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THE SCIENTIFIC QUESTIONING AND EXPERIMENTAL SKILLS OF ELEMENTARY SCHOOL STUDENTS: THE INTERVENTION OF RESEARCH-BASED LEARNING

B. Khumraksa*[1] and P. Burachat[2]

[1,2]Faculty of Education, Suratthani Rajabhat University, Thailand

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ABSTRACT

Research-based learning is a learning strategy that encourages the use of scientific inquiry, thereby allowing students to develop an understanding of the scientific process. The aim of this study was to design a research-based, scientific learning activity on the topic of the mass and volume of matter, to be implemented with elementary school students. The study sample consisted of 16 fourth-grade students selected by purposive sampling. This mixed methods study, performed as an embedded design, examined the pre-experimental results of this research-based learning activity on students' scientific questioning and experimental skills. The science process skills evaluation form was used as a quantitative instrument. The quantitative data were analyzed by simple statistics including mean and standard deviation. Meanwhile, the gathering of qualitative data was accomplished through the taking of field notes. Deductive analysis was employed to highlight the patterns that emerged regarding the students' science process skills. The findings revealed that this research-based learning design encouraged students' scientific questioning and experimental skills, with the mean level being at the developing level. This was achieved by giving students the opportunity to engage in challenging, age-appropriate activities with explicit scientific methodology guidance provided by their teachers. Furthermore, it was found that the students were very much satisfied with this research-based learning activity. This suggests that incorporating research-based practices would serve to fulfill the educational aims of the science classroom. The science inquiry-based approach represents an area worthy of increased focus in order to encourage elementary school students to practice science process skills.

Keywords: experimental skills; elementary school students; research-based learning; scientific questioning skills

INTRODUCTION

Science process skills are the most significant skills scientists use when performing scientific research (Ozgelen, 2012; Sideri & Skoumios, 2021). In order to continue working as a scientist in the real-world, one of the goals of science education is to teach students how to effectively think like a scientist, for whom their defining characteristic is their use of science process skills (Ozgelen, 2012; Subali et al., 2019). Science process skills are directly related to students' cognitive development, since these skills support students' thinking, reasoning, inquisitiveness, problem-solving, and creativity. Therefore, the science process skills are a key factor for success in science education (Di Mauro & Furman, 2016; Subali et al., 2019).

Lacking authentic scientific experimental practice in the science classroom may lead to students not having practiced science process skills, leaving them short on the skills necessary to learn and construct knowledge on their own. This ultimately hinders students from achieving the goal of learning science (Kalthoff et al., 2018; Szalay et al., 2020). Hands-on activities with a science laboratory are often the first introduction students have to engage with the scientific process

*Correspondence Address
E-mail: bannarak.kh@gmail.com

(Durmaz, & Mutlu, 2017; Kalthoff et al., 2018). Simple laboratory experiments are sometimes identified as science inquiry-based learning, even though students were allowed to conduct the experiments exactly as stated in the manual, much like cooking by following a recipe (Durmaz, & Mutlu, 2017; Rokos, & Zavodska, 2020; Szalay et al., 2020). As a result, laboratory work-based learning may not be as effective as it could be (Rokos, & Martincová, 2020; Rokos, & Zavodska, 2020). Truthfully, students should be able to work according to operations of their own design, and not just follow a manual as directed the teacher (Faikhamta et al., 2018; Rokos, & Martincová, 2020; Schwichow et al., 2022). A previous study by Szalay and TÓth (2016) revealed that students who were assigned to do an experiment with a few partial inquiry-based activities incurred a significant positive effect on their experimental design skills than that of the control group, which only did the experiment following the traditional step-by-step lab direction (Szalay & TÓth, 2016). Therefore, the re-designing of science learning activities to promote science process skills for elementary school students is necessary and plays an important role in making science teaching and learning effective.

Research-based learning (RBL) is a constructivist, student-centered, form of learning related to scientific inquiry (Noguez & Neri, 2019). RBL may involve the application of content from both research knowledge and findings. It also might feature teachers using research methodology or techniques as a method of organizing students' learning (Kloser et al., 2013; Noguez & Neri, 2019). However, the strategy in which teachers allow students to perform research as part of their learning is the best RBL instructional method aligned with inquiry-based science learning (Brew & Saunders, 2020; Cairns, 2019) because it can provide student-centered learning in which students acquire knowledge by themselves through a systematic-thinking process and problem-solving (Kloser et al., 2013; Winkelmann et al., 2015; Oztas Cin & Yurumezoglu, 2020). Teachers' roles as lecturers should be minimized, as they should really focus on being coaches and mentors who facilitate student learning (Huet, 2018; Oztas Cin & Yurumezoglu, 2020).

