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Development of Scientific Problem-Solving Skills in 5th Grader Using Problem-Based Learning

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Abstract

The purpose of the research was to develop scientific problem-solving thinking skills in fifth-grade pupils by using problem-based learning (PBL). The target group was 21 pupils attending a primary school located in Sakon Nakhon province, northeast Thailand. Data were collected twice (first and second cycle) in substance change learning unit in the second semester of 2021 academic year. Three types of research tools were the following: six PBL plans within 12 hours (pupils experienced 3 plans in each cycle and 2 hours for each plan), scientific problem-solving thinking skill test (SPSTST), and observation of scientific problem-solving behavior (OSPSB). A minimum criterion was 70% of mean score in SPSTST and SPSBO, and at least 70% of the pupils reached that. The results in the 1st cycle showed that pupils had 67.46% in SPSTST and 57.14% of them passed the minimum criterion. They had 65.85% in SPSBO and 57.14% of them passed the minimum criterion. In the 2nd cycle, pupils had 91.67% in SPSTST and 90.48% of them met the minimum criterion.

They had 87.58% in SPSBO and 90.48% of them met the minimum criterion.

Keywords: Problem-based learning, Scientific problem-solving skill, Scientific problem-solving behavior

1. Introduction

In the 21st century, the world is changing rapidly in various areas of economic, social, environmental, and technological aspects. The change has greatly affected livelihoods due to science and technology innovations causing economic expansion, change in society, and capability to compete with countries. According to such an emerging circumstance, people need urgent actions to accomplish imperative skills e.g., critical thinking, communication, problem-solving, creativity, technology, and digital literacy to elevate the quality of life in globalization (Stutesman, Havens, & Goldstein, 2021; Nuangchalerm, 2020). Improving well-versed skills in science and technology with a good problem-solving ability to adapt to changes since childhood is vital. Bloom et al. (Krathwohl, Bloom, & Masia, 1964) mentioned that the cognitive, attentive, and psychomotor development of pupils was crucial for pupils. The development of intelligence was the learning to solve real-world problems (Tan, 2003). Furthermore, the National Education Act B.E. 2542 (1999) and the second amendment B.E. 2545 (2002), and the third amendment B.E. 2553 (2010), which was congruent with the core curriculum of fundamental education (The Basic Education Core Curriculum, 2008) in Thailand set guidelines for learning from actual experiences, practicing cognitive process skills, and applying knowledge to solve problems. In addition, subject matters in schools have Basic Education some of them may appear in their daily life. Therefore, teaching and learning especially the PBL approach that enables pupils to inquire, discover, and analyze causes and effects of problems as well as enhance scientific thinking skills to tackle them are appropriate pathways. Scientific problem-solving skills were congruent with improving the quality of life of pupils and aligned with the science learning management curriculum (Youngtrong, Siridhrungsri, & Khamdit 2017). Pupils struggling with problems should be taught how to solve them systematically.

Office of the Education Council (2007) mentioned that the appropriate patterns of learning activities for developing scientific problem-solving thinking skills are in PBL approach. It consists of 6 learning activity stages including 1) problem determination 2) problem understanding 3) research phase 4) knowledge synthesis 5) summary and evaluation of answers, and 6) presentation and evaluation. If pupils encounter problems and learn from experiences under expert supervision, they are probably familiar with and establish their habit to confronted problem that can enrich scientific problem-solving thinking skills (Hawamdeh & Adamu, 2021). Ali (2019) mentioned that providing more chances to pupils to practice working as a team, communicating effectively, and developing self-learning process could elevate skills. PBL approach is determined one of effective pedagogies to promote those skills (Duch, Groh, & Allen, 2001; Rajabzadeh, Mehrtash, & Srinivasan, 2022) in a classroom.

