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FOSTERING FIFTH GRADERS' SCIENTIFIC CREATIVITY THROUGH PROBLEM-BASED LEARNING

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Abstract. *This research aims to determine whether Problem-Based Learning (PBL) helps in fostering scientific creativity among fifth graders. Students' scientific creativity (SC) was investigated in the product dimensions of (a) solving scientific problems, (b) understanding scientific phenomena, (c) advancement in scientific knowledge, and (d) improvisation skills with a technical product. A pre-test and post-test single group experimental design was employed. Pre-test measures on SC were administered to 232 fifth graders. Students participated in PBL hands-on activities that required solving open-ended problems. After these were completed, post-test measures on SC were assessed. Students' reactions to the PBL experience were also recorded. The results of paired sample t-tests showed significant differences in all product dimensions of SC, except in the understanding of scientific phenomena. Further analysis found significant differences among the creativity traits of fluency, flexibility and originality in each product dimension of SC, except in the originality in the advances of scientific knowledge. Students felt that the PBL activities were easy, fun, and interesting as well as a practical way of gaining and advancing science knowledge. Students also found their participation in sharing ideas in cooperative learning groups inspired them to be more creative. This research suggests that the PBL activities have a positive impact in fostering student's SC in science lessons.*
Key words: *creative traits, fifth graders, problem-based learning, product dimension, scientific creativity.*

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Introduction

The ability to think creatively is essential in solving problems in daily life. Scholars have noticed the needs for students to develop and practise the creative traits of being fluent, flexible and original, so that students will be able to make a connection to wider creative processes (Meador, 1997). For example, students could practise fluency in order to produce many ideas or solutions to a problem, but this may be more meaningful if their ideas were original and flexible. Felder (1987) stressed that creativity is an ability that teachers should inspire in their students through suitable environments and exercises. The learning environment should advocate the use of open-ended questions, where students have to determine what needs to be solved in a problem, as well as brainstorming and other techniques which encourage students to think of as many solutions towards a specific problem. On the other hand, exercises should encourage creative thinking by having multiple solutions. Researchers claim that problem solving, hypothesis generation, experiment design, and technical innovation all require a particular form of creativity peculiar to science (Lin, Hu, Adey and Shen, 2003). In school science, this reflects the concept of scientific creativity. In particular, scientific creativity as a domain is one of the most important areas contributing to the advancement of human civilization (Hu, Shi, Han, Wang and Adey, 2010). However, the potential of student's scientific creativity has not been widely studied in the primary school classroom. Therefore, there is a need for current practices in primary school classrooms to provide opportunities for students to cultivate scientific creativity.

Problem-Based Learning (PBL) has been proposed for the sake of encouraging students to think creatively in solving a specific problem (Felder, 1987). According to Meador (1997), PBL can aid students to engage in the process of creative investigation as this process stimulates students' creativity in developing solutions. He also posits that this is due to the subsequent training in becoming more proficient in discovering and defining problems.

Malaysian researchers have started research on PBL approach in the engineering fields (Awang & Ramly, 2008). However, research on PBL has yet to be done in fostering scientific creativity in primary school classrooms, indicating the need for analysis regarding teachers' understanding and implementation of PBL in science teaching. While it is recognised that PBL activities stimulate creative thinking, research highlights that some form of intervention is required in order for this to be effective along with research on primary school students' perception of the use of PBL in learning science. Such knowledge could provide relevant information for education and training institutions on how to employ PBL in fostering scientific creativity in primary science classrooms. On a bigger scale, implementing a PBL approach in primary science teaching could be a catalyst towards achieving one of the goals of the Malaysian Education Blueprint 2013 – 2025, which is to spark creative thinking among students. In order to help achieve this blueprint, this research was conducted to investigate whether PBL foster primary school students' scientific creativity in Malaysian school classrooms.

Theoretical Background

Problem Based Learning (PBL)

According to Marra, Jonassen, Palmer, and Luft (2014), PBL is an instructional method where student learning occurs in the context of solving an authentic problem. Problem-solving involves students to produce solutions to problems by looking at a variety of solutions in novel ways, solving problems in a short period of time and using experimentation to find the best creative solution (Fields, & Bisschoff, 2013). The use of group work in solving authentic problems is highlighted as a particular feature of the PBL that drives student learning. Savin-Baden and Major (2004) identify the "cooperative team", the "tutor-guided learning team", and the "collaborative learning team" as types of or groups which are common in PBL (p. 71).

Isaksen, Dorval, and Treffinger (1994) proposed four steps of Creative Problem Solving (CPS) learning model which describes how PBL should follow the problem solving process of defining the problem, searching for alternative solutions, testing the solution, and actively reflecting on outcomes. Indeed, research on the use of creative problem solving (CPS) lends support to the idea that such instruction can nurture inventive thinking skills, by linking the learner's natural creativity and problem-solving approaches (Schack, 1993; VanTassel-Baska, Bass, Ries, & Poland, 1998).

The National Center of Education and Economy recommended PBL as a means of developing the creative abilities fundamental to innovative achievement (Adams, 2006). Recent analysis by Neber and Neuhaus (2013) shows that PBL can even support productivity and innovate efforts in benefit of infusing creative elements into regular classrooms. In this aspect, Plucker and Nowak (2000) recommended PBL as a program for enhancing creativity as a general and non-specific ability. According to them, PBL is based upon the theories of situated cognition, which claim that the transfer of knowledge occurs infrequently and that learning requires certain situation-specific competence. PBL is the sort of learning environment which may induce the development of creativity among students.

