Development and evaluation of an integrated project-based and stem teaching and learning module on enhancing scientific creativity among fifth graders

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DEVELOPMENT AND EVALUATION OF AN INTEGRATED PROJECT-BASED AND STEM TEACHING AND LEARNING MODULE ON ENHANCING SCIENTIFIC CREATIVITY AMONG FIFTH GRADERS

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Abstract. *This research aimed to i) determine the validity, reliability, and appropriateness of an integrated project-based learning and STEM teaching and learning module (PjBL-STEM), and ii) evaluate its effects on the scientific creativity of Fifth Graders. The first phase of evaluation involved seven subject matter experts and 30 Fifth Graders. Data were captured through students' responses to two 5-point Likert scale questionnaires, open ended questions and scientific creativity test. The second phase of evaluation employed a pre- and post-test non-equivalent control group quasi experiment design. A total of 60 Fifth Graders from two primary schools were randomly assigned to a PjBL-STEM group (n=30) and a control group (n=30). The results of the PjBL-STEM evaluation indicated a good content validity and an acceptable reliability with alpha Cronbach's value of .65 to .87. Students showed a moderately high positive perception (m=4.37) towards the PjBL-STEM activities. The positive written responses of students indicated the appropriateness of the module. The result of independent samples t-test established the significant positive effects of the PjBL-STEM on all trait dimensions of scientific creativity. These findings showed that PjBL-STEM provides a reliable, valid, appropriate and effective teaching and learning module to foster the scientific creativity of Fifth Graders.*

Keywords: *fifth graders, project-based learning, scientific creativity, STEM.*

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Introduction

Creativity is a premier skill needed by 21st century learners who have the potential of shaping the future of a country. A creative individual is able to develop unique and useful solutions in both the digital and real world. Hu, Shi, Han, Wang and Adey (2010) identified scientific creativity as a domain-specific creativity that contributes to the advancement of human civilization. According to Simonton (2012), individuals who possess scientific creativity are more capable of developing scientific ideas that are novel, useful and unique. In this matter, Hu and Adey (2002) proposed a Scientific Creativity Structure Model (SCSM) to measure scientific creativity through three dimensions called trait, process and product. Children are natural learners and constantly search for ways to express their uniqueness. Thus, the scientific creativity of fifth graders can be advanced profoundly and measured with proper engagement in their process of learning.

Accordingly, the Malaysian Ministry of Education has placed emphasis on fostering the creativity of students in the Science subject as stated in the revised Primary School Standard Curriculum (Curriculum Development Centre, 2010a). Since then, primary school teachers across Malaysia have been urged to shift their pedagogy to address this new skillset. However, a teaching and learning module to promote scientific creativity has not been widely developed for practice in the primary school science classrooms.

Several research studies have focused on the design and development of learning modules for science-related fields at the elementary level (Dimopoulos, Paraskevopoulos, & Pantis, 2008). However, little attention has been emphasized on the design and development of modules that foster scientific creativity at the elementary school level. A related research incorporated problem-based learning in a learning module for fostering the scientific creativity among Fifth Graders (Siew, Chong & Lee, 2015). However, the learning module focused on activities that required children to produce

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new and original ideas through writing and a small amount of sketching. There is hardly any substantive research that emphasizes on the development and evaluation of a learning module that fosters the technical product at primary school level. Technical product is one of the product dimensions in SCSM proposed by Hu and Adey (2002). A technical product refers to a science-based prototype that is technologically engineered to perform specific tasks and is subject to innovation (Hu & Adey, 2002). Constructionism posits that individuals learn best when they are constructing a personally meaningful artifact that can be shared with others and reflected upon (Harel & Papert, 1991; Kafai & Resnick, 1996). Thus, emphasis needs to be given to the design and development of the technical product. In this way, students are triggered in flaunting their individual creativity by designing and creating novel and unique science-based prototypes. The demand for creative development calls for the need of a reliable, valid, appropriate and effective learning module that can guide teachers to foster scientific creativity by integrating appropriate instructional methods.

Project-based learning (PjBL) has been recognized as an instructional method centered on the learners (Grant, 2002). Through PjBL, learners typically have more autonomy over what they learn (Loi, 2017; Yuliani & Sri Lengkanawati, 2017). With more autonomy, learners 'shape their projects to fit their own interest and abilities' (Mousund, 1988, p. 4). Scholars have noticed the significance of project-based learning to develop creative abilities in students (Isabekov & Sadyrova, 2018). Thus, it was hypothesized that project-based learning and the design and development of technical product will enable the expression of diversity such as scientific creativity in students.