The majority of previous studies focused on the use of RBL activities to encourage students to develop their science process skills including scientific questioning, hypothesis construction, experimental skills, data interpretation skills, data organization skills, scientific report writing skills, and so on (Kloser et al., 2013; Tomasik. et al., 2014; Winkelmann et al., 2015; Khumraksa & Ruksakit, 2019). This is due to the fact that the RBL approach allows students to learn through a research process that is based on the scientific method (Leedy & Ormrod, 2015), where students are able to perform the systematic thinking process just as if it were a scientific investigation conducted by a scientist in a real world setting (Winkelmann et al., 2015).

RBL enables students to comprehend the reasoning behind each step they engage in, which is not accomplished through a prescribed, ritual procedure. During the learning process, students are driven to use science process skills autonomously, in parallel with a particular learning activity (Winkelmann et al., 2015; Subali et al., 2019). In addition, self-efficacy, and a positive attitude toward science learning also stand to be enhanced (Winkelmann et al., 2015; Vossen et al., 2018). Thus, extant literature suggests that RBL should be encouraged within science learning management to promote students' science process skills.

Although many categories of science process skills have been suggested (Ozgelen, 2012), the posing of a scientific question, which is one of the most essential parts of the scientific thinking process, is the starting point for science inquiry learning (Chin & Osborne, 2008; Huang et al., 2017). Therefore, to promote science process skills, students should begin by practicing to ask scientific questions. Simultaneously, a large body of research indicates that the most challenging scientific process skills to build in students are experimental skills (Durmaz & Mutlu, 2017; Kalfhoff et al., 2018; Sholahuddin, et al., 2020), since they integrate a number of other sub-skills (Di Mauro & Furman, 2016; Szalay et al., 2020). Thus, the development of students' experimentation skills is also essential in teaching science and poses a challenge for science educators.

The Thai students who participated in this study came from a small schools with limited resources for science education. Their previous classroom teachers were elementary school teachers who did not have science teaching degrees. As a result of these issues, this cohort of students had been denied the opportunity to study science through effective inquiry and were unable to practice scientific process skills. Moreover, the study of RBL in elementary school students was limited in existing research. For this reason, the present study aims to investigate the implementation of the RBL to enhance elementary school students' scientific questioning and experimental skills. The findings of this study address the following research questions; (1) Is the RBL lesson plan design appropriate for application to the science classroom of elementary school students?; (2) How do RBL activities result in the development of scientific questioning skills and experimental skills in elementary school students?; (3) To what extent are elementary school students satisfied with the RBL activity?

METHODS

This study is a pre-experimental research that attempts to develop a RBL lesson plan for an elementary school science course. The design of the lesson plan was grounded in the science inquiry approach, research methodology concept, and constructivist learning approach. In addition, the Thai Basic Education Curriculum was necessarily taken into consideration (Ministry of Education, Thailand, 2017). Thus, this work investigated the student's science process skills by engaging them in this RBL activity.

The mixed-method research design was employed as an embedded design (Leedy & Ormrod, 2015) in which quantitative and qualitative data were collected within the same general time frame. Quantitative analysis was dominant within the study in order to assess students' science process skill levels. Qualitative analysis served a complementary role to support findings from the quantitative data and highlight patterns of student science process skills that emerged in each level assessed. This research framework is shown in Figure 1.

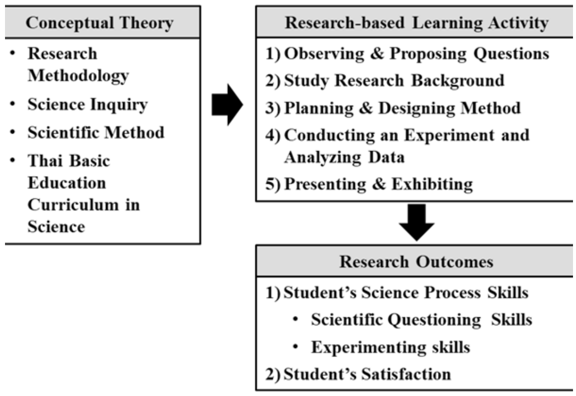

Figure 1. Research Framework

The target sample of this study was a single class of 16 fourth grade students with a mean age of 10, at a small elementary school in Surat Thani Province, in the south of Thailand. This school is located in a semi-urban area of low socioeconomic status. This target group of students were chosen for three reasons: first, the timetable afforded students the opportunity to fully complete the activities; second, the teachers and school principal welcome researchers and supported the research project; and third, one of the team's researchers was a former teacher at this school. In addition, prior to commencing the research, all participants in the study were required to obtain written permission from their parents. Furthermore, the children's continued willingness to participate was determined by asking them if they were glad to attend the class each time.