Furthermore, the effectiveness of PBL has been researched within ages ranging from kindergarten to college students. Awang and Ramly (2008) compared the effectiveness of PBL to a structured instructional approach on the originality and fluency of engineering students. They found that PBL resulted in higher originality and fluency scores with 'idea production' as indicators of general creative abilities. The same result was found in a research done at Temasek Polytechnic on PBL implementation for developing general creativity abilities. Together with the meta-analysis conducted by Gijbels, Dochy, Van den Bossche, and Segers (2005) were 40 studies showed that PBL strongly influences the acquisition of applicable knowledge; these findings suggest that PBL has a positive impact on students' general creativity across a wide age range.

Several researchers, specifically Tan, Teo, & Chye, (2009) explain that PBL works by catalysing creative thinking and providing opportunities for innovation. The problems are mostly real-world situations that are familiar and relatable to the students, which enable immersion of themselves in the whole PBL process. However, most applications of PBL on creativity lean towards the arts and language. There are instances of PBL environments employed in science subjects (Tan et al., 2009) but those are simply for improving science knowledge, and not the scientific creativity of students in primary schools. Thus, investigating of scientific creativity among primary school students in PBL environment is worth the attention.

Scientific Creativity

Hu and Adey (2002) defined scientific creativity as the ability to use scientific knowledge and skills to produce a certain product that is original and has certain social or personal value. They developed a Scientific Creativity Structure Model (Figure 1) which proposes that the product dimension of scientific creativity consist of abilities in:

- Improving technical products
- Showing advances in science or scientific knowledge
- Understanding scientific phenomenon
- Solving scientific problems.

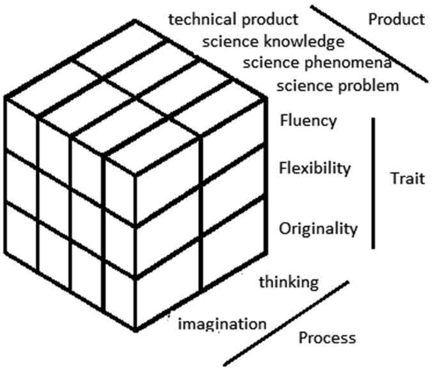

Figure 1: Scientific Creativity Structure Model (Hu & Adey, 2002)

Besides that, Fluency, Flexibility, and Originality are considered as traits or characteristics of a creative person. Fluency is a creative ability that allows students to produce many ideas or solutions (Meador, 1997). Osborn (1963) argues that when a student increases the number of ideas or problem solutions, they also increase possibilities for producing a relevant solution. Flexibility is the ability to bring different approaches to a problem, think of ideas in different categories, or view a situation from several perspectives (Davis & Rimm, 1994, p. 189). Flexible thinking encourages the selection of ideas or solutions from different categories or perspectives while Originality supports the development of something new (Meador, 1997) and is a necessary aspect of the invention or improving existing products.

A technical product refers to a science-based tool that is technologically engineered to perform specific tasks and is subject to innovation. The Product Improvement Task of Torrance (1974) provided a guide to measure the student's fluency, flexibility, and originality through the student's creative imagination and thinking in developing a technical product. Creative imagination is the ability to form new images while creative thinking is the process of producing a novel or innovative thoughts.

On the other hand, scientific knowledge by definition is knowledge gained by systematic study through scientific methods, based on observable and measurable evidence (Wilson, 1998) and accepted by the scientific community. Scientific knowledge refers to knowledge in any science-based field such as Physics, Biology, Chemistry, Geology, Engineering, and others. Students' fluency, flexibility and originality are measured through the practice of creative thinking in demonstrating their scientific knowledge. However, primary school students are not equipped with advanced scientific knowledge. This shows that the level of their scientific creativity should be based on accessible knowledge, such as basic concepts of gravity, photosynthesis, or simple measurement and scientific investigation.

A scientific phenomenon refers to observable natural physical events or occurrences that can be explained scientifically. Johnston (2005) states that the scientific concept that students develop everyday are relevant to the scientific phenomena they experience in their world. Students' fluency, flexibility and originality are measured through their imagination in demonstrating understanding of scientific phenomena. The students' scientific imaginations were evaluated by the quantity and relevance of their experience to phenomena.

Additionally, scientific problems refer to issues or problem situations that require scientific knowledge to be solved. By presenting a scientific problem to students, there is a possibility for them to produce a creative scientific

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solution (Lubart, 1994). Based on the level of cognitive development, basic scientific knowledge based on real-life experience will suffice for children in solving a scientific problem.

Kind & Kind (2007) claim that any approach to scientific creativity in school science needs to be 'authentic' in scientific research terms, and meaningful in the school context. In other words, scientific creativity in school science should be rooted in and reflect aspects of creativity seen in scientific research, and appropriate to children's needs and abilities. Thus, a key precept of scientific creativity in primary school students is the ability of students to use basic scientific knowledge to produce simple, appropriate and original products (not necessarily physical) that fulfil certain values.

Many studies have observed that creativity diminishes from childhood as most learning takes on a narrower meaning and educators become afraid of making mistakes or taking risks (Bohm, 1968). In conjunction with that, Beghetto (2009) hypotheses that creativity would largely be neglected in the classroom if teachers:

- Restricted its meaning to producing only completely novel and original ideas that do not correspond to curricular knowledge
- Consider major discoveries as creative achievements
- Believe that only a few students are able to be creative, or
- Assume that the promotion of creativity always requires special extracurricular programs.