Researchers found that taking a project-based approach to STEM learning can help foster creativity in students (Lou, Chou, Shih, & Chung, 2017; Siew, Amir, & Chong, 2015). STEM education is an interdisciplinary approach to learning which integrates the study of science, technology, engineering and mathematics into a cohesive learning paradigm. Through STEM education, students are challenged to make connections between learning and the real-world. In Malaysia, efforts to encourage students to take up STEM subjects have risen in recent years. However, student enrolments in almost every STEM subject area have continued to fall over the last decade (Yong & Phang, 2015; Ministry of Education Malaysia, 2014). For example, the percentage of students who pursue their studies in higher educational institutions in STEM related programmes has dropped from 48.6% in 2016 to 19.8% in 2017 (Education Statistics Malaysia, 2017). In order to increase college and career readiness in STEM, it's important that students experience an integrated project-based learning and STEM in the lesson, providing them with authentic opportunities to think and act like engineers and scientists (Williams, 2011). PBL focuses learning around real world problems which are complex and authentic (Buck Institute for Education, 2018). The complex and authentic nature of these problems require students to draw on knowledge across STEM disciplines as they work to develop solutions (English, King, & Smeed, 2017).

Accordingly, a thorough integration was applied in this research; each of the PjBL and STEM learning steps were performed simultaneously in the learning processes established in the proposed learning module. With this integrated approach, the students were prompted to think explicitly about the discipline of STEM and then undergo the PjBL process via team work. It is plausible that the integration of PjBL and STEM in developing a learning module may help Fifth Graders to think creatively for scientific solutions.

Theoretical Foundation

The design and development of the PjBL-STEM teaching and learning module was based on the analysis of various elements including the context of the project-based learning and STEM in primary schools and its implementation, the understanding of the way primary school students learn and its associated learning theories and instructional approaches, and relevant instructional design model. Based on the fact that this learning module was applied to a group of Fifth Graders, the researcher decided to adopt Piaget's (1952) cognitive development theory and Vygotsky's (1978) concept of the Zone of Proximal Development and scaffolding. Piaget's theory emphasises on cognitive constructivism where learners' schemes are built through active interaction with the learning environment. When a new problem is given, children will be engaged to assimilate and accommodate their scheme to a new situation (Qayumi, 2001) and think of many different solutions. In addition, attention has been given to social constructivism to ensure that less capable children will make further progress in their zone of proximal development with the help of their teacher(s) or more capable peers.

The researchers also acknowledge the pedagogical principle underlying the teaching and learning process in a primary school classroom that supports the process of cognitive and social constructivism. The increasing interest in PjBL has encouraged some researchers to incorporate cooperative learning (CL) in PjBL. Numbered Heads

Together (NHT) is a cooperative learning strategy that has been proven effective in fostering learners' scientific creativity (Maulana, 2014; Steen, 2013). Thus, the researcher has integrated the cooperative learning Number-Head Together (CL 'NHT') (Kagan & Kagan, 2009) into PjBL-STEM activities to create conducive environments for developing cognitive and team working skills. Children will go through the steps of PjBL-STEM as a team adhering to the principles of NHT. With this integration, children are exposed to real-world science problems and engage with peers in searching for many unique solutions from different perspectives based on their learned scientific knowledge and relevant practical knowledge.

In addition, specific attention has been given to the four phases of Directed Creative Model (Plsek & Associates, 1997) which represent a creative phase to engage learners in Preparation, Imagination, Development, and Action. Students are also engaged in an improved engineering design process proposed by the Massachusetts Department of Elementary and Secondary Education. (2016). The engineering design process focuses on solutions by sketching and constructing prototypes that drive students to encounter the five-trait dimension of scientific creativity. In regards to this research, an operational definition of trait dimension of scientific creativity refers to Torrance, Ball, and Safter (2008)'s creative abilities of producing i) a variety of different ideas [Fluency]; ii) ideas that are unusual or unique [Originality]; iii) ideas that could be developed or embellished [Elaboration]; iv) abstract title for the sketches [Abstractness of Title]; and v) completed and detailed sketches from a variety of perspectives [Resistance to Premature Closure]. For example, students display fluency of ideas which are original through sketching their designs. Finally, an improved Scientific Creativity Structure Model (SCSM) (Hu & Adey, 2002) is used as a theoretical model of scientific creativity to guide the development of the teaching and learning module and test items through three dimensions namely Product (Technical product), Trait (fluency, originality, elaboration, abstractness of title and resistance to premature closure) and Process (imagination, thinking).

