International Education Studies; Vol. 16, No. 4; 2023
ISSN 1913-9020 E-ISSN 1913-9039
Published by Canadian Center of Science and Education

Development of Scientific Problem-Solving Skills in Grade 9 Students by Applying Problem-Based Learning

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Received: February 3, 2023 Accepted: April 20, 2023 Online Published: July 20, 2023

doi:10.5539/ies.v16n4p29 URL: https://doi.org/10.5539/ies.v16n4p29

Abstract

Making predictions and observations, interpreting data, and drawing conclusions are all examples of scientific problem-solving procedures. The purpose of this research was 1) to develop scientific problem-solving skills by applying problem-based learning as a basis for students in grade 9 to pass the 70 percent requirement and 2) to study the satisfaction of grade 9 students with respect to problem-based learning management. With these aims in mind, the author developed science learning activities in everyday life by applying problem-based learning management in four plans and developing students' scientific problem-solving skills. Data were collected with a 20-item, multiple-choice scientific problem-solving skill assessment. A total of 32 students in grade 9 in a public secondary school were chosen as study participants. The data were examined with respect to the mean, standard deviation, and percentage. The results revealed that the grade 9 students had an average scientific problem-solving skill score of 15.28 points, representing 76.40%. From this, it can be seen that students had problem-solving skill scores higher than the base requirement. Regarding grade 9 students' satisfaction with PBL management, the mean value was 4.62, representing the most satisfied level.

Keywords: problem-based learning, scientific problem-solving skills, secondary school, pre-experimental

1. Introduction

Scientific understanding is urgently required to address and solve the world's challenges in the twenty-first century. By acquiring scientific information, students who are a part of the community are developed into a scientific society. Harris (2012) asserts that students with a strong science background are better equipped to address and solve societal issues, especially those who possess profound knowledge, application-ready creativity, and critical thinking. According to the PISA (OECD, 2019), scientific literacy involves explaining scientific phenomena, evaluating and designing scientific investigations, and comprehending scientific data and evidence. According to Lee & Grapin (2022), it is essential to consider students' knowledge of how to describe scientific phenomena. The evaluation and planning of scientific research, as well as other facets of interpreting scientific evidence and data, must be understood by students.

The results of recent research are quite regrettable given the value of scientific literacy skills in the twenty-first century. Improved scientific literacy development is therefore required. Learning science stresses students' thinking processes so that they may grasp and solve problems in a critical, logical, meticulous, and complete manner and not just understand topics, developing a science-literate society (Darwanti, 2013). One of the most crucial abilities students should possess is solving problems creatively (Ead et al., 2022). Everyone faces challenges in daily life that demand problem-solving skills. Scientific problem-solving skills are the skills to analyze a problem and then review from memory the knowledge related to that problem (Muangjin, 2022). The capacity for problem solving teaches pupils to analyze numerous topics on their own in a holistic, significant, genuine, and applicable manner (Hariawan et al., 2013). Polya (1965) claims that recognizing an issue at hand, creating a solution plan and carrying it out, and reevaluating outcomes are all examples of problem-solving skills.

However, teachers frequently use Flipbook material developed from student textbooks for teaching and learning activities in lower secondary schools. In addition to mastering science, there is a propensity to be theoretical. The instructor will present the material using PowerPoint; the teacher explains and the students take notes. As a result, pupils need more motivation to learn science. Students hardly exercise problem-solving techniques, since this type of learning does not result in contextual understanding connected to everyday situations. Scientific literacy is the ability to engage in science-related issues (OECD, 2019), and problem-solving skills are a person's basic skills to solve critical, logical, and systematic problems. For such cases, teachers must reform the learning process, which is the heart of education reform. The National Education Act has stipulated guidelines for education management that adhere to the learner as the most important component. This requires a student-centered approach to learning experiences, and a student-centered approach to learning involves a variety of principles, instructional styles, and techniques. Therefore, an ideal learning method for developing scientific knowledge and problem-solving skills is problem-based learning with the integration of scientific issues. According to Rosyidi (2018), Problem-Based Learning (PBL) is a learning model aimed at helping students learn and discover concepts and solve problems by linking real-world problem situations. PBL also aims to help students improve their thinking, problem-solving, and cognitive skills (Nurdin & Uleng, 2023) and can help students hone their capacity to interact, communicate, and solve problems (Nurfajriah et al., 2022; Schwartz, 2013). In addition, PBL assists in the solution of numerous issues from various angles. This significance comes from the fact that this type of learning management is founded on a problem-based methodology and is a form of learner-centered learning management. It supports the gradual development of students' knowledge acquisition through problem-solving skills. This will improve their ability to apply knowledge to real-world situations. In addition, students should produce a piece of work on their own to develop and demonstrate that they can do things according to the role of the student. Problem-based learning has many advantages, accustoming students to problem solving and challenging them to solve problems relevant to learning in the classroom and everyday life (Suarsana et al., 2019).