Where such unclear or limited notions of creativity are adopted by teachers, undesirable situations that hold students from being creative are expected to happen. Therefore, it makes sense to deploy explicit curricular guidance to promote students' creativity in classrooms (Parnes, 1988). DeHaan (2009) also found evidence that students need to be repeatedly reminded and shown how to be creative, to integrate material across subject areas, to question their own assumptions, and to imagine other viewpoints and possibilities. In view of these points, students' scientific creativity would be fostered if they are taught to develop the product dimension of scientific creativity in original, flexible and fluent ways. Notwithstanding that while extensive research has been done on PBL, it remains a concern that little has been written about creative traits and their connection to the product dimension of scientific creativity in a PBL environment. It is thus fundamental to examine whether PBL enhances the creative traits, and product dimension of students' scientific creativity.

The Purpose of the Research

Current published research suggests that deficiencies continue to exist in science education in the development of scientific creativity among primary school students. According to Piaget's developmental theory, the formal operations stage starts from the age of 11 or 12 to adulthood (Inhleder & Piaget, 1958). Hence, fifth graders at age 11 are likely to make the transition from concrete operations stage to formal operational thinking. During the transition stage, children develop the ability to think in a logical way (Inhleder & Piaget, 1958). However, Driver (1978) cites problems with Piaget's theory in that the clinical method that Piaget used to generate his theory is not quantitative and that the transition into formal stage is not clearly defined. Fifth graders may be able to think abstractly about things with which they are very familiar, but not as much with less familiar things or concepts. Arguments against Piaget's theory concerning formal stage have generated research which believes that children may be more competent than Piaget originally thought, especially in their practical knowledge (Luria, 1976). Vygotsky (1978) believed that children are able to progress further in their zone of proximal development when they are given a cognitive task, in the presence of a more competent peer or adult, and with mediating artefacts. Thus, it is plausible that scientific creativity amid fifth graders may be developed and fostered with the assistance of more competent peers or adults.

Consequently, the purpose of this research is to determine whether PBL fosters scientific creativity among fifth graders. Moreover, measurement of creative traits gained by students in each product dimension of scientific creativity was also carried out. The research further investigated students' responses to the PBL experience and how these experiences helped them be more creative. In this research, scientific creativity refers to the product dimensions of scientific creativity which measured the ability of primary school students to:

1) Show an advance in basic science or scientific knowledge
2) Describe an observable natural physical phenomena
3) Solve a problem using basic scientific knowledge, and
4) Improve a given technical product in both primary and auxiliary purposes by illustrating it through a drawing.

Students' creative traits were investigated in terms of fluency, flexibility, and originality.

The research questions guiding this research are:

1. Is there a significant difference between post-test and pre-test mean scores in the product dimensions of scientific creativity among Fifth Graders before and after the PBL lessons?
2. Is there a significant difference between post-test and pre-test mean scores in the creative traits in each product dimension of scientific creativity?
3. What are the Fifth Graders insights and experiences using PBL in learning science; and how do these experiences help them be more creative?

Methodology of Research

Research Design and Sample

A large single group pre-test and post-test with intervening PBL experience design was used in this research. This involved assessment on the students' creativity based on the scientific creativity tests which was implemented prior and subsequent to the intervention. A mixed methods design of combining both quantitative and qualitative approaches served as a model to address research questions. Creswell (2012) indicated that the integration of results from both qualitative and quantitative approaches at the interpretation phase provides a convergence of the findings as a way to strengthen the knowledge claim of the study (pp. 540). The quantitative method involved the use of scientific creativity tests while the quantitative involved open-ended questions. An attempt was made to ensure that the data would not reveal individual characteristics; this was done by using codes to protect the identities of the students.

Purposive sampling was employed in the selection of the research sample to minimize experimental contamination (Fraenkel & Wallen, 2000). Selection of participants who possessed the characteristics, knowledge, ideas or experiences of particular relevance to the study would best help the researcher understand the research question (Creswell, 2003). The sample consisted of 232 fifth graders from two urban primary schools in an industrial suburb of Kota Kinabalu. Approximately 40% of the parents were government servants and 60% worked in other occupations (e.g. businessman, teachers, self-employed workers, labourers). The schools were categorized in the middle band in terms of science achievement based on the Subject Average Grade set by the Kota Kinabalu District Education Office. Participants comprised 133 females (57.3%) and 99 males (42.7%) aged 11 years old. Seven classes, each of about 30 students were involved in the research with the consent of the school principal. The selected classes had moderate science achievement as assessed by their science teachers in end-of-semester test marks (65-85 %).

Instruments

Scientific creativity tests. Two equivalent and parallel scientific creativity tests (Form A and Form B) developed by Siew, Chong, and Chin (2014) were used as pre-test and post-test respectively to measure students' scientific creativity. The scientific creativity test was found to have high internal consistency reliability, inter-scorer reliability and face validity. The item discrimination (r) of items in Form A and B were between 0.21 and 0.32 and the internal consistency reliability of the test was 0.77 in Form A and 0.68 in Form B.

