Original Research Article

Development of a Problem-Based Learning Model Integrated with 21st Century Skills

ABSTRACT

This research aims to develop the PBL-4C Learning Model to promote mathematical problem-solving skills among students and to create a valid, practical, and effective PBL-4C learning model. It falls under the category of research and development (R&D). The model development process follows the Plomp development model, which comprises four phases: (1) initial investigation phase, involving student needs analysis, task analysis, concept analysis, and learning objective formulation; (2) design phase, encompassing the design of the PBL-4C learning model, including model syntax, social principles, reaction principles, instructional impact, facilitation, and support system; (3) implementation phase, which involves the complete construction of the PBL-4C model based on the previous design phase; and (4) testing, evaluation, and revision phase, which includes validation and pilot testing. The validation results of various validity instruments include the average score of the PBL-4C learning model book (3.67), student's book (3.98), student's worksheets (4.35), lesson plans (4.48), learning outcome tests (3.71), students' response questionnaires on the implementation of the PBL-4C learning model (4.12), students' response questionnaires on the student's worksheets (3.73), students' response questionnaires on the student's book (3.75), teacher's response questionnaires (3.65), students' activity observation sheets (3.75), and learning implementation observation sheets (3.40). Each of these validity instruments falls under the highly valid category, indicating that the PBL-4C learning model book and its supporting instruments meet the validity criteria. The PBL-4C model product is effectively implemented in teaching mathematics, specifically the topic of systems of linear equations with two variables. The effectiveness of the PBL-4C learning model is evaluated based on data analysis of its effectiveness components: (a) the average percentage of student activities during the implementation of the PBL-4C model in pilot test I is 63.25%, which falls under the "good" category, and the average percentage of student activities in pilot test II is 79%, falling under the "good" category; (b) the average percentage of student responses in pilot test I is 76% with positive responses, and in pilot test II, it is 82% with positive responses; (c) the learning outcome test results indicate that in pilot test I, 80% of students achieved mastery, while in pilot test II, 92% of students achieved mastery, thus meeting the criteria for classical mastery.

***Keywords**: Development, PBL-4C Model, Mathematical Problem-Solving*

INTRODUCTION

The increasing forces of globalization have intensified competition in various aspects of life, including the field of education. This presents a significant challenge in society, necessitating the need for high-quality human resources and an emphasis on improving the quality of education. The provision of human resources capable of critical thinking is an important agenda and a vital issue in modern education. Quality education is crucial for the development of individuals who can contribute to building a better society. Educational advancements should naturally occur in tandem with changes in cultural life. Continuous improvements in education at all levels are necessary as a means of anticipating future needs (Trianto, 2009). The government continues to make changes and innovations in the field of education towards better outcomes, including the curriculum renewal and innovation represented by the emergence of the 2013 curriculum. The 2013 curriculum emphasizes a learning approach aligned with the demands of the 21st century.

Skills for living and working in the 21st century encompass individuals' abilities to work effectively with diverse teams, embrace open-mindedness towards various ideas and values, establish and achieve goals, manage projects efficiently, take responsibility for outcomes, demonstrate good ethics, and be accountable to oneself and the larger community (Pasific Policy Research Center, 2010: 7). Aji (2019) defines 21st-century learning as an educational approach that equips learners with 21st-century skills, which include the 4Cs: 1) Communication, 2) Collaboration, 3) Critical Thinking and Problem Solving, and 4) Creativity and Innovation. One distinguishing characteristic of 21st-century learning is its focus on developing students' problem-solving abilities. According to Sugiyarti et al. (2018), the

implementation of the 4Cs concept within the 2013 curriculum has had a significant impact on the next generation's preparedness to face the challenges of the 21st century.

Low mathematical problem-solving abilities among students in Indonesia require attention from all parties. This can be seen from the results of the mathematics test conducted in 2015 as part of the PISA survey on 15-year-old students, which was conducted by the Organisation for Economic Co-operation and Development (OECD). The survey ranked Indonesian students 63rd out of 72 countries. However, in a study conducted in 2018, Indonesia's ranking further declined to 72nd out of 78 surveyed countries. There are several factors contributing to the low mathematical problem-solving abilities, including insufficient student participation in learning activities and inappropriate instructional models for developing problem-solving skills.

