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Development of Problem-Solving Abilities in Science by Inquiry-Based Learning With Cooperative Learning for Grade 4 Students

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Abstract

Considering problem-solving ability as an important qualification in the 21st century that could be developed by instructional methods that allow learners to construct their knowledge via questioning through cooperative learning activities, we conducted action research with the purpose of investigating the effectiveness of inquiry-based and cooperative learning on grade 10 students' problem-solving ability and studying students' satisfaction with inquiry-based and cooperative learning in developing their problem-solving ability. The participants were 7 grade 4 students in the Thai educational context. They were selected from a class of 20 students using the results of a placement test. The instruments were a learning management plan designed using the integration of inquiry-based learning and cooperative learning, a problem-solving ability evaluation form, and a satisfaction questionnaire. The data was analyzed using the statistics of percentage, mean score, and standard deviation. The result shows that the integration of the two methods was beneficial in improving the problem-solving skills of the majority of the participants. Participants were also satisfied with learning management throughout the semester it was implemented.

Keywords: Inquiry-based learning, Cooperative learning, Problem-solving

1. Introduction

1.1 Introduce the Problem

In the 21st century, learning management focuses on enhancing the competitiveness of learners in producing innovations that could solve problems in the next era of human civilization. Thinking skills are one of the qualities that could contribute to this ability. According to Saido et al. (2015), the thinking process and cognitive processing capacity are crucial for learners in the era of improved network technology and information flow. Consequently, the challenges are more complex and entail topics such as multicultural awareness, disruptions in technology, global citizenship, etc. Therefore, learners must be creative, critical, and analytical to overcome the problems of the twenty-first century. This also places a demand on educators to use the appropriate educational methodology to develop these skills.

This perspective also raises the importance of problem-solving ability – the process one uses to combine skills and abilities to overcome challenges in his or her context. To illustrate, critical and analytical thinking are used to process the problems while creativity is combined with skills to present the most appropriate solution. According to Mayer and Wittrock (2006), problem-solving is characterized as a cognitive process that focuses on achieving a goal for which students are unfamiliar with a solution strategy. Likewise, ability is defined as an intellectual activity of the brain that seeks an explanation for a given problem or identifies a strategy to achieve a given objective (Haury, 2002). In problem-solving, the brain uses all its cognitive abilities such as critical thinking, decision-making, and reflective thinking to process the information and provide resolutions to the problems (Juliyanto et al., 2021). Individuals can comprehend what problem-solving is and why it's important when they are able to overcome problems and difficulties effectively and use their knowledge and abilities to complete their jobs and achieve their goals (Kapur, 2020).

In addition, it should be noted that developing problem-solving ability is a complex process. Mayer (1992) categorizes problem-solving skills as cognitive, process, directed, and personal. In more detail, cognitive-problem solving happens in a student's mind. It can only be deduced from the student's behavior or perspective, including physiologic changes, self-analysis, and problem-solving activities. The second involves the analysis of processes used in solving the problems. This entails changing a conceptual representation through action. Directed problem-solving is conducted to achieve a certain goal. Lastly, personal problem-solving is the concept influenced by the individual’s prior knowledge. Therefore, a problem can be a problem for one person but not for another who knows how to fix it.

Polya (1945) recommended four phases for problem-solving: comprehending the situation, formulating a plan, executing the plan, and reflecting. The author says to assess unknowns, data, conditions, and potential of fitting conditions. In this process, figures could divide the condition. A plan that connects unknown and available data to find a problem-solving answer should also be created. Plan execution must be evaluated, and plan implementation must be systematic. Lastly, questions should be asked to verify the outcomes of the plans, other arguments that could follow, possible comparative solutions, validation of the results, and feasibility of the plan to other issues. Therefore, problem-solving requires logical reasoning to handle information effectively and efficiently.

The complexity of problem-solving creates difficulties in educational environments. Carson (2007) proposed that learning to solve a problem is a heuristic process in which learners are expected to apply their knowledge and skills in each circumstance until they discover the most effective solution. Therefore, challenges in teaching problem-solving abilities depend on students' knowledge as much as thier problem-solving knowledge. In learning to solve problems, the challenges presented in class require just the application of prior information to be resolved. Consequently, curriculums are also intended to assist students to acquire the information necessary to solve challenges in their contexts. At a contextual level, Thai students were reported to have problem-solving problems as they lacked the knowledge to process information. As a result, they were unable to effectively utilize their analytical abilities, which led to poor problem-solving solutions (Vongtathum, 2015).