To construct the RBL lesson plan, the frameworks for research methodology, scientific inquiry, and scientific method that built on previous research (e.g. Khumraksa & Ruksakit, 2019) were synthesized. The scope of the learning content was on the topic of "mass and volume of the matter", covered in the unit on the state of matter taken from the science learning standard of the Thai Basic Education Curriculum (Ministry of Education, Thailand, 2017). The RBL lesson plan consisted of five-step activities, summarized in Table 1. Full implementation required two, two-hour sessions per week, for a total of 6 weeks. The learning process was collaborative, with students divided into four heterogeneous groups, each consisting of four students (based on gender and achievement level). The design for this RBL lesson plan was then validated by three science educational experts using a 10-item, 5-point Likert scale. The expert's advice and recommendations were integrated to finalize the RBL lesson plan. Subsequently, the completed RBL lesson plan was implemented in the science classroom with the target students.

Table 1. Summary of Research-based Learning Activity

Steps	Learning activities	Timeline	Student's Activities
1	Observing and proposing questions	Week 1	Observe the teacher's demonstration and ask questions about the phenomenon that has occurred along with brain storming to select the most interesting question
2	Studying research background	Week 2	Search basic information from the internet and/or books related to the questions of their own group
3	Planning and designing method	Week 3	Do an activity "Archimedes and the Golden Crown" to inspire the idea for designing the experiment
		Week 4	Design the experiment which related to their research question
4	Conducting an experiment and Analyzing Data	Week 5	Do an experiment related to their own designed method and analyzing data to draw a conclusion
5	Presenting to share research findings	Week 6	Present their experimental results and discussion

The primary research data involving students' science process skills were evaluated mainly from experiment reports and scores gathered by using the 3-point Likert scale science process skills evaluation form (Table 2). This instrument was developed by the research team to use specifically in this study by adapting from the criteria used in previous research (e.g. Chin & Kayalvizhi, 2002, Huang et al., 2017). It was then validated by three science education experts, resulting in the item objective congruence (IOC) indices having an acceptable value in the 0.67-1.00 range (Turner & Carlson, 2003).

Table 2. Rating Criteria of Student's Science Process Skills Evaluation

Science Process Skills	Scoring
Scientific Questioning Skill	
1.1 Feasibility to practice under authentic context	
The question should lend itself to hands-on, manipulative activities where students can manage in time and equipment available. It is also not too difficult.	3
It is feasible, but need the teacher's help to revise such a question into a more testable hypothesis.	2
It is not feasible.	1
1.2 Interest of the questions	
The question is interesting and challenging, both practically and conceptually. It is also meaningful and appealing to the pupils, to sustain their interest.	3
It is interesting and inspired by their interests, but not challenging.	2
It is not interesting and not challenging.	1
1.3 Leading to inquiry process	
The question leads to finding out something which was previously not known to them and provides opportunities for students to show what they can do.	3
It leads to finding out unknown things but does not provide opportunities for students to show what they can do.	2
It is not lead to the discovery of new knowledge.	1
2. Experimental skills	
2.1 Designing experiment	
Design the experiment according to the posted question/problem. Choose a method that is reasonable and feasible in practice.	3
It is related to the question that students want to know and feasible, but need some teacher's help to revise such an experiment into a more testable way.	2
It is related to their posted question, but this method is not testable or unreasonable.	1

Science Process Skills	Scoring
2.2 Selection of experimental equipment	
Choose the correct equipment for experimental measuring and specify the correct glassware's size to use.	3
Choose the correct equipment for experimental measuring, but need some teacher's help to suggest an appropriate size of glassware.	2
Unable to determine the tools and equipment required for their experiment.	1
2.3 Conducting an experiment to collect data	
Do the experiment as planned methodology carefully and correctly. Take time to experiment according to regulations.	3
Do the experiment as planned methodology, but not complete according to the experimental plan or does not meet the agreed time.	2
Unable to perform experiments according to their experimental plan, takes more than the time limit and require a lot of help from teachers.	1
2.4 Recording experimental results and observations	
Determine how to record the results in advance and record realistic and thorough results.	3
Determine how to record the results in advance and record realistic results, but still lack the data precision.	2
There was no preparation for recording the results and did not know how to record the results. They also need a big help from a teacher.	1