Mathematics education and mathematical problem-solving abilities are essential skills that students must possess. The significance of problem-solving skills in mathematics, as stated by Branca (1980), includes: (1) problem-solving skills as a general objective of mathematics teaching; (2) problem-solving, which involves models, procedures, and strategies, as the core and main process in the mathematics curriculum; and (3) problem-solving as a fundamental skill in learning mathematics.

The objectives of mathematics learning can be achieved by planning appropriate mathematics instructional processes. Therefore, the use of suitable instructional models in the teaching and learning process is necessary. According to Kunandar (2014), a good teacher should plan their lessons before implementing them in the classroom. Lesson planning can be designed in the form of instructional materials. The researcher conducted initial observations and interviews with a mathematics teacher in a junior high school in Gowa Regency. The interviews focused on aspects related to the development of instructional models and supporting materials such as syllabi, lesson plans, and student worksheets used by the teacher in the teaching and learning process.

The interview results revealed that the existing instructional models did not specifically focus on problem-solving approaches, which resulted in very low problem-solving abilities among students. Without a specific model, the instructional materials used by the teacher were only based on existing instructional models, while what needs to be addressed is the improvement of students' problem-solving skills. Therefore, the development of an instructional model aimed at enhancing students' problem-solving abilities is necessary.

A study conducted by Putri (2020) on the mathematical problem-solving abilities of eighth-grade students in the topic of statistics illustrated that although students were able to determine and write down the given information and the questions in the problem, they faced difficulties in answering the questions. Students were unable to correctly determine the problem-solving strategies required to solve the given problems. One form of preparation that teachers need to undertake in the teaching process is the development of instructional materials. There is a need for innovative mathematics teaching methods that focus on student-centered learning and provide opportunities for students to enhance their learning activities.

According to Arends (cited in Trianto, 2009), Problem-Based Learning (PBL) is a learning model that utilizes real-world problems as a context for students to learn problem-solving skills. In line with the research conducted by Novianti et al. (2020), it was concluded that the PBL model enhances mathematical problem-solving abilities among seventh-grade students at SMPN 9 Pekanbaru. The Problem-Based Learning (PBL) model involves the presentation of contextual problems related to everyday life by the teacher, which trains students to solve problems that require creative thinking. Based on an analysis of the instructional materials used by mathematics teachers during the 2018/2019 academic year, including syllabi, lesson plans, and student worksheets, it was found that there are still many deficiencies in creating and developing these instructional materials. Therefore, the development of instructional components that can serve as examples and assist teachers in the teaching and learning process, tailored to the needs of students in their environment, is highly necessary.

Furthermore, research conducted by Yustianingsih & Syarifuddin (2017) and Baharuddin (2014) produced integrated mathematics instructional materials incorporating 21st-century skills through the implementation of the Problem-Based Learning (PBL) model to enhance students' mathematical problem-solving abilities in the topic of statistics for eighth-grade students at the junior high school level. The instructional materials were considered highly valid, practical, and effective after undergoing validation processes by qualified experts and eighth-grade students to ensure the practicality of the developed instructional materials. However, there has been no research designing and developing a learning model that integrates 21st-century skills to specifically sharpen students' mathematical problem-solving abilities through the proposed model.

Based on the preliminary study conducted at MTS Arifah Gowa, the following information was obtained: (1) students' ability to solve contextual problems is still very limited. Students rely heavily on

teacher assistance in understanding contextual problems and have not developed their own knowledge; (2) in the learning process, teachers have not fully assumed the role of facilitators for students but rather remain the main actors in the classroom. This is due to teachers' limited ability to design learning activities that encourage student engagement; (3) it is essential to familiarize students with problem-solving activities to promote the development of critical thinking, reasoning, and creative thinking skills; (4) students' potential for higher-order thinking skills in mathematics learning is lacking, despite the increasing demand for such skills in 21st-century education; (5) there is a great potential for developing students' higher-order thinking skills if the learning process incorporates 21st-century skills, as these skills will help students improve their analytical and reasoning abilities. Therefore, it is crucial to develop a Problem-Based Learning (PBL) model that integrates 21st-century skills to enhance students' problem-solving abilities.

To develop 21st-century skills, the learning approach should be student-centered, promote teamwork, and connect to students' daily life contexts. Everyday life problems encountered by students can serve as learning topics where they can apply the knowledge concepts they have acquired. One learning approach that meets these criteria is the constructivist approach, with the project-based learning model being popular within this approach.

