided a greater improvement in problem-solving skills in the experimental class. The independent samples t-test confirmed a significant difference in the post-test between the experimental and control classes, with a gain value of the experimental class of 0.67, which was categorized as quite effective. The d' effect size value of 7.227 showed a strong influence of learning using STEAM workbooks. Thus, the application of this media significantly improved students' problem-solving skills, which are an important aspect in 21st-century education facing global competition. The improvement in student performance is also seen in the problem-solving skills indicators detailed in Figure 4.

Indicators of Understanding the Problem

The indicator of understanding the problem emphasizes students' skills in understanding relevant information, main issues, and the nature of the problem as a whole. An example of a question in this indicator is a student trying to move a rock. Students are asked to understand why the student still has difficulty even though she has used aids. A problem and questions related to levers were presented (Figure 6a).

In the pre-test stage (Figure 6b), although the students' answers were not entirely wrong, they were unable to provide specific explanations in accordance with the concept of mechanical advantage in levers. This shows that the students did not fully understand the problem, including the content of the questions and instructions, so the explanations they provided were inaccurate. Conversely, in the posttest (Figure 6c) with the same indicators and questions, there was an improvement. Students began to focus on the core of the question and were able to provide more complete, relevant, and conceptually appropriate answers. The use of the STEAM workbook contributed to the development of students' problem-solving skills. The post-test results show an improvement in these abilities, which is also reflected in the students' answers in Activity 4. One of the indicators observed is the ability to understand the problem. Based on the students' answers (Figure 7a and b), they are already able to identify and understand the problems presented. This activity also reflects the STEAM aspect, particularly the science component, as it encourages students to analyze problems in depth.

Indicators Planning Solutions

The solution planning indicator focuses on students' skills in developing appropriate problem-solving strategies, such as sketching, recognizing patterns, or utilizing previous experience with similar tasks. One example of a problem that fits this indicator is a problem about a steep path in a park that is difficult for wheelchair users to navigate. In this problem, students are asked to design a solution that can be used to overcome the problem, as shown in Figure 8a.

In the pre-test stage (Figure 8b), most of the students' answers did not show in-depth analysis and were still general in nature. Solutions such as building footpaths or adding handrails did not reflect an understanding of the main obstacles experienced by wheelchair users. This indicates that students' skills in planning solutions still need improvement, particularly in understanding the core of the problem and formulating appropriate answers. Conversely, the posttest results (Figure 8c) show a significant improvement. Students were able to identify causes more specifically and provide appropriate technical solutions. Answers were more structured and reflected a better understanding. These findings are reinforced by the activities in the STEAM workbook (Figure 9a and 9b), which train students to design and conduct independent experiments. These activities not only align with the PSS approach but also reflect indicators of science (Figure 9a) through scientific analysis of the presented problem, as well as engineering and art (Figure 9b) through creativity in designing experiments.

Indicators Solve Problems based on Solutions that have been Created

The implementation plan indicator focuses on how students carry out the steps that have been designed in a structured manner and demonstrate caution, accuracy, and consistency in their processing and calculation methods. One example of a question in this aspect is the problem of a river in a village with a current that is not too strong. Students are asked to select a problem, design a solution, and explain that solution simply. Figure 10a presents the problem and the questions students must answer.

In the pre-test stage (Figure 10b), students still had difficulty identifying the core problem and tended to provide general solutions, demonstrating limited technical understanding of the

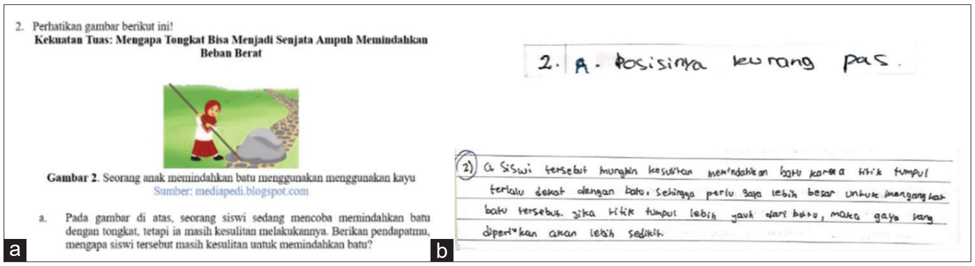

Figure 6: (a) Pre-test and post-test questions on the indicator of understanding problems; (b) Students' pre-test answers on the indicator of understanding problems; (c) Students' post-test answers on the indicator of understanding problems