Although the National Education Act B.E. 2542 and the amendments and core curriculum made very effort to improve pupil skills to survive in 21st century, Office of Nation Education

Standards and Quality Assessment (Chailert & Maneekoson, 2015) found that only 12.90% of pupuls, approximately 13,000 schools in nationwide, had good thinking skills. In general, these pupils rarely took subjective and rationality exams because teaching and learning activities still emphasize on content and memorization rather than developing systematic thinking skills. In addition, the Trends in International Mathematics and Science Study 2015; TIMSS 2015 (Institute for the Promotion of Teaching Science and Technology, 2017) found that the pupils could not do exam that required reasoning, problem-solving thinking skills, and analyzing problems. They cannot attribute or describe as a step about problem and solution because teaching and learning did not emphasize the thought process.

According to revealed issues and advantaged PBL, this action research, therefore, attempted to develop the scientific problem-solving skills of 5th graders in topic Substance Changes by using PBL.

2. Methodology

(1) As convenience sample, twenty-one participants, 11 males and 10 females, were pupils in 5th grade (age 10-11) attending a primary school located in Mueang District, Sakon Nakhon Province, Thailand.

(2) Data were collected in the second semester of 2021 academic year.

(3) The tools used in the research were as follows: 6 problem-based learning plans (PBLPs), scientific problem-solving thinking skill test (SPSTST), and observation of scientific problem-solving behavior (OSPSB). Note that each PBL plan took 2 hours, so it was 12 hours overall within 6 weeks.

(4) This action research used McTaggart model (Kemmis & McTaggart, 1988) as shown in Figure 1. Each cycle consisted of 4 stages: plan, act, observe, and reflect (PAOR).

(5) In the 1st cycle, participants experienced 3 PBL plans and then took SPSTST and OSPSB.

(6) In the 2nd cycle, participants experienced 3 PBL plans and then took SPSTST and OSPSB. According to the 1st cycle, collected data while teaching and learning were deliberately determined and properly used to reinforce in the last 3 PBL plans for the 2nd cycle.

(7) Descriptive statistics, mean score and standard deviation, were used to analyze collected data.

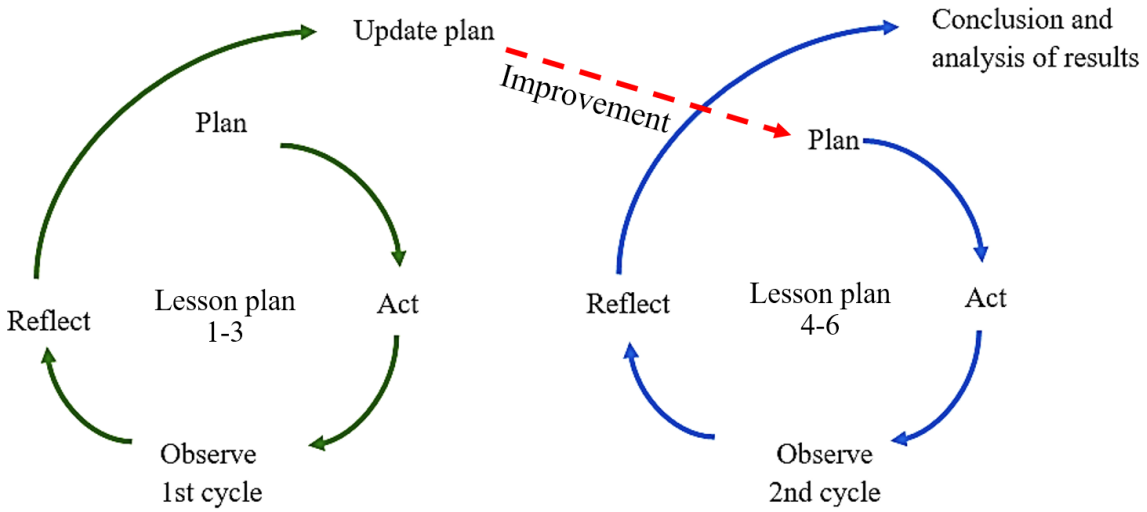

Figure 1. Two cycles of action research

The detail of PAOR of action research are described below:

Step 1 Plan: Teacher identifies a specific problem of pupils which found that 5th graders have a difficulty on scientific problem-solving then teacher designs to improve it. After literature about enhancing scientific problem-solving abilities, teachers construct lessons using problem-based models, coordinate learning activities, and develop tools.