Problem-Based Learning (PBL) is designed based on innovative learning theories, such as constructivism and experiential learning, by presenting problems that involve various disciplines to find appropriate solutions. PBL is considered one of the methods that educators can use to assist students in becoming competent problem solvers and facing future challenges. Edens (2000) suggests that PBL equips students with 21st-century skills. In line with this, the author intends to conduct further research on the development of a 21st-century PBL model to enhance students' mathematical problem-solving abilities.

METHOD

The research adopted a Research and Development (R&D) approach with the aim of developing the PBL-4C Learning Model to enhance mathematical problem-solving abilities. The study conducted by the researcher falls under the category of development research or Research and Development (R&D). R&D in the field of education is a process used to develop and assess the validity of a product. According to Sugiyono (2011: 333), the R&D research method is employed to produce a specific product and test its effectiveness. Nana Syaodih Sukmadinata (2009: 164) defines R&D research as a process or series of steps to develop a new product or improve an existing product that can be accountable. The research would be conducted at MTs Arifah Gowa, located on Bakolu Street. Thus, the researcher was interested in selecting seventh-grade students as the research subjects to conduct product testing.

The PBL-4C learning model would be developed and studied for its validity, practicality, and effectiveness through content validity testing, language accuracy assessment, and expert validation. This assessment would determine the achievement level of the PBL-4C learning model, the feasibility of implementing the PBL-4C model, and field testing.

Data collection would be conducted during the validation and evaluation stages, utilizing quantitative data obtained through the completion of instruments such as questionnaires, observation sheets, and test instruments. The collected data would be analyzed using quantitative data analysis techniques, including descriptive statistical analysis, frequency distribution and percentage analysis, as well as the one-group pretest-posttest Normalized Gain (N-Gain) analysis to measure the effectiveness of the PBL-4C learning model.

RESEARCH FINDINGS

The development of the PBL-4C learning model in this study employed the Plomp development model. One of the objectives of this research was to produce a valid, practical, and effective PBL-4C Learning Model to enhance students' mathematical problem-solving abilities in the topic of Systems of Linear Equations with Two Variables for seventh-grade students at MTs Arifah Gowa. To achieve this purpose, a systematic development process was undertaken by following the modified steps of the Plomp development model as mentioned in Chapter III. The development stages in the Plomp model included (1) initial investigation phase, (2) design phase, (3) realization/construction phase, and (4) testing, evaluation, and revision phase.

The product generated in this research was the PBL-4C learning model. The specifications of the developed product are as follows:

1. A high-quality PBL-4C learning model that meets the criteria of validity, practicality, and effectiveness.

2. A book on the PBL-4C learning model containing the basic theory of model development, the concepts of the PBL-4C learning model, implementation guidelines, and assessment techniques for the PBL-4C learning model.
3. Supporting documents for instructional implementation, including a teacher's guidebook (implementation instructions for the model), student book, lesson plans, student worksheets, validation sheets, model implementation observation sheets, classroom management observation sheets, student activity observation sheets, students' response questionnaires, teachers' response questionnaires, and learning outcome tests.

The first validation process involved submitting the initial design of the PBL-4C learning model, along with the developed instructional materials, which included: (1) the PBL-4C learning model book; (2) the student book with the PBL-4C learning model; (3) lesson plans; (4) students' worksheets; (5) achievement tests; (6) students' response questionnaires; (7) teachers' response questionnaires; (8) students activity observation sheets; and (9) classroom management observation sheets. The second validation process was carried out by revising the materials based on the feedback received from the validation team during the first validation process.

The results of the assessment and analysis of the PBL-4C learning model materials can be summarized in the following table, with further details provided in the appendix.

Table 1: Average Validation Results of the PBL-4C Learning Model Materials

Learning Materials	Average Validation Results
PBL-4C Model Book	3.67
Students' Book	4.06
Lesson Plans	4.48
Students' Worksheets	4.35
Learning Outcome Test	3.71

The validation results of the PBL-4C learning model instruments can be summarized in the following table, with further details available in the validation results appendix.