Each parallel test consisted of four items in written open-ended format posed in the form of: improvisation skills with a technical product, advances in science or scientific knowledge, understanding of scientific phenomenon and scientific problem solving (Appendix A). The students were asked to express their own ideas in writing the answer. Pearson's correlation coefficient for the pre-test and post-test was 0.30, indicating a medium correlation (Du Plessis, 2010; Zikmund, 2008, p. 551). Paired sample t-tests were used to see if there is a significant difference between pre- and post- scientific creativity scores.

Open-ended question. A paper-based open question was administered. Students were asked to reflect on their learning experiences and feelings following their participation in the PBL intervention, and how the participation in PBL impacted their creative abilities, by responding to the question: 'I like/dislike the methods in which the science activities were carried out because …' and 'The science activities enable me to be creative by......'

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Promoting scientific creativity among fifth graders using PBL

To provide an opportunity for students to explore experientially the problem solving process, a PBL learning module was developed using the four steps of Isaksen et al. (1994) CPS learning model. The four steps were, (1) defining the problem, (2) searching for alternative solutions, (3) testing the solution, and (4) actively reflecting on outcomes. The content selected for the module was appropriated to developing each stage of the problem-solving process. It consisted of five lesson plans as a series of hands-on activities that studied themes such as Material Science, Technology, Microorganisma, Heat, and Acid and Alkaline. The selected themes were already included in the syllabus of Year Three, Four and Five Primary Science Curriculum & Assessment Standard Document (Curriculum Development Centre, 2013), thus students had learned the major science concepts connected to those themes. Activities were posed as problems that were mostly real-world situations familiar to the students as below:

1. How do you move water from one glass to another without touching the glass? (Material science)
2. How do you suck water out of the glass without using your mouth? (Technology)
3. How do you bring yeast back to life? (Microorganism)
4. How do you inflate (fill with air) a balloon without using your mouth or air pump? (Heat)
5. How do you make orange juice bubble by itself? (Acid and alkaline)

In the first step of identifying and defining the problem, teachers posed problems in the form of open-ended questions (as stated above) thus allowing for divergent thinking or many possible creative solutions. Questions such as 'Can you find a way to remove water from a glass?' and 'What happens to yeast powder if you put it in an empty bottle?' were used to guide students in the discussion. This would enhance the students' understanding of the problem-situation and leads to the second step, searching for solutions and alternative solutions. Fluency of ideas was reflected in the activity when students thought of many different solutions for solving the problem. Students were also asked to display fluency of ideas through sketching and presenting their design in front of other groups. When students were asked to examine the solutions from other students' perspectives, they were expected to think flexibly. It was observed that when students produced a solution new to them and different from others, they were considered as generating original ideas.

Critical thinking followed this period of solution generation where students selected the best solution from suggested multiple options. Students used divergent thinking first to generate ideas, and then used critical thinking to make specific decisions and focused their thoughts on the best solution. Students were asked to consider the materials provided and other factors when judging their choices. It was through this process that students developed their creative traits as they tried to polish their ideas in order for problems to be solved efficiently. After choosing their most favored solutions, they carried out step three of the hands on activities which is to test the success of their choices.

Finally, the last step involved students' group reflections on the solution they had thought of. They were instructed to summarize what they did during the respective activities as well as to prepare a presentation of their solution in front of the class. This step enabled other students to evaluate the solutions of their peers. Throughout this process, the students' creative traits and product dimension of scientific creativity were fostered with the help of the teachers, who provided sufficient time and resource for creativity to be nurtured among the students.

Two senior science teachers were trained to carry out the PBL intervention in the seven classes prior to the start of the research. Both of them were Master Trainers for science in primary schools in Kota Kinabalu and one of them helped the researcher develop the PBL module. The researcher guided the teachers through the five lesson plans using the PBL learning module in order to ensure the consistency and reliability in the implementation of the lessons across all 232 subjects. Prior to the intervention, students' creativity was assessed using pre-scientific creativity test (Form A). Based on pre-test scores obtained, students were grouped into groups of 4-5 of different levels of ability: high-, medium- and low creativity achievements. To ensure active and equal participation within a group, each student was assigned to perform a specific role: a reporter, recorder, runner, checker, and sketcher. All participants were given identical activities in a PBL module and underwent similar interventions. The PBL intervention consisted of five lessons lasting of two hours each.

Data Analysis

Analysis of Students' Level of Scientific Creativity

Scoring procedures. The students' scientific creativity was scored using criteria adapted from Torrance's Test of Creative Thinking (TTCT) (Torrance, 1990) and Hu and Adey (2002) whom evaluate the creative traits of fluency, flexibility and originality through student answers in test items. The reliability coefficient of the TTCT ranges from 0.78 to 1.00, at different grade levels (Torrance, 2000). Table 1 shows the scoring criteria used for assessing the scientific creativity.

The research team classified the answers for each test item into categories. Each category consisted of several response items. The response items were then coded by the team, with numbers representing categories while letters of the English Alphabet representing response items under categories. Matlab and MS EXCEL statistical functions were used to compute the scoring. The scores of items 1 to 3 were the sums of fluency, flexibility, and originality scores. The fluency score was obtained by counting all the separate student responses regardless of quality. The flexibility score for each task was obtained by counting the number of categories given in the answer. Frequencies and percentages of each response were computed to obtain the originality score. If the probability of a response was smaller than 5%, 2 points were given; for 5-10% probability, 1 point was given; for > 10%, 0 points were given (Table 1).