Step 2 Act: The learning management plan was implemented in a science class in a topic of Substance Changes for 5th grader in the second semester of 2021 academic year. Two learning cycles were utilized. Plans 1-3 are being put into practice in the first learning cycle. After the 1st cycle completed, plans 4-6 were developed and implement in learning cycle 2.

Step 3 Observe: after implement the designed learning plan**,** the pupils then took SPSTST and OSPSB to assess the improvement.

Step 4 Reflect: Analyze the collected data form each tools, discuss and summary the achievement of pupils.

3. Results

In the 1st cycle, after experiencing 3 PBLPs, pupils' performance in SPSTST showed in Table 1, and in OSPSB is shown in Table 2.

Categories included in both tables were mean score and standard deviation of problem indication, problem analysis, problem-solving, result checking, total score, percent of the score, and the passing criterion (70% of score) respectively. In addition, the first four categories have 3 points for each, interpreted into low-level, medium-level, and high-level skill in PSTST (Srisaard & Nilkaew, 2018), so the total score was 12 points.

Table 1. Pupil performance in SPSTST of the 1st cycle

Categories	The 1st cycle: Scientific problem-solving thinking skill test (SPSTST)						
	Problem identification (3)	Problem analysis (3)	Problem solving (3)	Result checking (3)	Total score (12)	Percent of score	Passing criterion (Yes/No)
x̄ (S.D.)	2.48 (0.68)	2.14 (0.79)	1.86 (0.65)	1.62 (0.5)	8.10	67.46	No
Interpreting*	Medium	Medium	Medium	Medium			

Note. *2.59-3.00 high level skill in SPSTST, 1.50-2.49 medium level skill in SPSTST, and 1.00-1.49 low level skill in SPSTST.

In the Table 1, pupil performances in SPSTST of the 1st cycle were classified to medium performance in all four categories. The pupils obtained the highest score in problem indication (2.48) and the lowest score in checking result (1.62). Last, the total score was 8.10 points out of 12 points (67.46%), therefore considered as not passing minimum criterion (No).

Table 2. Pupil performance in OSPSB of the 1st cycle

Categories	The 1st cycle: Observation of scientific problem-solving behavior (OSPSB)						
	Problem identification (3)	Problem analysis (3)	Problem solving (3)	Result checking (3)	Total score (12)	Percent of score	Passing criterion (Yes/No)
x̄ (S.D.)	2.22 (1.54)	2.11(1.49)	1.84 (1.72)	1.73 (1.62)	7.90	65.85	No
Interpreting*	Medium	Medium	Medium	Medium			

Note. *2.59-3.00 OSPSB in high level, 1.50-2.49 OSPSB in medium level, and 1.00-1.49 OSPSB in low level.

In Table 2, pupil performances in OSPSB of the 1st cycle were considered as medium performance in all four categories like SPSTST. The pupils obtained the highest score and the lowest score in problem indication (2.22) and checking result (1.73), respectively. The total score was 7.90 points out of 12 points (65.85%), therefore considered as not passing minimum criterion (No).

After the 1st cycle, the pupils experienced another 3 PBLPs in the 2nd cycle. The pupil performances in SPSTST showed in Table 3 and in OSPSB showed in Table 4. All vital categories included in the tables were still the same as in Tables 1 and 2.

Table 3. Pupil performance in SPSTST of the 2nd cycle

Categories	The 2nd cycle: Scientific problem-solving thinking skill test (SPSTST)						
	Problem identification (3)	Problem analysis (3)	Problem solving (3)	Result checking (3)	Total score (12)	Percent of score	Passing criterion (Yes/No)
$\bar{x}$ (S.D.)	2.90 (0.30)	2.90 (0.30)	2.71 (0.46)	2.48 (0.60)	11	91.67	Yes
Interpreting*	High	High	High	Medium			

Note. *2.59-3.00 high level skill in SPSTST, 1.50-2.49 medium level skill in SPSTST, and 1.00-1.49 low level skill in SPSTST.