Additionally, a researcher was situated in the classroom during the activities to make observations, take field notes and gather qualitative evidence of relevance to student thinking and learning processes (collaborative work, discussion, dialogue, mood, etc.). Finally, the student's satisfaction was measured by using a 10-item satisfaction questionnaire, utilizing a 5-point Likert-scale where 1 = 'very dissatisfied' and 5 = 'very satisfied'. The items of the questionnaire were also validated by three educational experts and found IOC indices was in the range 0.67-1.00 which was considered acceptable (Turner & Carlson, 2003). The RBL lesson plan, which was deemed suitable after validation by experts, was interpreted by simple statistics, including mean score and standard deviation. The level of suitability was expressed using generic criteria ranging from very poor (0.00 – 1.80) to very good (4.21 – 5.00) (Pimentel, 2010).

The score of student's science process skills was also analyzed by simple statistics, including mean and standard deviation. It was then interpreted by using the criteria that were used in Reinagel & Bray Speth (2016) which is as follows: a mean score <1.5 was assigned as 'beginning'; a mean score between 1.5 and 2.5 was assigned as 'developing'; a mean score >2.5 was assigned as 'mastered'. The qualitative data was sought out to complement the explanation of research findings for each sub-skill more explicitly, by means of deductive analysis. Common codes were established for similar statements occurring in the field notes according to the researcher's interpretation. The codes were characterized, and pools of codes were grouped into three themes, namely: mastered, developing, and beginning. Later, the frequency of each theme was calculated and presented in a percentage graph to illustrate the more in-depth results.

Finally, student's satisfaction was analyzed by mean and standard deviation as well. The mean score of student satisfaction was assessed with a criteria range that was the same as that used in the recent work of Nyutu, et al. (2021) which is as follows: 1.00 - 1.80 was interpreted as 'very dissatisfied'; 1.81 - 2.60 was interpreted as 'dissatisfied'; 2.61 - 3.40 was interpreted as 'neutral'; 3.41 - 4.20 was interpreted as 'satisfied' and 4.21 - 5.00 was interpreted as 'very satisfied'.

RESULTS AND DISCUSSION

The RBL lesson plan that was developed for this study was on the topic of, "the mass and volume of matter." The lesson plan was validated by three science education experts and it was found that the overall suitability of the RBL lesson plan was at a very good level ($\bar{X}$ = 4.60, S.D. = 0.34). Indeed, it was found that the suitability average was at a very good level for almost all items, except item 4 which was only at a good level ($\bar{X}$ = 4.0, S.D. = 0.00) as shown in Table 3.

Therefore it can be suggested that the RBL lesson plan that was developed is consistent with Thai science learning curriculum standards, and at a level that is suitable for implementation in elementary school science classrooms. This is because the RBL activity allows students to learn through open inquiry, a science teaching method strongly supported by science educators (Cairns, 2019; Fitzgerald et al., 2019; Huet, 2018), as it is a learning model in which students learn by acquiring scientific knowledge, just as scientists investigate the natural world (Kloser et al., 2013, Subali et al., 2019).

Table 3. The Evaluation of the Designed RBL Lesson Plan

No.	Items	Mean	S.D.	Interpretation
1	The components of the lesson plan are complete and consistent with science learning curriculum standards	4.7	0.58	very good
2	The lesson plan has clear operational procedures according to the research-based learning approach	4.7	0.58	very good
3	The learning activities are organized according to the content and objectives of the learning standard	5.0	0.00	very good
4	The learning activities are appropriate for the ages and skill levels of the students	4.0	0.00	good
5	Learning activities encourage students to practice their scientific questioning skills	4.3	0.58	very good
6	Learning activities encourage students to practice their experimental skills	4.3	0.58	very good
7	The role of a teacher in the learning activity facilitates and encourages the students to discover knowledge through an inquiry	5.0	0.00	very good
8	The use of learning materials and learning resources is consistent with learning objectives	5.0	0.00	very good
9	The timing, length, and sequence of activities are reasonable	4.7	0.58	very good
10	Defining methods for measuring and evaluating students' learning outcomes in accordance with the learning objectives	4.3	0.58	very good
Overall		**4.60**	**0.34**	**very good**