As a result, the present author was interested in fostering scientific problem-solving thinking among students by using problem-based learning management as a foundation. This research aimed to 1) develop scientific problem-solving skills by applying problem-based learning as a basis for students in grade 9 to pass the requirement of 70 percent and 2) study the satisfaction of students with problem-based learning management.

1.1 Related Research

Sari et al. (2021) studied a PBL model in which students solved problems and reported them in scientific articles. Their results showed that problem-based learning significantly affected students' problem-solving, scientific writing, and collaborative problem-solving skills. In line with this, Sagala et al. (2017) study assessed the influence of the PBL model on the scientific process skills and problem-solving ability of students. The results showed a medium improvement in physics skills using problem-based learning, while the average increase in the science process skills of students using everyday learning was high. In the common criterion, the average problem-solving skills of physics students using the problem-based learning style were in the moderate and medium categories. There was also an increase in students' science process skills when using conventional learning; in contrast, the average increase in the problem-solving skills of students using the traditional learning model was more significant than the increase in science process skills. These results suggest that PBL is better at solving students' problems than traditional learning. Furthermore, Simanjuntak et al. (2021) presented the effectiveness of PBL combined with computer simulation for students' problem-solving and creative thinking skills. Their results also showed a positive relationship between students' problem-solving and creative skills. This suggests that PBL combined with computer simulation is more effective than problem-based or traditional teaching methods alone. PBL education, according to Argaw et al. (2017), helps students develop problem-solving abilities that are applicable to their everyday lives. Priorities in physics education are necessary to decide the optimal manner for pupils to study physics, and the authors recommend raising student achievement. Schools must carefully modify their PBL strategy. Students' reasons for studying physics, however, remained unclear. Syafii and Yasin (2013), in contrast, investigated how high school students' problem-solving abilities and academic performance are affected by adopting problem-based modules (PBM) for biology topics. Their findings suggested that PBM could enhance problem-solving skills and student productivity in terms of learning and achievement. Comparing the experimental group to the control group, the experimental group scored higher in the three categories. In addition, Fitriani et al. (2020) showed the effects of PBL integrated with Predict, Observe, Explain (POE) on problem-solving skills and self-efficacy. The results indicated that PBLPOE strongly impacted students' problem-solving skills and self-efficacy when compared to PBL, POE, and conventional learning alone.

2. Method

2.1 Research Methodology

This study represents pre-experimental research in the form of a one-group post-test-only design.

2.2 Sample group

The population of this study was 120 secondary school students in semester 1 of grade 9 in the 2022 academic year; the target group was 32 students. There were 20 females and 12 males in the target group, obtained by purposive sampling. The average score for problem-solving skills of these students was below 70%.

2.3 Research Tools

The tools used in this research consisted of the following:

1) Four plans for learning management based on applying PBL to materials in daily life, including polymer, ceramic, and composite materials. The results were affected by the use of polymers, ceramics, and composite materials. The time spent in learning management was a total of 8 periods of 50 minutes each. The tool was checked for quality and reviewed by three content experts. The average suitability was 4.78, which was the highest suitability level with a consistency index of 1.

2) A multiple-choice scientific test covering skills related to analyzing problems, proposing solutions, and verifying results. The scientific problem-solving assessment form had 4 options and 20 items, with a consistency index of 1. The difficulty value (P) and distinguishing power value (R) were calculated to be between 0.72 and 0.78 and 0.19 and 0.50, respectively.

3) A questionnaire on satisfaction with learning management involving the application of problem-based learning. The questionnaire consisted of a five-point Likert scale (1932) with ten items and had a consistency index of 1.

2.4 Data Collection

The study data were collected as follows:

1) The students completed the questionnaire for solving scientific problems before studying individually.

2) The data from the pre-test scores for scientific problem-solving thinking were analyzed.

3) The PBL management plans were implemented, after which students completed a quiz on scientific problem-solving using the post-test. Then, all students were asked to complete the ten-question satisfaction questionnaire on receiving the applied PBL learning management.

4) The test scores for scientific problem solving and satisfaction were then taken for data analysis.