The item 4 score was the sum of the flexibility and the originality scores. The flexibility score for item 4 was obtained by counting the number of methods or created symbols given in the answer. As there was only one method or symbol in each response, flexibility represented the same scoring of fluency, thus only flexibility was included in the scoring. The item 4 score was computed again by tabulating all answers of all students, and then rating a particular answer for its originality score as employed by Hu and Adey (2002). A probability < 5%, received 3 points; probabilities of 5-10, got 2 points; probability > 10, got 1 point. There was one score for each method of division (Pre-test) and creating symbols (Post-test) in task 4 (Table 1). Most students got 2 or 3 points; some got 15 points. Generally, it was impossible for a student to get 0 points because there were at least two or three very simple divisions in Pre-test and symbols creation in Post-test.

Table 1. Scoring criteria for Creative Trait.

Creative Trait	Scoring criteria	Score awarded
Fluency	Number of different ideas produced	1 point for each idea
Flexibility	Number of categories of ideas produced	1 point for each category
Originality (Item 1 to 3)	Uniqueness of the ideas produced, as compared to the whole sample	< 5% - 2 points Between 5% and 10% - 1 point >10% - 0 point
Originality (Item 4)	Uniqueness of the ideas produced, as compared to the whole sample	< 5% - 3 points Between 5% and 10% - 2 points >10% - 1 point

Inter-rater reliability. Due to the subjectivity of scoring criteria, it was necessary for an independent person to reliably interpret student answers using the same scoring system. A science teacher and the researcher independently rated scores for 20 randomly chosen answer scripts. Both raters attended training in scoring the creative traits. Before starting the scoring, each rater scored the same set of 20 student answers independently following the scoring criteria given in Table 1. Disagreements in scoring the student answers were resolved by a discussion between the raters. The Pearson product-moment correlation coefficients between the two sets of scores for fluency and flexibility in pre-test and post-test were computed. The originality index was not included, because it would be scored using the frequencies and percentages of the whole sample. Correlations between scores vary from 0.65 to 1.00. Hence, results suggest that the scoring procedure was reliable.

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Analysis of Qualitative Data

For written qualitative data, the researchers used interpretive methods (Erickson, 1986) to explore common themes that emerged out of 232 participants' statements and words. An iterative process of coding, memo writing, focused coding, and integrative memo writing (Emerson, Fretz, & Shaw, 1995) was also integrated into the process. In the section named Findings, quotes in italics are the participants' statements.

Results of Research

Quantitative Analysis

Findings for research question 1. Results in Table 2 indicated that there were significant differences ($p<0.05$) in scientific creativity mean score between pre- and post-test in the dimension of Technical product, Scientific knowledge and Scientific problem. However, there was no statistically significant difference in the dimension of understanding of scientific phenomenon ($p=0.36$).

Table 2. Paired Sample t-test for product dimension of scientific creativity.

Product Dimension				Paired Differences				
		M	*SD*	*M*	*SD*	*t*	*df*	*p*
Technical product	Pre	6.61	3.76	-4.67	6.99	-9.44	198	p<0.05
	Post	11.28	6.29					
Scientific knowledge	Pre	5.76	5.27	-6.45	8.23	-11.06	198	p<0.05
	Post	12.21	7.98					
Scientific phenomenon	Pre	5.56	4.12	0.37	5.67	0.93	198	0.36
	Post	5.19	4.35					
Scientific problem	Pre	4.05	2.02	-5.07	7.24	-9.88	198	p<0.05
	Post	9.12	7.46					
Overall	Pre	21.98	8.59	-15.82	15.23	-14.65	198	p<0.05
	Post	31.80	13.19					

Note. Significant level at α=0.05

Findings for research question 2. Results comparing students' creative traits (Table 3) indicated significant differences in fluency, flexibility and originality for each product dimension of scientific creativity ($p<0.025$), except that there were no significant differences in the originality of scientific knowledge ($p=0.08$). Results suggests that students did not gain or lose scores for the originality in scientific knowledge. Besides, the creative traits of fluency and flexibility also reported a significant difference in decreasing trend of 0.70 and 0.38 respectively in scientific phenomenon.

Table 3. Paired sample t-test for creative traits in each product dimension of scientific creativity.

Product dimension	Traits				Paired Differences				
			M	*SD*	*M*	*SD*	*t*	*df*	*p*
Technical Product	Fluency	Pre	2.78	1.33	-1.75	2.78	-8.91	198	p<0.05
		Post	4.53	2.51					
	Flexibility	Pre	2.74	1.30	-1.64	2.67	-8.68	198	p<0.05
		Post	4.39	2.39					
	Originality	Pre	1.09	1.54	-1.28	2.50	-7.20	198	p<0.05
		Post	2.36	2.22					

Scientific knowledge	Fluency	Pre	2.53	2.21	-2.71	2.82	-13.60	198	p<0.05
		Post	5.25	2.55					
	Flexibility	Pre	1.77	1.52	-3.28	2.54	-18.20	198	p<0.05
		Post	5.06	2.36					
	Originality	Pre	1.45	2.05	-0.46	3.65	-1.77	198	0.08
		Post	1.91	3.51					
Scientific phenomenon	Fluency	Pre	2.20	1.48	0.70	1.83	5.40	198	p<0.05
		Post	1.50	1.23					
	Flexibility	Pre	1.65	1.01	0.38	1.32	4.02	198	p<0.05
		Post	1.27	1.00					
	Originality	Pre	1.71	2.04	-0.70	2.93	-3.39	198	p<0.05
		Post	2.41	2.27					
Scientific problem	Flexibility	Pre	2.02	1.01	-1.94	2.82	-9.69	198	p<0.05
		Post	3.95	2.91					
	Originality	Pre	2.03	1.02	-3.14	4.55	-9.73	198	p<0.05
		Post	5.17	4.66					

Qualitative Analysis on Student Written Reflections

Findings for research question 3. A total of 232 student written reflections about PBL was coded and categorized into themes emerged as shown in Table 4.