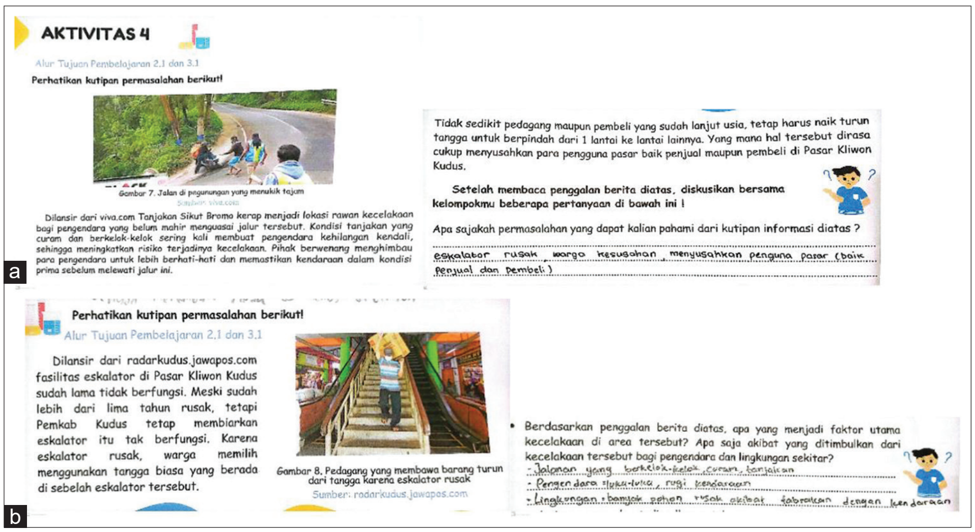

Figure 7: (a) Student activities and answers in the STEAM workbook with indicators of understanding problems and science aspects; (b) Student activities and answers in the STEAM workbook with indicators of understanding problems and science aspects. STEAM: Science, Technology, Engineering, Arts, and Mathematics

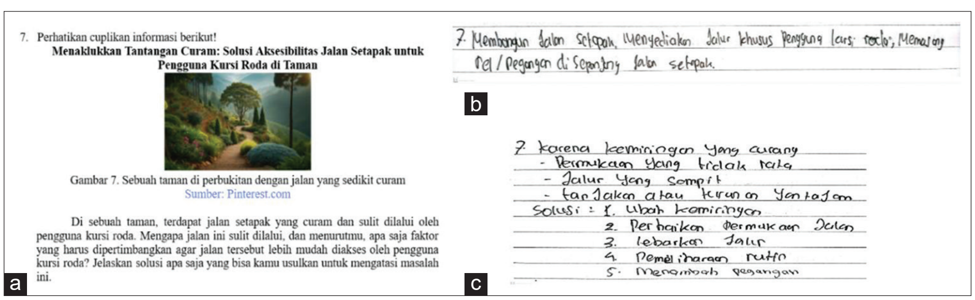

Figure 8: (a) Pre-test and post-test questions on the indicator of planning solutions; (b) Students' pre-test answers on the indicator of planning solutions; (c) Students' post-test answers on the indicator of planning solutions

relationship between water wheels and renewable energy. In contrast, in the post-test (Figure 10c), with the same indicators and questions, students' responses showed improvement. They were able to propose more specific technical solutions, such as a combined drive system for low water flow, and explain the structure and function of water wheels more accurately. This improvement reflects the significant contribution of the STEAM workbook in developing students' problem-solving skills. The activity in Figure 11 supports this, with indicators of problem-solving based on the solutions created. Students were able to provide clearer and more relevant answers, for example, by designing a pulley system from everyday materials. These activities foster conceptual understanding and applied skills, integrating STEAM elements such as Technology (Figure 11a) through QR codes linking to news sites, and Arts and Engineering (Figure 11b) through the creation of pulleys from recycled materials.

Indicator Rechecks the Answer

The indicator of reviewing answers emphasizes students' skills in reflecting on results, checking for correctness, and critically evaluating the solution process. Students are also expected