It is interesting that some experts argued this learning activity meets the desired science learning goals, when it is not recommended that 9-10 year old's begin at the highest level of open inquiry. The expert opinions are consistent with some previous studies that recommend the use of guided inquiry to replace open inquiry for elementary school students (Di Mauro & Furman, 2016; Artayasa et al., 2017; Artayasa et al., 2021). Some arguments point out that the goal of the elementary school science curriculum does not need students to acquire new knowledge or encounter unexpected results. This is because the knowledge they are expected to acquire depends on the scope of the curriculum and the decision of the teacher. It is also consistent with Artayasa et al. (2021) who stated that guided inquiry is a substitute when students are not yet ready to implement open inquiry.

However, the experts' controversial opinions may be countered by Sadeh and Zion's (2012) argument, which stated that students who participated in open inquiry were more satisfied and felt they received more benefits from implementing the project than students who participated in a guided inquiry. Additionally, there is some evidence from previous studies showing the positive potential for the use of open inquiry in elementary classrooms (Khumraksa & Ruksakit, 2019; Rokos & Martincová, 2020) and having students learn with more explicit, reflective instruction about the nature of science (NOS) (Subali et al., 2019). For example, Khumraksa and Ruksakit (2019) showed that even young children (aged 7 to 8) are able to engage in open inquiry within the scope of content specified in their grade level curriculum. This is why it is critical to provide evidence that the use of RBL with students in other grade levels is likely to be beneficial as well. Our research points out the importance of RBL in the core curriculum of elementary science education, as well as proof of the viability of implementing an open inquiry strategy for young children in a relatively short period of time. Perhaps more importantly, this study demonstrated that this RBL lesson plan was feasible in the context of a public low-income, semi-urban school, using low-cost materials and working with children with varying levels of performance.

This section aims to answer the second research question; how do RBL activities result in the development of scientific questioning skills and experimental skills in elementary school students? For the quantitative analysis, the analyzed scores for students' scientific questioning skill and experimental skill are shown in Table 4.

Table 4. Scores of Students' Science Process Skills

Science Process Skills	Sub-Category	Mean	S.D.	Skill Category
Scientific questioning skills	Feasibility to practice under authentic context	2.8	0.45	Mastered
	Interest of the problem	2.3	0.48	Developing
	Leading to inquiry process	2.3	0.34	Developing
Overall of Scientific Questioning Skills		**2.40**	**0.32**	**Developing**
Experimental skills	Designing experiment	2.7	0.48	Mastered
	Selection of experimental equipment	2.2	0.40	Developing
	Conducting an experiment to collect data	2.4	0.51	Developing
	Recording experimental results and observations	2.4	0.52	Developing
Overall of Experimental Skills		**2.45**	**0.21**	**Developing**

The results show that the students who participated in the RBL had an average score of 2.40 (S.D. = 0.32) and 2.45 (S.D. = 0.21) in scientific questioning and experimental skills respectively. It was also positive to note that none of the students scored at the beginning level on any of the items. Consequently, student's overall scientific questioning and experimental skills were interpreted as being on the developing level.

The findings of this study outperformed previous research in that elementary school students developed experimental skills after only 6 weeks of participation in a RBL activity. Previous research by Dimoro and Furman (2016) which examined Argentine elementary school students used the same open-problem instructional strategy, but through the use of guided inquiry, took up to 8 weeks to result in student's performing at the developing level.

To explain the research findings more explicitly, qualitative data based on field notes related to students' science process skill levels were interpreted and highlighted. In this analysis of data obtained from qualitative sources, we converted qualitative data into quantitative data. This was achieved by expressing the frequency of student responses from each sub-category, which are illustrated in Figures 2 and 3. Scientific questioning skills comprise three sub-categories while experimental skills comprise four sub-categories.

As seen in Figure 2, students reached a mastered level only in the first sub-category of scientific questioning skills, which refer to students' ability to ask a scientific question that can be manipulated through practical experiment and that students can handle in terms of available time and equipment. While in the second and third sub-categories, the percentage of students at a mastered level was below that of the developing level. This was especially true in the third subcategory, where the developing level dominated with 87.5%.