It can be seen that the process of problem-solving development includes learning opportunities that allow for the development of thinking, knowledge, and knowledge-application techniques. Consequently, inquiry-based learning (IBL) could be an alternate paradigm for allowing students to develop knowledge from their past knowledge using an inquisitive mindset to seek a solution to a scientific question (Coffman, 2017). According to Caswell and LaBrie (2017), IBL is a method of instruction in which students take ownership of their learning by posing and answering questions. In IBL, students engage in active learning processes in which they take charge of their education through problem-solving contexts involving information sharing and data analysis (Archer-Kuhn et al., 2022). The IBL exercises could begin by encouraging students to pose questions and investigate real-world issues. In science classrooms, for instance, students are frequently given a problem to solve and instructed on how to apply the scientific process to find a solution. Since problem-solving is heuristic, (Maxwell et al., 2015) letting students build their own knowledge through inquiry-based learning would help them improve their skills.

The empirical evidence of the impact of inquiry-based learning on problem-solving development can be seen in previous studies (*e.g.*, Divrik et al., 2020; Rust, 2011; Sabourin et al., 2012). In particular, Divrik et al. (2020) found that the integration of the IBL and metacognitive strategies positively affected the young learners' problem-solving ability. Moreover, it also helped in developing their mathematical learning achievement. In Rust (2011), the participants in 9th grade could develop both problem-solving abilities and conceptual knowledge of physics after learning in an inquiry-based learning class. Meanwhile, game-based learning environments were supported by the IBL learning activities in Sabourin et al. (2012).

Moreover, given that tackling real-world problems requires cooperation between individuals with diverse knowledge and experiences, cooperative learning would also improve the IBL activities' question-answering. Cooperative learning (CL) is a method that enables students to work together to solve issues, complete activities, or create projects (M. Laal & M. Laal, 2012). In CL, students are challenged socially and emotionally as they listen to the ideas of others and defend their own. Learners construct their own conceptual frameworks rather than relying on ideas developed by experts, which may not be applicable to their circumstances. Students can communicate with classmates, present and defend ideas, exchange diverse points of view, and question conceptual frameworks in a CL class (Leonard & Leonard, 2001). The merger of inquiry-based learning with cooperative learning may be advantageous for learners in the process of developing problem-solving skills, as it would enable them to ask questions and provide cooperative responses using the scientific method.

Likewise, cooperative learning activities have been applied to support learners' problem-solving abilities as shown in the results of previous studies (*e.g.*, Adolphus et al., 2013; Suryatin, 2020; Wismath & Orr, 2015). In detail, Adolphus et al. (2013) found that cooperative learning was beneficial in teaching problem-solving and the concept of simple harmonic motion to senior secondary students. Suryatin (2020) also found the benefits of cooperative learning in developing the mathematical problem-solving skills of college students in Indonesia. Likewise, Wismath and Orr (2015) discovered that cooperative learning helps students solve problems as a group. The discussion between peers also assisted students in assuming responsibility for their own learning and conceiving acceptable solutions to problems.

Considering the importance of problem-solving ability in 21st-century learning and the potential of inquiry-based learning and cooperative learning in designing an instructional package to develop the ability, we integrated the two principles and applied them in a science course. We proposed two objectives for the studies including 1) to investigate the effectiveness of inquiry-based and cooperative learning on grade 10 students' problem-solving abilities and 2) to study students' satisfaction with inquiry-based and cooperative learning in developing their problem-solving abilities.

2. Method

2.1 Research Design

The study was designed utilizing an action research methodology (Kemmis & McTaggart, 1988). The strategy focuses on resolving classroom issues for students who struggle with a subject. A placement exam is used to identify and select students who are below the class's expected outcomes. Two PAOR (Plan–Act–Observe–Reflect) learning circles are assigned. Each requires one-half of the semester. In learning circle 2, the improvement of learning activities in learning circle 1 is evaluated. This is done to ensure that the participants receive the best possible treatment.

2.2 Participants

The participants were grade 4 students in the Thai educational context. They were selected from a class of 20 students as they failed the placement test regarding plans in daily life – the concept learned in the class. For the background of participants, they were in a small school in a rural area of a Thai educational context. This type of school faces educational disparity in terms of budget, teaching materials, and facilities (Prasartpornsirichoke & Takahashi, 2013). Therefore, the students had limited knowledge of scientific concepts and problem-solving abilities.

2.3 Instruments

2.3.1 Learning Management Plan

The learning management plan was designed using the integration of inquiry-based learning and cooperative learning. Therefore, learning includes processes that allow students to answer class questions by doing group activities. The discussion among peers was encouraged, and the group's answers were presented to the class to discuss with the teacher and other peers. In detail, there were eight sub-lesson plans that took 16 hours to complete. In detail, 1-4 sub-lesson plans were categorization of plants, flowering plants, roots and stems, and water and minerals conveying respectively. Meanwhile, the 5-8 sub-lesson plans were transpiration, photosynthesis, components of flowers, and function of flowers respectively. The design of the learning management system was informed by the opinions of five experts who deemed it feasible and suitable for the teaching environment.