Table 4. Summary of student reflections.

Student reflections	Frequency (N=232)	Percentage (%)
I like the methods in which the science activities were carried out because …		
A fun, interesting, easy way of gaining and advancing science knowledge	139	59.9
Learned new knowledge by doing science	75	32.3
The science activities enable me to be creative by......		
Shared and gained ideas via cooperative learning groups	72	31.0
Involved in a challenging activity	22	9.5
Became fluent via sketching science	20	8.6
Worked and reasoned like a scientist	13	5.6

A fun, interesting, easy way of gaining and advancing science knowledge. A total of 59.9% students felt that PBL activities were easy, fun, and an interesting way of gaining and advancing science knowledge. Sample responses include:

> *"It has become easier for me to understand and know the given topic, Science is fun and interesting"* (S4); *"I can learn science easily and have fun"*; *"It is very easy for me to absorb the learning content into my brain"* (S10); *"It's is fun and gives me idea about Science. I like the fifth activity because it was very easy. I gain a lot of new knowledge from there"* (S19); *"I love it because it is fun and can work with friend. The more I learned from the activities which I did not know before, the more I am able to gain new knowledge"* (S23); *"It improve our knowledge regarding to science"* (S160); *and "…… I am able to gain new science knowledge from the experiment such as making the water flow without moving it, making the yeast alive, making water pump and blowing balloon without using mouth by submerging bottle into water"* (S32).

Learned new knowledge by doing science. Additionally, a total of 32.3% students remarked that they liked problem-based learning because they could perform hands-on experiments and gain new knowledge. Some of their responses include:

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> *"I like science activities assigned by teacher because I could get more experience and learn with my classmate how to perform the experiment"* (S7); *"I like to do more and more science activities and experiments that bring me a lot of fun"* (S8); *"I like it because we can do science. We can update our knowledge about the world of Science and Technology"* (S20); *"I love to do science activity and I can quickly understand it without looking at the text book"* (S30); *and "I can obtain a broader science knowledge easily without using any reference book"* (S147).

Shared and gained ideas via cooperative learning groups. Students expressed that they enjoyed being able to have fun and working with a cooperative spirit. Furthermore, sharing ideas with peers in solving problems helped them to be more creative. They reported:

> *"I like to work with my friends during the experiment, I gained different ideas to solve an unknown problem when working with my friends in group activities"* (S6; S21); *"... I feel easy to share ideas by working with my friends in the experiment"* (S22); *"...it is totally fun to know many solutions and able to work cooperatively in a group….."* (S229); *"...I can play and learn many things by having discussion with my friends in the science laboratory. I wish to carry out the experiment again"* (S5); *"The assigned activities were interesting. It improved our science knowledge by working with peers. My group had presented a lot of great ideas to solve a problem"* (S81; S160); *"I can share new knowledge and having fun with my friends"* (S179); *"I learn to cooperate with others to learn more about science"* (S4; S26); *and "I can discuss many things about science with friends and I found it was exciting and easy"* (S15).

Involved in a challenging activity. About ten percent of students reflected that they underwent complex cognitive challenges and thus forced them to generate novel ideas. As students stated:

> *"I like these activities because it is challenging and forcing me to come out with unusual ideas"* (S26); *"This activity is really testing our brain and ability in order to generate many ideas"* (S51); *"This activity challenges my mind, it is more enjoyable than just sitting in the classroom without thinking of new things"* (S64); *"I love it so much as it challenges my mind and I have fun to have discussion with friends to present different kinds of ideas"* (S112); *and "It's really fun and testing my intelligence"* (S171).

Became fluent via sketching science. About ten percent of students indicated sketching activities encouraged them to demonstrate fluency of ideas:

> *"We learned to sketch our plan of the experiment on a blank sheet of paper and found different kinds of ideas that I did not know"* (S50); *and "I love sketching activities. I can show many ideas to do the experiment"* (S102).

Worked and Reasoned like a scientist. A total of 6.0% of the students viewed themselves as 'working and thinking like a scientist', especially when they were doing the experiments (Hands-on activities) which consequently improved their creativity. They noted:

> *"We have to use our mind during the experiment, and think like a scientist to solve problems or inquiries that we do not know yet the answers"* (S48; S167); *"We have to think a lot in order to gain new science knowledge"* (S74); *"... I can produce many ideas when I think like a scientist"* (S79); *and "Science activity is interesting for me and I have exercised/activated my brain intellectually"* (S211).

While others felt that they went through the scientific way of doing PBL activities, as they mentioned:

> *"... it was exciting and scientific way of doing work. I can discuss many ideas with friend about science and I found it is easy"* (S15); *"The science activities enable us to do various sort of testing or experiment and we learn to know many new scientific matters"* (S58); *"... it involves thinking like scientists do"* (S168); *and "... it can strengthen our mind and it is fun to gain many ideas from group members"* (S202).