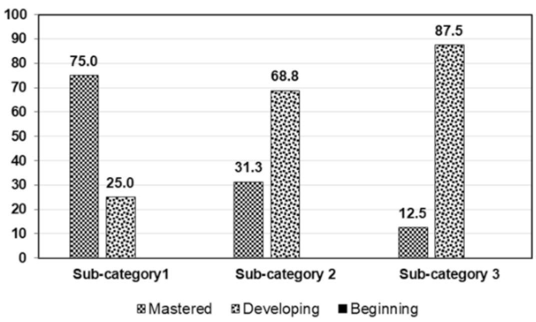

Figure 2. The Percentage of Students in Sub-categories of Scientific Questioning Skill

The most crucial learning activity for developing scientific questioning skills is the first step of RBL, where the teacher encourages and requires students to identify research problems or formulate their own scientific questions. At the beginning of this task, students created mainly non-investigable questions. These questions were interesting, but quite imaginative and could not lead to a practical experiment, such as; "If a rock is weighed between Earth and Moon, will it have the same mass?" Someone else asked a question in which the answer was already knows. This would not lead the student to finding out new information or something which was previously not known, such as; "If water is transferred from one container to another container of a different shape, will the shape of the water change?"

The guidance of the teacher is indeed essential. Herein, the teacher encouraged students to think again and conjure a variety of questions based on their own experiences in daily life. This practice is consistent with Chin and Kayalvizhi's suggestion (2002) that the teacher should focus on students' prior knowledge and personal interests, which often provide ideas for inquiry, such as their homelife and hobbies. With the teacher's assistance, all students were eventually able to formulate a feasible, investigable, scientific question. The teacher then had each group of students hold a discussion and choose the most interesting question from within their group for their research. It is proposed that the intervention with this short learning period of the RBL activity (step 1, 2 hours) could encourage students to ask simple scientific questions, allowing them to practice the inquiry process in a relevant situation. When students posit questions that they want to answer and which they came up with by themselves, they will be alert and keen to find those answers. This is an excellent beginning point for scientific inquiry learning, as it is also consistent with the view of science educators. This being that scientific inquiry begins with scientific questioning (Chin & Kayalvizhi, 2002). Students' questions have the potential to direct inquiry-based learning and drive knowledge construction (Chin & Osborne, 2008).

However, an important piece of evidence from the qualitative observation showed the incompleteness of the students' scientific questioning, which led to them having failed to achieve a mastered level. It appeared the students lacked the curiosity to want to know things that they did not know before. It is suggested that students need courage to learn something new without fear that they will not succeed. This requires providing students with appropriate incentives, modeling the asking of questions, and creating a receptive atmosphere in the classroom (Chin & Kayalvizhi, 2002; Huang et al., 2017). Therefore, the most important thing in the science classroom is that teachers should not stifle students' inquisitive nature.

In experimental skills, students' overall competence was also at the developing level. Figure 3 shows that students who participated in the RBL activity reached the mastered level in only the first sub-category of experimental skills. This is where students can design an experiment related to the question they posed and the method is suitable for collecting data or obtaining scientific evidence. It can be implied that students understand the significance of their research question and that it is not beyond the scope of their age and ability. As such, they are able to design an experiment with a method that is reasonable and feasible in practice

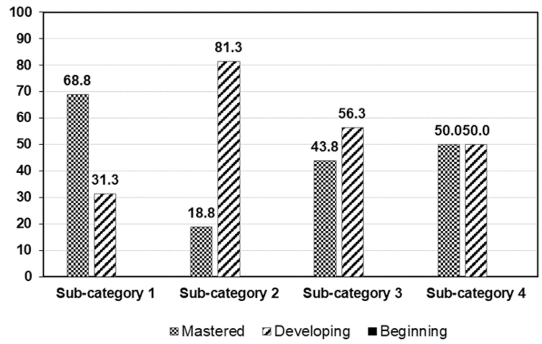

Figure 3. The Percentage of Students in Sub-Categories of Experimental Skill

A previous report of Szalay and co-workers' study assessed students' experimental design skills from a problem-solving test and found that student-led inquiry learning activities failed to show the effect of developing experimental skills differently from the control group significantly (Szalay et al., 2020). However, Szalay and colleagues argued that the task was to help students develop' experimental skills in just six lessons over a very short amount of time (8-17% of the total time that grade 7 students spent). Students, however, must continue to practice over time. The previous strategy needs to be improved because it does not appear to be successful for younger students and over the long term.

Therefore, the results of this research, although only at the pre-experimental stage, showed more promising results than the previous study by Szalay and co-workers (2020) in enabling students to develop experimental skills at the developing level. It also corresponds to previous studies that found elementary school students can design and work their own experiments with explicit teacher guidance (Di Mauro & Furman, 2016; Khumraksa & Ruksakit, 2019; Rokos & Martincová, 2020). Therefore, this study brings 'a proof of possibility' of what students can learn provided they are offered suitable learning opportunities.