Table 2: Average Validation Results of PBL-4C Learning Model Instruments

Learning Instruments	Average Validation Results
Students' Response Questionnaire on the Students' Book	3.75
Students' Response Questionnaire on the Worksheets	3.73
Students' Response Questionnaire on the Implementation of the PBL-4C Learning Model	4.12
Teacher's Response Questionnaire on the Implementation of the PBL-4C Learning Model	3.65
Observation Sheet on the Implementation of the PBL-4C Learning Model	3.48
Observation Sheet on Teacher's Classroom Management Skills	3.56
Observation Sheet on Students' Activities	3.75

Learning mastery is the most important component in assessing effectiveness, and it was not fully achieved in Trial 1. Therefore, this component deserves attention and improvement. Another aspect that influences learning mastery and needs further improvement is activity 3 (activity related to problem-solving preparation). This aspect is also influenced by the teacher's ability to manage learning using the PBL-4C learning model in Phase 3, which is not yet optimal.

Before conducting Trial 2, revisions would be made by providing more intensive guidance and training to teachers, ensuring that they pay close attention to the aspects when implementing the PBL-4C learning model.

The effectiveness of the PBL-4C learning model in Trial 2 is summarized in the following Table 3.

Table 3: Summary of Development Results of the PBL-4C Learning Model in Trial 2

No.	Effectiveness Indicators	Criteria	Attainment	Outcome
Practicability				
a.	Average observation results of syntactic	> 3.4	4.35 > 3.4	Fulfilled

	component implementation			
b.	Average observation results of social system component	> 3.4	4.6 > 3.4	Fulfilled
c.	Average observation results of principle reaction component	> 3.4	4.4 > 3.4	Fulfilled
d.	Average observation results of support system component	> 3.4	5 > 3.4	Fulfilled
e.	Average observation results of teacher's classroom management skills	≥ 3.5	4.2 > 3.4	Fulfilled
Effectiveness				
a.	Learning outcomes			
	Average student learning outcomes	≥ 75	85 > 75	Fulfilled
	Percentage of students who achieved mastery based on Minimum Proficiency Level (MPL)	≥ 75	90 > 75	Fulfilled
	Percentage of students who achieved classical mastery	KK ≥ 85%	90 > 85	Fulfilled
b.	Students' Activities			
	Observation results of student activities	≥ 60	85 > 60	Fulfilled
c.	Students' Response			
	Response to the students' book	≥ 60	85 > 60	Fulfilled
	Response to the students' worksheets	≥ 60	85 > 60	Fulfilled
	Response to the PBL-4C learning model	≥ 60	88 > 60	Fulfilled

The above results indicate that in Trial 2, the PBL-4C model has met the criteria of validity, practicality, and effectiveness. In other words, a high-quality PBL-4C model has been achieved.

DISCUSSION

Based on the results of the validity test, which involved assessments from expert validators, it can be concluded that the PBL-4C learning model and other valid instruments have met the validity criteria as described in Chapter III, despite undergoing revisions based on the suggestions provided by the validators.

The validation analysis results from the validators indicate the validation of several instruments, including the PBL-4C model book with an average rating of 3.67, student book with an average rating of 3.98, students' worksheets with an average rating of 4.35, lesson plan with an average rating of 4.48, learning achievement test with an average rating of 3.71, students' response questionnaire on the implementation of the PBL-4C learning model with an average rating of 4.12, students' response questionnaire on students' worksheets with an average rating of 3.73, students' response questionnaire on the students' book with an average rating of 3.75, teacher's response questionnaire with an average rating of 3.65, students' activity observation sheet with an average rating of 3.75, and learning implementation observation sheet with an average rating of 3.40. Each of these validity instruments falls under the category of highly valid. Therefore, the PBL-4C model book and its supporting instruments meet the validity criteria.

The validated learning model, observation sheets, student response questionnaires, and learning achievement tests were then piloted with the students to determine the effectiveness of the learning model through the data obtained during the pilot activities.

Based on the previous discussion on effectiveness testing, the effectiveness of the learning model is assessed based on: (1) student activities, (2) student responses, and (3) learning achievement tests.

The data analysis results for these effectiveness components are as follows: (1) the average percentage of students' activities in implementing the PBL-4C model during the first pilot was 68%, falling under the "good" category, and the average percentage of student activities during the second pilot was 85%, categorized as "good" (2) the average percentage of positive student responses during the first pilot was 80%, and during the second pilot, it was 85%, both indicating positive responses. (3) In terms of learning achievement tests, 77% of students achieved competency in the first pilot, and in the second pilot, 88% of students achieved competency, meeting the criteria for classical competence. Based on the results of these pilot tests, all three criteria were fulfilled, indicating that the developed learning model meets the effectiveness criteria.