Overall, student written reflections pointed out that the PBL activities had provided a fun, interesting, easy and practical way of gaining and advancing science knowledge. Student's feedback indicated that PBL activities had provided a learning environment that supported them in sharing and gaining ideas by means of cooperative learning groups. It also gave them the opportunity to perform and rationalize like a scientist in challenging activities that encouraged creativity. Students also noticed that sketching activities aided them in displaying fluency of ideas.

Discussion

The research found that students were able to improve their overall mean scores in the product dimension of scientific creativity after carrying out the four steps of problem-based learning. Further analysis showed that students improved their scores in the dimensions of improvising a technical product, solving a science problem, and advancing science knowledge. While solving a science problem collaboratively via groups and hands-on activities in PBL environment, students were engaged in searching for ideas with different categories or approaches by using learned scientific knowledge and relevant practical knowledge. Students also sketched their ideas on paper to justify their design. Additionally, students formulated new ideas, and combined them in a new way to solve a science problem. PBL also provided a learning environment where problems were posed in the form of open-ended questions thus allowing researchers to see students' improvement in science knowledge. As stated in written reflections, students found PBL a fun, interesting, easy as well as a practical way of gaining and advancing knowledge of science. In the same way, students found PBL activities challenging hence made them perform and reason like a scientist; and that the experiences helped them to be more creative.

Students also found their participation in PBL intervention such as sketching science and sharing ideas in cooperative learning groups fostered their scientific creativity. In like manner, communication and information sharing have been identified as social process variables which are being linked to improved creative outcomes (Reiter-Palmon et al. 2012; Paulus, Dzindolet, & Kohn, 2012). For example, individual students demonstrated the creative traits to generate a number of new ideas with different categories that contribute to improved scores of product improvisation, solving a science problem and advancing science knowledge. As a result, students' overall product dimension of scientific creativity had improved through engagement in PBL.

This research's findings are supported by Tan's (2000) research that PBL modules contribute positively to student development of creativity. When students carry out PBL through hands-on activities, they gain inspiration and a sense of creativity (Lou, Chung, Dzan, & Shih, 2012). A Stanford University Newsletter (2001) on teaching stresses that students who brainstorm in a collaborative situations while solving a problem helps them develop both domain knowledge and problem solving skills. This research's findings are also confirmed by data presented in the form of student written reflections. They expressed enjoyment in interacting with peers in the cooperative learning activities and found that the scientific learning process became easier. These student views are also similar to the ones highlighted by Brophy (2006) who confirmed that groups of interacting individuals were better at solving complex, multipart problems than single individuals. This result is in agreement with the learning theories proposed by proponents of cooperative learning. Vygotsky (1978) argued that children, whom are given a cognitive task in the presence of a more competent peer or adult, and with mediating artefacts, are able to progress further in their zone of proximal development compared to a child who does not have these influences.

Similarly, nursing school students in Chan's (2013) research agreed that PBL activities increased their problem solving skills. Cavas, Kesercioglu, Holbrook, Rannikmae, Ozdogru, and Gokler (2012) also found that scientific creativity of students increased when problem solving skills were emphasized in robot design and development involving hands-on and minds-on activities.

However, students showed no significance change of overall mean scores in explaining a scientific phenomenon. At this stage, as hypothesized by Piaget theory, fifth graders have not yet fully developed the ability to think logically in order to describe in a scientifically natural physical phenomenon. McCain (2015) states that students need to properly understand how a theory works before they are able to generate possible explanations of a particular phenomenon.

In this research, while most PBL dealt with solving daily problems which could be solved, PBL could not foster fifth graders' imagination and thinking to describe a system where our surroundings exhibit complex and chaotic behaviour (e.g.: sun is losing its light, plants can move like animal). According to Kirschner, Sweller, and Clark, (2006), minimal guided instructional approaches such as PBL ignore the structure of human cognitive architecture. Kirschner et al. (2006) addressed that guidance from a more competent person can only be gradually removed when students become independent learners who can perform the task on their own. Some literature suggests not involving novice learners in minimal guidance instructional approach such as PBL because they need direct guidance for developing the concepts (Klahr & Nigam, 2004; Mayer, 2004). Hmelo-Silver (2004) stressed that PBL should be tailored to students' cognitive development level.

Further scrutiny indicated an increase in student's creative traits of being fluent, flexible and original in solving a scientific problem, and in improvising a technical product and advancing scientific knowledge. In this research, the teacher posed a problem to students with many possible solutions through the four steps of Isaksen et al. (1994) Creative Problem Solving learning model. Although solutions differed among student groups, each group was required to think of the best solution. Thus, students were trained to develop flexible thinking by moving and rearranging the components of the problem (Meador, 1997). Students were also geared toward the developing something new (originality) when they were involved in sketching activity. By using open-ended questions and brainstorming, students were encouraged to think of as many ways as possible to define and solve a specific problem, consequently resulting a greater fluency.

Student written reflections revealed that learning science though PBL enabled them to generate many ideas, display fluency of ideas through sketching and scientifically create solutions to a novel problem. Students displayed this ability in post-test when they were asked to suggest as many scientific improvements to whiteboard pens to make it look interesting and unusual through drawing. While many students drew one or two characteristics, such as wings, sound recorders or speakers on their marker pen, the fluent and flexible students applied many characteristics from different technology tools and scientific principles. This included features like a temperature indicator, compass, laser, dictionary, microphone, fans, highlighter and MP3. In other words, PBL helped students to develop the ability of making a number of suggestions (fluency), forming new ideas (originality), and combining and selecting the best action plan to carry out the solutions (flexibility). Consequently, this resulted in an increase in student's creative traits in solving a scientific problem, improvising a technical product and advancing scientific knowledge. This is supported by Awang and Ramly (2008) whom also revealed that the overall creativity traits in terms of fluency, flexibility and originality were improved with the application of PBL.