However, the percentage of students achieving a mastered level in the second sub-category, which was related to experimental equipment selection, was very low (18.8%). The vast majority of students (81.3%) were at the developing level. Qualitative data revealed that most of the equipment that the students chose for their experiments were basic items that are easily found in science classrooms, such as beakers, cylinders, eureka beakers, and spring scales. Although these are basic pieces of equipment that are suitable to the student's grade level and ability, they are likely to lack experience in using them, resulting in some students choosing the wrong type or size of glassware that is not suitable for the liquid volume. It is possible that students in economically disadvantaged schools lack the opportunity to use such scientific tools, or the facilities do not come equipped with laboratories dedicated to science courses. Simultaneously, in the third and fourth sub-categories which involved conducting an experiment and observing, and recording experimental results, students were quite equally divided between mastered and developing levels (Figure 3). The evidence from student's experiment reports indicated almost all groups of students drew incorrect conclusions that were inconsistent with scientific theory. This is because the incorrect data was caused by inaccurate measurements and reading of scales. This is the reason why students still could not reach the mastered level in the third and fourth sub-categories of experimental skills.

This finding is similar to the study of Rokos and Martincová (2020) who found that students have a problem with collecting data from their own experiments. It is suggested that this RBL activity should be further re-designed to isolate these sub-skills for improvement. Teachers should first encourage students to practice in order to become more proficient at using scientific equipment, and also raise students' awareness of the importance of accuracy in the measurement of data.

Furthermore, the teacher's corrective feedback, including discussions about the causes, are crucial for promoting student science process skills. Metcalfe (2017) suggested that teachers can gain valuable information from errors. Tolerating student error could actually create situations where it could be used to promote active inquiry and generate engagement by the students. Following this concept, the teacher needs to lead the discussion and get students to explain whether the experimental evidence can be used to answer the research questions. If it is not, students have to discuss it.

In addition, for the last activity of the RBL unit (week 6), each group of students was given the opportunity to display their work by drawing on chart paper, as illustrated in Figure 4, and orally present it to the class. This task encourages students to recognize what they have learned throughout the experiment and create and explicit summary of what they have done. The presentation activity provides students a better understanding of the science community by making them aware of the importance of scientific communication as part of the scientific enterprise (Guidotti, 2016). When scientists find new results based on their investigations, the information is made available to the public. In this way, it is available for further use as well as scrutiny. It provides an opportunity for other scientists to offer their criticisms and academic opinions in order to increase the knowledge base and promote reliability (Fischhoff, 2019).

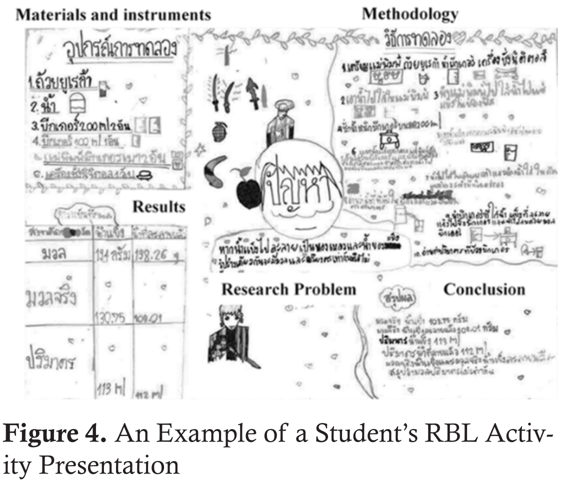

Figure 4. An Example of a Student's RBL Activity Presentation

Table 5 shows the average satisfaction level of students with RBL activity. The result indicated that overall students were most satisfied with RBL activity (= 4.28, S.D. = 0.36). It may be implied that elementary school students' cognitive learning was likely to be the field-dependent (FD) learning style, as FD students prefer to learn by collaboration and be alert to participate in learning (Sholahuddin et al., 2020). For this reason, in this RBL activity, students were able to learn through collaborative learning by learning in small groups and clearly assigning group members to tasks. This allowed each student to be aware of their priorities and not feel neglected in their science learning classroom.