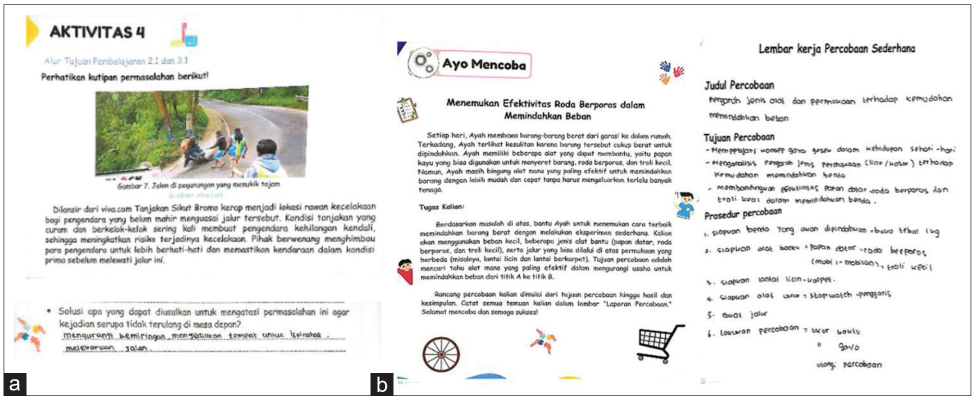

Figure 9: (a) Student activities and answers in the STEAM workbook with indicators of planning solutions and science aspects; (b) Student activities and answers in the STEAM workbook with indicators of planning solutions and engineering and arts aspects. STEAM: Science, Technology, Engineering, Arts, and Mathematics

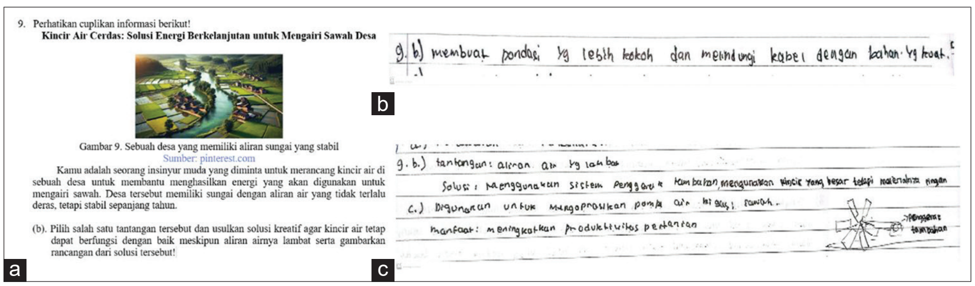

Figure 10: (a) Pre-test and post-test questions on the indicator of solving problems based on existing solutions; (b) Students' pre-test answers on the indicator of solving problems based on existing solutions; (c) Students' post-test answers on the indicator of solving problems based on existing solutions.

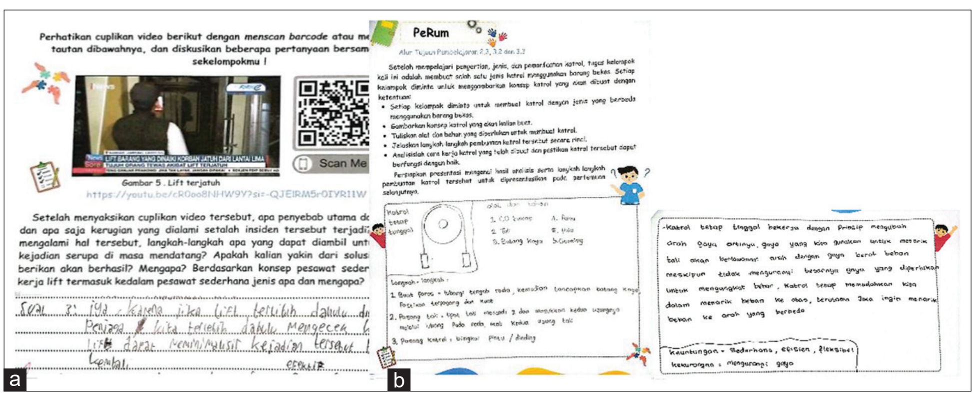

Figure 11: (a) Student activities and answers in the STEAM workbook with indicators of planning solutions and aspects of technology; (b) Student activities and answers in the STEAM workbook with indicators of planning solutions and aspects of engineering and arts. STEAM: Science, Technology, Engineering, Arts, and Mathematics

to consider alternative solutions if necessary. An example of a problem is a conveyor belt in a factory. Students are asked to identify preventive measures to prevent a similar problem from recurring, as shown in Figure 12a.