Nevertheless, the statistical result showed no significant differences in originality in the advances of science or scientific knowledge. The students could be influenced by their prior knowledge of the science concept of 'magnet' and 'microorganism'. For example, students might have responded directly to the stimuli (magnet/microorganism) based upon their prior knowledge rather than contributing something novel. The PBL activities were still lacking in showcasing their originality to respond these questions with regard to their uses, characteristics, types and effect. This could be due to the rather short duration of intervention. Students needed a longer exposure on various challenging science problems for development in originality in the advances of science or scientific knowledge.

Similarly, with the understanding of scientific phenomenon, the fifth graders showed a decrease in the score of fluency and flexibility but an increase in originality. Student responses to 'the sun is losing its light' (pre-test) were widely influenced by their prior knowledge about sun, thus they were able to develop more idea on the topic (fluency) and combine ideas from peers (flexibility) than making unique ideas (originality). However, while responding to the 'plants can move like animal' (post-test), they were more likely to imagine and create new stories (originality) based on an observable natural physical phenomenon compared to giving and combining more different ideas (fluency and flexibility). Students needed both time and experience for the development of fluency and flexibility in describing an observable natural physical phenomenon that exhibits complex and chaotic behaviour.

Conclusions

Fundamentally, Problem-Based Learning based on Creative Problem Solving learning model has helped to promote scientific creativity among fifth graders. Students demonstrated improved creative traits of being fluent, flexible, and original in their solutions for a scientific problem, improvising a technical product, and advancing scientific knowledge. Fifth graders also found that PBL activities helped them be more creative. This research indicates that students need to be engaged to work collaboratively in a group environment, to understand the needs of an open-ended problem, and to think of multiple solutions. When students were trained to be more fluent, flexible and original at developing solutions, they were encouraged to become more scientifically creative.

However, this research did not demonstrate positive effects on creativity traits in all product dimensions of fifth graders' scientific creativity, such as fluency and flexibility in describing scientific phenomenon, and originality in advancing scientific knowledge. Two interventions would help clarify further the remaining gaps of PBL in developing young people's scientific creativity: 1) a longer intervention period with extra science themes and open-ended problems compared to the current research, and 2) a wider age range of primary students (10-12 years old). More information about creativity development would be obtained through investigation across a larger multi-age group.

It would be useful to undertake further investigation on the extent to which PBL could assist primary students of high, moderate and low performance in science subjects in fostering their scientific creativity and creative traits. Educators should consider the fact that students with different abilities might have different probabilities of developing their talents in producing alternative solutions and novel ideas.

It is believed that this research has important implications for science education and creativity researchers. This research will be able to provide science educators and researchers an important indicator that adapting Problem-Based Learning into science lessons will spark scientific creativity among primary school students. Specifically, it suggests that helping science teachers work with PBL to foster scientific creativity, would achieve one of the Malaysian Education Blueprint 2013 – 2025 goals which is to "......create a generation who can think creatively, innovatively and critically".

The scientific creativity and creative traits that PBL builds would place students at an advantage in making the best use of their potential, especially after post-secondary education. These skills are mostly needed in a professional context and the fact is that PBL holds a strong connection with professional career choice. This research shows that students are yet very young hence they have more potential to develop scientific creativity. Training student's scientific creativity from a young age may contribute to their being more able to handle the challenges of their future lives.

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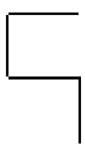
Appendix A

Item/Product Dimension/Description	Form A	Form B
Item 1: Technical Product Improvising a given technical product (a pen and marker pen) for both primary and auxiliary purpose by illustration. (A technical product is a science-based tool that is technologically engineered to perform specific tasks and is subject to innovation)	Suggest as many scientific improvements to a pen to make it look interesting, and unusual. There is with no need of making it practical. You can draw your idea out.	Suggest as many scientific improvements to a whiteboard pen to make it look interesting and unusual. There is no need of making it practical. You can draw your idea out.
Item 2: Scientific Knowledge To demonstrate an advance in basic science knowledge, a brief description of scientific terms associated with the Year Five Science Syllabus is requested.	Write down as many scientific words as you know about 'magnet' in terms of its uses, characteristics, types, and effects.	Write down as many scientific words as you know about 'microorganisms' in terms of its uses, characteristics, types, and effects.
Item 3: Scientific Phenomenon A story to describe the possible implication of the given phenomena based on student's connection and experience with an observable natural phenomenon.	Write as much as possible about an interesting scientific story on: 'The sun is losing its light'	Write as much as possible about an interesting scientific story on: 'Plants can move like animals'
Item 4: Scientific Problem The creative science problem solving abilities of the students can be determined by the quantity of symbols they can create as well as use of basic scientific knowledge on different methods to divide a square.	By using as many methods as possible, divide a square into 4 equal parts (same form). Show your answer in a drawing.	By rearranging or removing matchsticks of the following symbols, create as many symbols as possible by using 5 matchsticks. 

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