2.3.2 Problem-Solving Ability Evaluation Form

The problem-solving ability evaluation form consisted of 2 tests. Each test has 20 four-multiple-choice question items. The content of the test is related to 4 situations regarding plans found in daily life. The questions aim to evaluate the student's abilities to identify problems, set hypotheses, gather information, process information, and summarize the answers. The index of item objective congruence (IOC) was 0.6-1.0.

2.3.3 Satisfaction Questionnaire

The questionnaire consists of 10 positive statements regarding learning management. It was designed on a 5-likert scale. The index of item objective congruence (IOC) of the statements was 0.6-1.0.

2.4 Data Collection and Data Analysis

The learning management plan was implemented in a fourth-grade science class for one semester. Two learning circles were utilized, with sub-lesson plans 1-4 being implemented in learning circle 1. The test was administered to evaluate the problem-solving skills of the students, and the results were discussed in an effort to enhance the teaching strategy. The 5-8 sub-lesson plans were utilized in learning circle 2 as a result of the improved teaching technique. Again, the problem-solving skills of the students were assessed to determine the efficacy of the learning management system. The data was analyzed with the improvement of the student's abilities in each learning circle accompanied by the statistics of percentage, mean score, and standard deviation. The data collection processes can be seen in Figure 1.

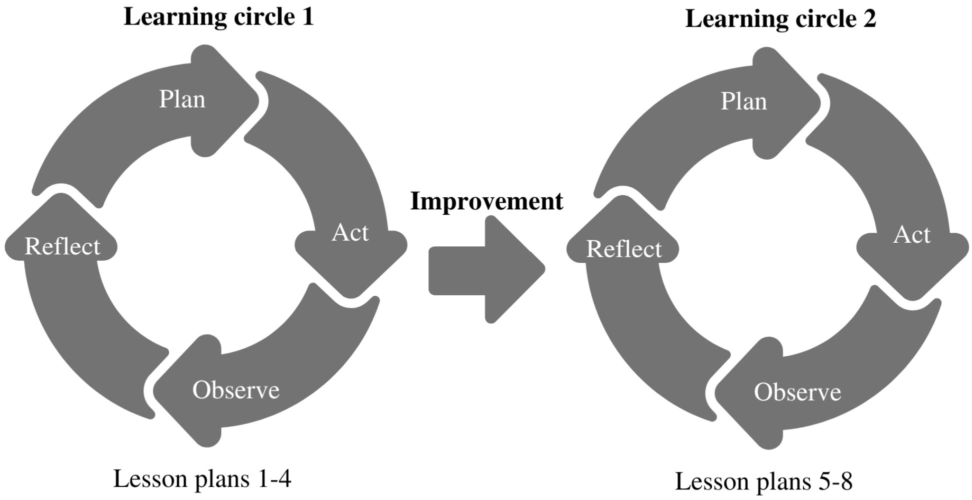

Figure 1. Learning circles of data collection

3. Results

3.1 Learning Circle 1

Table 1. Participants' problem-solving abilities after learning circle 1

Students (n)	Learning circle 2		
	Problem-solving Abilities in Science	% (out of 20)	Evaluation
1	8	40.00	Failed
2	11	55.00	Failed
3	13	65.00	Failed
4	16	80.00	Passed
5	6	30.00	Failed
6	10	50.00	Failed
7	6	30.00	Failed
$\bar{x}$	10.00	50.00	
S.D.	3.70		

The results of the study indicate that only 1 student passed the expected performance after learning circle 1. The average score of the students was 10 (S.D. = 3.70), which accounts for 50 % of the full score. The results were involved in the discussion to improve the teaching strategy, which can be seen below.

It was found that the primary issue in learning circle 1 was communication between students and teachers, which prevented them from connecting the information to draw conclusions and respond to the given situation. In addition to lacking group work skills, the students did not listen to their group members. Moreover, they lacked the ability and knowledge to use scientific instruments. Due to a lack of confidence in front of the class, no member of the group volunteered to be the representative during the presentation session. The exercises did not correspond to the expected outcomes of the course, which were for students to practice problem-solving.

Therefore, the teaching strategies in learning circle 2 involved teacher intervention as a facilitator role. There was a brief lecture on conceptual knowledge, exemplification of tools, and the role of members in cooperative learning at the early stage of each class. Exercises were adjusted to respond to problems found in the previous section.