In the pre-test (Figure 12b), students' answers showed limitations in evaluating results, as they only presented one solution without explanation, indicating suboptimal understanding and evaluation skills. In the post-test (Figure 12c), there was an improvement, with students able to formulate more diverse and relevant preventive measures, such as material selection and load planning. This improvement is related to the use of the STEAM workbook during learning. This is also evident in the activities in the workbook (Figure 13a and 13b). It appears that students evaluate solutions based on the physics concepts they learned in Activity 4 (Figure 13b), reflecting their ability to evaluate results. This activity also reinforces the application of the STEAM approach, particularly the mathematics (Figure 13a) and science (Figure 13b) aspects,

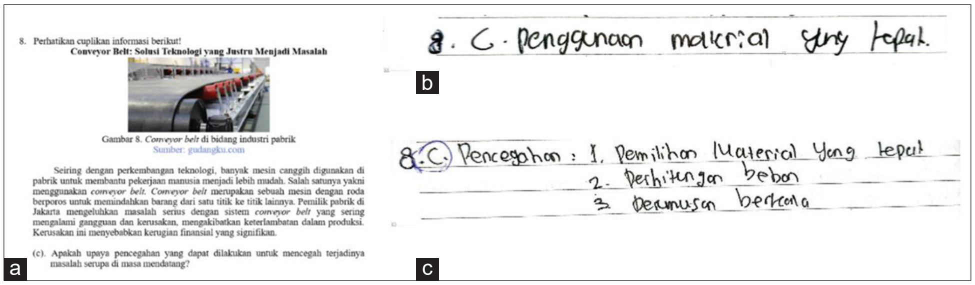

Figure 12: (a) Pre-test and post-test questions on the indicator of evaluating results; (b) Students' pre-test answers on the indicator of evaluating results; (c) Students' post-test answers on the indicator of evaluating results

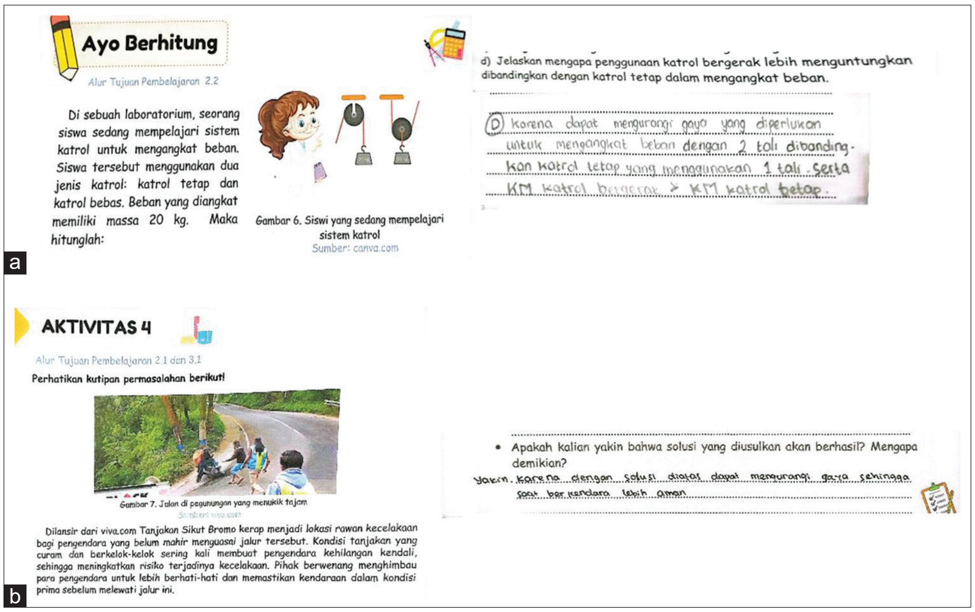

Figure 13: (a) Student activities and answers in the STEAM workbook with indicators of planning solutions and mathematical aspects; (b) Student activities and answers in the STEAM workbook with indicators of planning solutions and scientific aspects. STEAM: Science, Technology, Engineering, Arts, and Mathematics

through analysis of technical solutions and mathematical calculations.

The use of STEAM workbooks has been proven to have a crucial positive impact on students' PSS. This is demonstrated by the results of the post-test in the experimental class, which showed an increase compared to the pre-test, with an N-Gain value of 0.67. Learning activities in STEAM workbooks support improvements in all PSS indicators, especially in the indicator of evaluating results, which increased by 203.47%. This data is further supported by observations in (13a and figure 13b), which show students' ability to answer questions related to that indicatoru. Therefore, the use of the STEAM workbook can be considered effective in significantly improving students' problem-solving skills.

CONCLUSION

Based on the analysis and discussion conducted, it can be concluded that the STEAM workbook on the topic of simple aircraft developed is capable of fostering problem-solving skills in students. This learning resource is considered feasible and effective in fostering students' problem-solving abilities based on validity and reliability tests. The d' effect size test yielded a value of 7.227, indicating a significant impact of the implementation of the STEAM workbook on students' problem-solving skills. The content of the PSS indicators and STEAM elements within the developed workbook has proven effective in training each problem-solving indicator of students in an integrated manner. The t-test also indicated a notable difference in students' problem-solving skills before and after using the STEAM workbook.

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