2.5 Data Analysis

The students' scientific problem-solving skills were analyzed using the mean, standard deviation, and percentage. If the average score was less than 70 percent, the requirement was not met; a score of 70 percent met the criteria. Student satisfaction was also analyzed using mean and standard deviation for the five-point Likert scale rating system, where 4.50 or higher indicated most satisfied, 3.50 - 4.49 was very satisfied, 2.50 - 3.49 was moderately satisfied, 1.50 - 2.49 was less satisfied, and below 1.50 denoted least satisfied.

3. Results

The results of analysis of scientific problem-solving skills in grade 9 students with the application of PBL management are shown in Table 1.

Table 1. Scientific problem-solving skills test results

Student No.	Post-test scores	
	Score out of 20 points	Percentage
1	14	70
2	14	70
3	17	85
4	14	70
5	15	75
6	15	75
7	14	70
8	15	75
9	17	85
10	16	80
11	16	80
12	14	70
13	14	70
14	18	90
15	18	90

16	16	80
17	17	85
18	16	80
19	14	70
20	14	70
21	17	85
22	14	70
23	14	70
24	14	70
25	14	70
26	16	80
27	16	80
28	14	70
29	14	70
30	15	75
31	15	75
32	18	90
Average	15.28	76.40
Standard deviation	1.37	

From Table 1, the students who received PBL management had a mean score for scientific problem-solving skills of 15.28 with a standard deviation of 1.37, representing 76.40 percent. All students passed the requirement of 70 percent.

The results of the satisfaction survey of grade 9 students who received PBL management are shown in Table 2.

Table 2. Student satisfaction with PBL management

List	Average	Standard deviation	Interpret
1. Learning activities enable students to gain knowledge in their learning content.	4.63	0.59	Most suitable
2. Learning activities make students feel entertained.	4.60	0.65	Most suitable
3. Learning activities train students to search for knowledge by themselves.	4.51	0.74	Most suitable
4.Learning activities train students to be assertive.	4.57	0.74	Most suitable
5. Learning activities encourage students to think critically about problems to lead to problem solving.	4.78	0.48	Most suitable
6. Learning management activities promote students' ability to think and solve problems.	4.66	0.64	Most suitable
7. Learning management activities encourage students to take initiative and be critical.	4.21	1.63	Very suitable
8. Learning management activities allow students to think differently and perform activities independently.	4.69	0.63	Most suitable
9. The learning management activities have appropriate time allocation for lectures and integration activities.	4.78	048.	Most suitable
10. The learning activities use suitable media and equipment for learning management.	4.75	0.55	Most suitable
Average	4.62	0.71	Most suitable

Based on Table 2, it was found that grade 9 students who managed to learn by applying PBL were satisfied, with a mean score of 4.62 and a standard deviation of 0.71, which was the highest level of satisfaction. When considering the ten items, it was found that items 5 and 9 had the highest average level of satisfaction, with a mean of 4.78.

4. Discussion

Problem-based learning management is a collection of learning and teaching activities based on the scientific method with a learner-centered focus. It strongly emphasizes encouraging students to learn, do their research, gather information, and contribute to knowledge creation. Students engage in social interaction, knowledge sharing, and physical movement. Additionally, students master groupwork, problem-solving, and management techniques. Applying knowledge to solve problems is a novel approach to education that infuses the classroom with interest and enthusiasm rather than boredom. Students make the most of their abilities, get the chance to communicate their ideas, and are free to choose how to respond to inquiries and develop their knowledge. The ability to freely share their thoughts when solving problems is important to students, and designing learning activities where students can inquire about the problem's reality in the context of the circumstance is crucial.

The four steps in developing scientific problem-solving abilities are problem identification, problem analysis, technique selection, and result monitoring. Thus, instructors must redesign their learning management system for learners to achieve all four criteria. In this research, PBL management was reduced from six steps to four phases; as a consequence, 70% of all grade 9 students passed the requirement. This was accomplished by adjusting the learning activities to foster the development of scientific problem-solving skills. The following is a detailed explanation of how learning management systems and learning exercises that encourage scientific problem-solving are leveled.

The PBL management described by the Ministry of Education (2007) has six steps, where the first step consists of defining the problem. This is the stage where the teacher sets up numerous scenarios to pique the students' interest and help them identify the issue they are interested in learning about and eager to solve. The next phase is understanding the problem that the students must comprehend to learn; students must be able to describe concepts associated with the situation. Study and research are the third steps. What is studied is decided by the learner, who will carry out independent research and self-study using a variety of techniques. Knowledge synthesis is the fourth step. This is a stage in which students bring the information they have learned from their research to share, discuss, and synthesize the learned information. At this point, the question is asked whether the information is appropriate or inappropriate, and the responses are analyzed before summarizing the five steps. By trying to explore concepts inside their group independently, each group of students summarizes their group's work and determines if the information studied was appropriate or not. Each group contributes to a new summary of the information regarding the problem's overall picture. The final step is to review and assess the work. The data acquired is used by the learners to categorize their knowledge and convey it in several ways. The result is then reviewed collectively by all learner groups, including those who contributed to the issue.