Based on the findings from the first and second pilots, it can be concluded that students' mastery of mathematics subject matter falls into the high category, indicating an improvement in students' understanding of mathematics through the implementation of the PBL-4C learning model.

The syntactic development of the PBL-4C learning model encompasses the concept of mathematical problem-solving closely related to several concepts found in mathematics learning, such as modeling and the mathematical process. This process involves formulating real-life problems into the language of mathematics. Consequently, these problems can be solved as mathematical problems, and the mathematical solutions can be interpreted to provide answers to real-life problems. By using the PBL-4C learning model, students are accustomed to solving problems related to everyday life. This is in line with the theory that problem-based learning, especially mathematical problem-solving, is an effective strategy for developing higher-order thinking skills (Nur, 2000; Weiss, 2003).
The characteristics of the PBL-4C learning model in this study are as follows:

a. The PBL-4C learning model trains students' ability to solve mathematical problems. The planning and problem-solving phase is where students gather the necessary information to solve the given problems.
b. The evaluation tools, including tests and assignments, use non-routine contextual problem-solving tasks based on mathematical problems. These evaluation tools aim to measure students' learning outcomes, particularly their ability to solve mathematical problems. This is in line with the theory that problem-based learning, especially mathematical problem-solving, is an effective strategy for developing higher-order thinking skills (Nur, 2000; Weiss, 2003).
c. The developed PBL-4C learning model is accompanied by supporting materials, including lesson plans, the PBL-4C learning model book, student's books, student's worksheets, and evaluation tools, each with its distinctive features:
    1. Lesson plans are designed according to the stages of the PBL-4C learning model.
    2. The PBL-4C learning model book is designed for ease of use. It provides implementation instructions for the model and examples of assessment that facilitate teachers in using the PBL-4C learning model.
    3. The student book is designed according to the stages of the PBL-4C learning model. It includes readings and competency tests that consist of Higher-Order Thinking Skills (HOTS) questions, thereby developing students' mathematical problem-solving abilities.
    4. The worksheets are designed to be engaging, motivating students to work on the included problems. They are accompanied by instructions for completion, making it easy for students to use them.
d. The PBL-4C learning model is designed to develop students' mathematical problem-solving abilities. The mathematical ability referred to here is the ability to model or simplify real-life problems into mathematical form.
e. The PBL-4C learning model is designed to develop students' communication and problem-solving skills. This aligns with the planning and preparation phase, where students present their problem-solving results to other groups. The presenting group showcases their problem-solving outcomes, while other groups critique and evaluate the presented solutions.

CONCLUSION

The development of the PBL-4C learning model followed the five stages of Plomp's development approach, which are (a) initial investigation stage, (b) design stage, (c) construction realization stage, (d) testing, evaluation, and revision stage, and (e) implementation stage. The validation results for several validity instruments are as follows: the PBL-4C learning model book with an average of 3.67, student's book with an average of 3.98, student's worksheets with an average of 4.35, lesson plans with an average of 4.48, learning outcome tests with an average of 3.71, students' questionnaire responses to the implementation of the PBL-4C learning model with an average of 4.12, students' questionnaire responses to the student's worksheets with an average of 3.73, students' questionnaire responses to the student's book with an average of 3.75, teacher's questionnaire responses with an average of 3.65, observation sheets of students' activities with an average of 3.75, and observation sheets of instructional implementation with an average of 3.40. Each of these validity instruments falls into the category of very valid. Thus, the PBL-4C learning model book and its supporting instruments meet the validity criteria. The PBL-4C model product was effectively implemented in teaching the topic of systems of linear equations with three variables in mathematics. The effectiveness of the PBL-4C learning model is observed through the analysis of data from its effectiveness components, which are (a) the average percentage of student activities in the implementation of the PBL-4C model in trial I was 63.25%, categorized as "good," and the average percentage of student activities in trial II was 79%, categorized as "good"; (b) the average percentage of student responses in trial I was 76% with a positive response, and the average percentage of student responses in trial II was 82% with a positive response; and (c) the learning outcome test in trial I showed that 80% of students achieved mastery, and in trial II, 92% of students achieved mastery, meeting the criteria for classical mastery.

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