In Table 3, pupil performances in SPSTST of the 2nd cycle showed that all four skills were improved, compared with those of the 1st cycle. All skills were considered as high level with score between 2.48-2.90 points out of 3 points in each category. The total score was 11 points out of 12 points (91.67%), therefore considered as passing minimum criterion (Yes).

Table 4. Pupil performance in OSPSB of the 2nd cycle

Categories	The 2nd cycle: Observation of scientific problem-solving behavior (OSPSB)						
	Problem identification (3)	Problem analysis (3)	Problem solving (3)	Result checking (3)	Total score (12)	Percent of score	Passing criterion (Yes/No)
$\bar{x}$ (S.D.)	2.83 (0.33)	2.75 (0.35)	2.54 (0.33)	2.40 (0.27)	10.51	87.58	Yes
Interpreting*	High	High	High	Medium			

Note. *2.59-3.00 OSPSB in high level, 1.50-2.49 OSPSB in medium level, and 1.00-1.49 OSPSB in low level.

Table 4 displayed the OSPSB pupil performance data of the 2nd cycle. Compared with those of the 1st cycle, the pupil performances in problem identification, problem analysis, and problem solving were improved from medium to high level with score between 2.54-2.83 points out of 3 points in each category. Note that result checking skill was still considered as medium level; however, its score was increased from 1.73 to 2.40. The total score was 10.51 points out of 12 points (87.58%), therefore considered as passing minimum criterion (Yes).

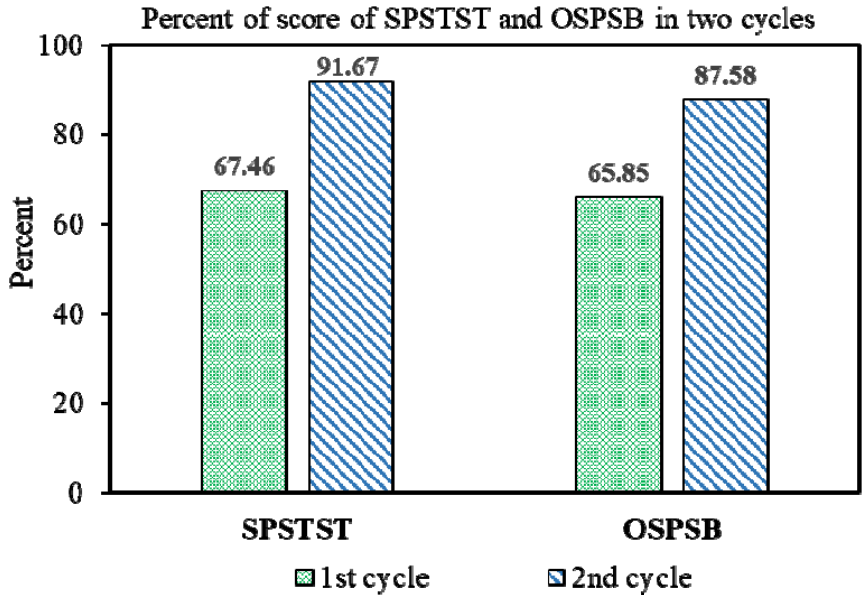

Figure 2. The comparison of pupil performance in two cycles in SPSTST and OSPSB

In Figure 2, data showed the comparison between the pupil performances in the 1st cycle and the 2nd cycle. In SPSTST, the pupils obtained 61.46% in the 1st cycle and 91.67% in the 2nd cycle. In OSPSB, the pupils obtained 65.85% in the 1st cycle and 87.58% in the 2nd cycle. Apparently, they showed higher performances (SPSTST and OSPSB) in the 2nd cycle than that in the 1st cycle.