In this study, steps 1 and 2 were combined to create a problem-based learning management system appropriate for learners in the school context. Additionally, steps 4 and 5 were combined in order to shorten the steps and increase the amount of time spent on activities that would help participants improve their ability to think critically and solve scientific problems across all four domains (Gallagher, 1997). Learning using the PBL management system created here consists of the following aspects: 1. Understanding and describing the challenge. At this point, the teacher sets up several scenarios, encourages students to show interest, and highlights issues. Students must be able to articulate the problem they wish to learn about and be motivated to seek solutions. This requires the student to be able to communicate details on the issue (emphasis on identifying the problem). 2. The study and research phase consists of the learners deciding what they want to learn. They use various methods to carry out research (problem analysis is highlighted). 3. The knowledge synthesis stage summarizes and assesses students' responses. This is the stage where students bring the information they have learned to share and learn together. Whether it is appropriate or not, the findings are discussed and the knowledge acquired is summarized. Each learning group analyzes the work produced by their group and determines whether the knowledge is relevant. They do this by striving to independently evaluate concepts inside their group (emphasis on determining methods to solve problems). Performance analysis is carried out in the last stage. In this last phase, students organize their knowledge based on what they have learned and display their work in several different ways. The knowledge of both instructors and students is evaluated (emphasis on the result verification stage).

Structuring learning activities with a problem-based model that allows students to create research groups produces different results in terms of the elements that lead to the development of scientific problem-solving abilities from the circumstances and identified issue. These activities should involve planning and creating a remedy by being aware of the problem, as well as putting the information learned from applying and summarizing the problem-solving strategy into practice. Students can practice problem-solving skills through the process resulting from learning management activities. Through these activities, which begin with problem identification and function as a tool to encourage the pursuit of information, students have the chance to exercise their problem-solving abilities. This encourages self-learning from the issue until it becomes a skill, which involves looking for any approach or technique to address it. The presentation of each solution is founded on reason and is verifiable. Students can learn continually through this process, which allows them to fully comprehend the content they are studying and build long-lasting knowledge from their process skills.

This is in line with Piaget's theory of cognitive development, according to which rational and abstract problem-solving, also known as formal operation, is the pinnacle of intellectual development. Children can grasp formulae or rules well if they can reason, establish and prove assumptions, and solve difficulties through thinking before tackling problems.

According to behavioral observations and interviews, students' prior knowledge produces scientific problem-solving abilities (Hernández-Suarez et al., 2022). Students are more creative when the classroom environment is favorable. Parents' and students' attention to scientific thinking results from teachers' attention, which is vital to both groups of people. Parents look out for their children and encourage their education to help them succeed in school (Weir, 1974). This aligns with research on the effectiveness of PBL management in learning management. In this study, the average degree of satisfaction was 4.62, which is the highest level. The students found the learning management activities to be satisfactory with respect to lectures and integrative activities, especially when learning management was in the knowledge synthesis stage. Thus, learning activities that enable students to think critically about the problem lead to problem-solving. Summarizing and assessing responses allows students to voice their thoughts in class and to their peers. In this way, learners can also recognize the needs of teachers.

5. Conclusion

The application of PBL management leads to the development of scientific problem-solving skills. Every stage of this form of learning management is designed to provide students with practice thinking and planning to formulate solutions. Additionally, it teaches students how to put the knowledge they have acquired to use by adapting and utilizing their strategies. Students learn how to solve problems by following a step-by-step procedure. Moreover, encouraging students to seek out information provides them with the chance to show their problem-solving skills. When answers are offered, they are logical, efficient, and verifiable, which gives students long-lasting knowledge.

6. Recommendations

To plan PBL activities efficiently and effectively, teachers must become adept in their duties at each step in organizing the activities. Additionally, teachers should allocate enough time for students to study all of the course material, as PBL activities require students to work in small groups and access proper study and research materials. In conjunction with PBL learning management, the buddy technique, which urges learners to explore with group members and creates a lively and motivating learning environment, is one technique teachers should employ to organize extra learning activities. In addition to encouraging collaboration and teamwork, learners must desire to learn more.

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