Table 2. Participants' problem-solving abilities after learning circle 2

Students (n)	Learning circle 2		
	Problem-solving Abilities in Science	% (out of 20)	Evaluation
1	13	65.00	Failed
2	17	85.00	Passed
3	16	80.00	Passed
4	17	85.00	Passed
5	11	55.00	Failed
6	16	80.00	Passed
7	10	50.00	Failed
$\bar{x}$	14.29	71.43	
S.D.	2.93		

The results of the study indicate that 4 students passed the expected performance after learning circle 2. The average score of the students was 14.29 (S.D = 2.93) which accounts for 71.43 % of the full score.

Comparatively, learning circle 2 successfully improved students' problem-solving abilities. The proportion of the participants passing 80% of the full mark increased from 14.28 % after learning circle 1 to 54.14 % after learning circle 2. Therefore, it could be assumed that the integration of inquiry-based learning and cooperative learning was beneficial in the development of participants' problem-solving abilities.

Table 3. Students' satisfaction with learning management

No.	Statements	x̄	S.D.	Degree of agreement
1	The purposes of learning activities were clear.	5.00	0.00	Very high
2	The teachers' advice was satisfying.	4.57	0.53	Very high
3	Interaction between teachers and students was satisfying.	4.29	0.49	High
4	The assessment was fair.	5.00	0.00	Very high
5	The assessment was transparent.	4.29	0.49	High
6	I had learned with independence.	4.57	0.53	Very high
7	I learned from class activities.	4.71	0.49	Very high
8	I learned the class concept by doing.	4.29	0.49	High
9	I could apply what I learned in class to daily activities.	3.71	0.49	High
10	I was eager to learn science.	4.00	0.00	High
Overall		4.44	0.15	High

The results of the study indicate agreement with the positive statements regarding learning management ($\bar{x}$ = 4.44, S.D. = 0.15). In detail, participants were pleased with the learning activities and assessment because they perceived them to be fair and evaluable. They also reported that independent and hands-on learning activities enhanced their learning. Briefly, the learning management system was teachable and inspired student enthusiasm for science. It could be interpreted that the participants were satisfied with learning science and problem-solving with activities designed with the integration of inquiry-based learning and cooperative learning.

4. Discussion

4.1 Inquiry-Based and Cooperative Learning Management and Problem-Solving Ability

The results show that the activities designed using the integration of inquiry-based learning and cooperative learning helped increase the number of students passing the expected outcome of the class. The results are consistent with others (*e.g.*, Adolphus et al., 2013; Divrik et al., 2020; Rust, 2011; Sabourin et al., 2012; Suryatin, 2020; Wismath & Orr, 2015) who also found the benefits of the two principles in developing students' problem-solving abilities. In the current study, questions related to the concept of plans were raised in the class where students cooperatively worked to answer them. They had practiced connecting their life experiences to the content of the class; finding answers; discussing; presenting ideas; questioning other ideas; and defending their ideas. As is shown by the results of the study, this led to the development of their problem-solving abilities.

4.2 Learner-Teacher Dependence in Cooperative Learning

Moreover, the effects of cooperative learning on students' problem-solving ability in the current study yield an interesting point about the implementation of cooperative learning strategies. In learning circle 1, students were given the freedom of group learning. It ended up with a failure in cooperative learning perspectives as the students did not listen to each other and could not present their discussion results to the class. After adjusting the cooperative learning activities went smoothly after the intervention of teachers as facilitators, they brought about positive results for the class. According to Xiaodan et al. (2019), learner-teacher dependence should be considered with the nature of each instructional context. Young students may require advice from their teachers in order to benefit from certain instructional methods.

4.3 Hands-On and Independent Learning Activity and Class Environment

According to the findings of the study, the implementation of the management plan led to positive learning experiences for the class. The hands-on and independent learning experiences provided by the IBL and CL-based learning activities made the class enjoyable and fostered positive attitudes toward science. According to Holstermann et al. (2010), engaging in hands-on activities to solve real-world problems assists students in establishing a link between their prior knowledge and class concepts. Students would also benefit from active learning environments - the factor that makes class engaging.

5. Conclusion

In this study, action research was conducted to improve the situations of students who had difficulty learning how to solve problems in science classes. In a classroom where seven students were the focus of the investigation, an inquiry-based learning and cooperative learning-based learning management plan was implemented. Even though we were unable to solve all of the participants' problems after two learning circles, we were able to improve the problem-solving skills of the majority of them. Throughout the semester that learning management was implemented, students were also pleased.

The results of the study could be implemented in teaching problem-solving. Teachers can use the techniques in inquiry-based learning and cooperative learning to develop students' problem-solving abilities in science classes. However, they should consider learner-teacher dependence issues to decide how much they should intervene in in-class cooperative learning activities. Some students would lose control of their learning if they had too much freedom, which wouldn't help them get better at learning on their own.

More research should focus on integrating the teaching model into inquiry-based learning and cooperative learning and figuring out how they affect problem-solving and other thinking skills like creative, analytical, and critical thinking.

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