4. Discussion

4.1 1st Cycle of Action Research

According to development of scientific problem-solving skills of twenty-one pupils in 5th grade on topic of Substance Changes using problem-based learning approach. The pupil performance in SPSTST of the 1st cycle, the total score was 8.10 points out of 12 points, representing 67.46 percent. Therefor considered as not passing minimum criterion which was designed as 70 percent. In terms of scientific problem-solving behavior, pupil represented their skills: problem identification, problem analysis, problem solving, and result checking, at mean score of 7.90 out of 12 points representing 65.85 percent. Moreover, it can be discussed that most pupils had the moderate level in the aspects of problem identification and problem analysis with the average scores of 2.22 and 2.11, respectively. This may be that due to the problem situations were interesting and relevant to their daily living basis. Accordingly, Piaget (1962) explains the theory of cognitive development as children learn things around them based on intellectual structures receiving and interpreting information to the maximum level of one's intelligence by adapting new things to existing knowledge. Problem solving, particularly, has a tendency to depend on the experience of the child. In the aspects of solution and the result review, the average scores were 1.84 and 1.73 respectively (moderate level). Pupils were not able to fully complete the solution procedures or present a clear

solution design approach. Some pupil presented impractical solutions and failed to describe a consistent and clear solution design. This phonomenon can be explained with the theory of cognitive development of Bruner (1956); children's rational thinking development depends on the influence of the child's verbal communication or language experience. In addition, the process of thinking and intelligence of children depends on various techniques, each of which requires skills using words as a medium of communication. Prathumthong (2020) has found that those with difficulties relating the solution methods to the examination of the results could pass the problem-solving requirements as their thinking skills are the foundation for solving problems. Thinking skills rely on the experience of knowledge gained and the apprehension attempts to determine the method to use in solving that problem. Nueangchalerm (2017) indicates that problem-based learning uses problems as a tool to help pupils to learn according to their learning goals. Teachers may lead pupils to face real-world situations, or they may arrange situations for pupils to face problems and practice critical thinking processes to promote problem-solving skills together as a group (Trevor et al., 2020; Yew & Goh, 2016) and real-world solutions (Mustofa & Hidayah, 2020). Pupils then have a clear understanding of the problem and be able to find various options and ways to solve that problem, and they also are enthusiastic to learn and strengthen their skills in solving different problems. The researchers agree that it is beneficial to apply these approaches in order to improve learners' scientific problem-solving skills. According to the interview results, pupils were satisfied with problem-based learning activities. The pupils argued that problem-based learning approach helped them to understand the materials learned and encouraged them to practice scientific problem solving in a systematic way. Sometimes the task seemed difficult but eventually it became challenging and motivating. Moreover, the experiments gave them clearer views.

4.2 2nd Cycle of Action Research

The score of pupils' scientific problem-solving skills on Substance Changes using problem-based learning approach was of 11 out of 12 (91.67 percent). Nineteen pupils or 90.48 percent passed the criteria of 70 percent. In terms of problem-solving behavior, pupils represented their skills of identifying the problem, analyzing the problem, seeking solutions, and examining results, at the overall average score of 10.51. Most pupils had the good behavior level that indicates scientific problem-solving skills in the aspects of problem identification and problem analysis with the high average scores of 2.83 and 2.75, respectively. Regarding solution and result examination stages, the scores of 2.54 (high) and 2.40 (moderate) reflect that pupils were able to design a variety of relevant solutions and presented the results systematically. Pupils could explain and give the details clearly, accurately, and appropriately according to the procedure of scientific problem solving. It can be said that problem solving is an application of knowledge, procedures or scientific processes (Office of the Education Council, 2007) and an application of existing knowledge with new knowledge that leads to the solutions (Zulkarnain et al., 2021). The researchers therefore are determined to encourage learners to develop scientific problem-solving skills for the above reasons, and to manage learning using problem-based models promoting pupils' level of scientific problem-solving skills. Khoiriyah and Husamah (2018) have studied