Table 5 shows the average satisfaction level of students with the RBL activity. The results indicate that overall students were most satisfied with the RBL activity ($\bar{X}$ = 4.28, S.D. = 0.36). It may be implied that elementary school students' cognitive learning was likely to be the field-dependent (FD) learning style, as FD students prefer to learn by collaboration and to be alert while participating in learning (Sholahuddin et al., 2020). For this reason, in the RBL activity, students were able to engage in collaborative learning through small groups and clearly assigning group members to tasks. This allowed each student to be aware of their priorities and not feel neglected in the classroom.

Table 5. Student's Satisfaction to RBL Activity

Items	Mean	S.D.	Interpretation
1. RBL activity is appropriate for learning time and learning topic	4.1	0.48	satisfied
2. RBL activity is not too difficult to learn and you can practice	3.9	0.43	satisfied
3. RBL activity allows you to come up with answers that you want to learn and learn by yourself	4.6	0.48	very satisfied
4. RBL activity encourages you to practice science process skills	4.1	0.33	satisfied
5. Research presentation activity provides you the confidence to communicate information to others	4.1	0.48	satisfied
6. You are enjoyed working with others on RBL activity	4.1	0.48	satisfied
7. You have fun during this RBL activity	4.6	0.50	very satisfied
8. The learning atmosphere in RBL activity is relaxing and does not put you any stressing	3.6	0.48	satisfied
9. The teacher provides support and guidance throughout the learning	4.8	0.39	very satisfied
10. RBL activity increases your interest in studying science	4.7	0.46	very satisfied
Overall	**4.28**	**0.36**	**very satisfied**

Students also reflected that this RBL activity made them become more interested in studying science. This finding has also been supported by Can and co-workers (2017) who found that hands-on activities highly benefited students' interest in science learning. Their findings also indicated that the activity which students were most interested in is science experimentation. Our finding is also similar to Nworgu's study, which demonstrated that when students engage in inquiries related to their interests, they are more comfortable performing their activities (Nworgu & Otum, 2013).

Even though our findings suggested that most students enjoyed this RBL activity, they also revealed that they faced stress and pressure while participating in the activity. It is illustrated by a lower level of satisfaction than the other items ($\bar{X}$ = 3.6, S.D. = 0.48). Indeed, this result is not too dire, because there are other reports that found that mildly stressful situations could create cognitive challenges that contribute to memory formation and therefore can positively impact learning (Vogel & Schwabe, 2016). Nevertheless, the teacher needs to transform stressful situations into a relaxed and safe learning environment to retain student's positive attitudes toward science learning. In our work, the teacher attempted to reduce student anxiety and stress through close supervision and guidance. The role of the teacher in the classroom was both as a coach and a kindly mentor rather than a commander. This is a reason students were most satisfied with the teacher's support and guidance throughout the learning period ($\bar{X}$ = 4.8, S.D. = 0.39).

CONCLUSION

Elementary school students' lack of science process skills will create barriers to learning with science inquiry, which can result in their not achieving the science learning goal of becoming a scientifically literate person. However, science instruction in many elementary schools was found to be lacking in the implementation of scientific process skills. To overcome such a problem, a science learning activity taking a research-based learning approach on the topic of the "mass and volume of the matter" for elementary school students was thus developed in this study. The aim was to encourage students' scientific questioning and experimental skills. The findings have shown that the designed RBL activity can enhance both students' scientific questioning skills and experimental skills up to a developing level. This result is therefore seen as a good example of using this learning process in teaching science to elementary school students. It was also found that students were most satisfied with this RBL activity. This study emphasizes the importance of incorporating the RBL strategy into the core curriculum of elementary science education. In addition, evidence points to the viability of implementing an open inquiry strategy for young children in a relatively short period of time, in the context of socioeconomically disadvantaged, urban schools, using low-cost materials, and working with children of varying levels of academic performance. The implications and future work are: (1) RBL is not considered a routine science activity in the normal science classroom and is very new to elementary school students, especially Thai students. Therefore, students have not had much experience with active learning and were not familiar with research methodology at all. For this reason, teachers should begin the RBL activity by informing the students that they will be adopting a new and different teaching style. Further information about the teacher's role in providing help and support throughout the duration of the RBL activity should also be explained; (2) The teachers using the RBL need to plan the learning activities well and dedicate appropriate lengths of time for various activities such as lab experiments and surveys. This is to give students enough time to complete their research. Due to the time constraints of school courses, students may be prevented from completing some activities; (3) This research was a pre-experimental research design, which was not randomized nor was there a control group. Therefore, it is suggested that future research should be designed to be a true-experimental research design with a large pilot sample, enabling generalization of the research's results.

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