problem-based learning management to improve learning achievements, creative thinking skills, and problem-solving skills of grade 7 pupils. The findings showed that the average levels of pupils' problem solving skills, in the first operational cycle and the second cycle were of 78.78 and 99.75 percent respectively. Creative skills in 1st cycle and 2nd cycle were with an average of 83.45 and 94.33 percent respectively. Finally, their learning achievement in 1st cycle was of 83.45 percent, and 94.70 percent in 2nd cycle. It can be concluded that teachers can apply the approach of problem-based learning into learning activities to develop pupils' creative skills, and enhance learning outcomes. Wuichaiyaphum and Nuangchalerm (2018) studied the improvement learning achievement and problem-solving skills of grade 8 pupils by using problem-based learning model with mind mapping. It was found that in operating cycle 1, 9 pupils achieved 75 percent of their academic achievements while in operating cycle 2, 15 pupils achieved 75 percent of the criteria. At the end of the operating cycle 1, 15 pupils had problem solving thinking skills which accounted for 62.36 percent on a fair level basis, and after the second cycle ended, 71.84 percent were at good levels according to the specified criteria. Most pupils had problem-solving behaviors in problem identification and problem analysis. The problem and the cause of the problem were well defined, and in the field of determining the solution, pupils could determine a consistent approach, a variety of options, and pupils can explain in detail clearly, accurately, completely according to the problem-solving thinking process. Prathumthong (2020) investigated context-based and problem-based learning management practices based on local water resources to promote critical thinking and problem-solving thinking for eight fifth-graders in the second semester of the 2018 academic year. The findings are explained as follows. First, context-based learning management practices on local water sources that promote critical thinking and problem solving consist of six steps: basic context preparation- presenting a global situation of water resources in the national and international levels, and in the learners community; understanding the situations of their local water resources; small group discussion to identify causes and solutions for the local water resources; Participants in the group plan to solve local water resources and choose a jointly planned solution; Learners discussed the information they had studied from gathered information and synthetic water resources solutions as a group solution; Discussing and summarizing learning outcomes as each group presented and discussed solutions to water resources in class and sharing learning reflections. Second, learners have an increase from basic to expert level in critical thinking and problem solving after the learning management. Kum-onsa and Laoakka (2020) studied learning achievement in biology and problem-solving thinking of 11th graders by managing problem learning as a base. The results showed that 1) pupils achieved an average of 77.38 percent of biology learning achievements, which met the 70 percent threshold; 2) pupils had an average problem-solving score of 67.56 percent, which met the 65 percent threshold. Therefore, teachers can apply such learning management to better suit the learner's learning situations.

5. Conclusion

In the 1st cycle, the pupils obtained 8.10 points out of 12 points (67.46%) in SPSTST. There are 12 pupils out of 21 pupils (57.14%) passed minimum criterion which was below 70%. In the 2nd cycle, the pupils obtained 11 points out of 12 points (91.67%) in SPSTST. There were

19 pupils out of 21 pupils (90.48%) passed minimum criterion which was above 70%. Ultimately, they increased performance in SPSTST 24.21% and in OSPSB 21.73% from the 1st cycle to the 2nd cycle. In addition, the standard deviation was low and mean point was high in SPSTST and OSPSB in the 2nd cycle compared to the 1st cycle.

PBL is effective pedagogy to develop scientific problem-solving thinking skills in 4 areas: problem identification, problem analysis, problem solving, and result checking. In the process of identifying a problem, it is a very important step because the problem motivates the learner to be interested. Teachers should plan their learning management carefully. In defining the situation, the problem should be succinct and clear, and media should be appropriately use to encourage pupils to raise issues. Furthermore, teachers should bring in actual everyday situations that learners have experienced before such as melted chocolate etc. They should also take on account of reading, writing, and language when they explained to pupils as well as the appropriateness of the content used to organize learning activities.

In the process of synthesizing data and problem solving, teachers should provide a variety of equipment according to the learner's interests and facilitate the use of searching tools. The teacher should set appropriate timing to activity

In the result checking, teachers must ensure that pupils are fluent in reading and writing as this stage will be very difficult and challenging for pupils, so they need to be good at language at certain level to understand reading and writing self-explanatory conclusions.

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