On the other hand, in the design and development of the PjBL-STEM teaching and learning module, the researcher has adopted the ADDIE model of Wegener (2006) due to its holistic nature and flexibility. This ADDIE instructional design model provides a structure for thorough a) analysis, b) design, c) development, d) implementation, and e) evaluation. Accordingly, the overall theoretical foundation regulating the design and development of the PjBL-STEM teaching and learning module is illustrated in Figure 1.

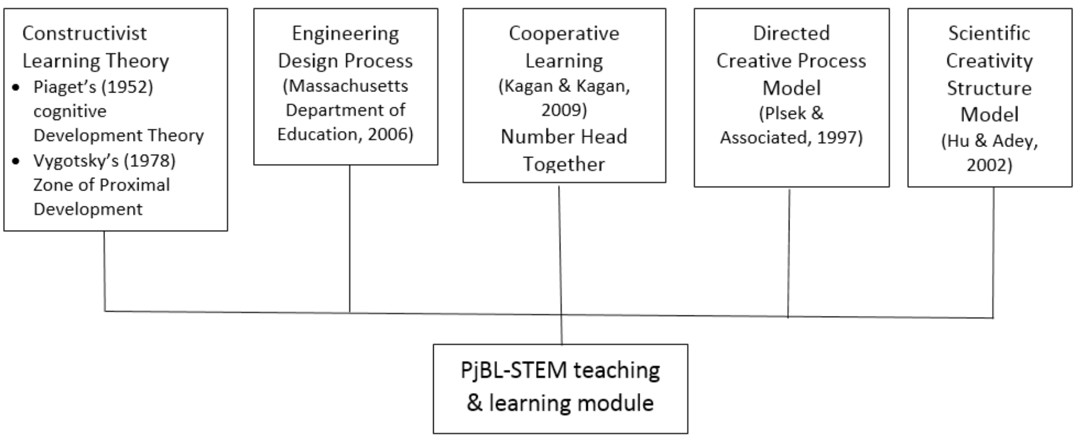

Figure 1. Theoretical foundation regulating the design and development of the PjBL-STEM teaching and learning module.

Research Aims and Questions

Accordingly, the aim of this research was to design and develop an integrated Project-based learning and STEM (PjBL-STEM) teaching and learning module and evaluate its effects on scientific creativity among Fifth Graders. Three research questions guided this research:

1. Is the developed PjBL-STEM teaching and learning module reliable, valid and appropriate for Fifth Graders?

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2. Is there a significant difference between fifth graders who are taught using the PjBL-STEM module and those without the PjBL-STEM module in their i) pre-test mean scores, and ii) post-test mean scores in scientific creativity?
3. What are the Fifth Graders' experiences using PjBL-STEM approach in learning science; and how do these experiences help them be more creative?

Methodology of Research

Research Design

Descriptive and quasi-experimental research designs were employed in this research. Descriptive research involved evaluation that aimed at assessing the validity, reliability, and appropriateness of the PjBL-STEM module. On the other hand, a quasi-experiment was conducted to determine the effects of the PjBL-STEM module on Fifth Graders' scientific creativity. The research lasted three months from January to March 2017.

Research Sample

The sample in descriptive research involved 30 Fifth Graders and seven subject matter experts. Chua (2011) notes that 30 respondents is sufficient to assess the aspect of consistency in a developed measuring instrument. On the other hand, the sample in the quasi-experimental research consisted of 60 Fifth Graders. The Fifth Graders were randomly selected from two government-funded primary schools in an urban district in Tawau and assigned to a PjBL-STEM group (n=30) and a control group (n=30). The Fifth Graders comprised of 34 (57%) girls and 26 (43%) boys. Approximately 65% of their parents are government servants and 35% work in other occupations (e.g. businessmen, self-employed workers, labourers).

Ethical Considerations

Permission to conduct the research was obtained from the primary school principals, teachers and students. At the beginning of the research, the Fifth Graders were presented with a letter of consent detailing the nature of their involvement in the research and the need for their consent on the sheet indicating their full understanding of the project. The purpose of the research was explained in detail and all the students were assured of the confidentiality of their responses. All Fifth Graders were informed that they could withdraw from the research without penalty.

Descriptive Research

Analysis Phase

The main educational goal of the PjBL-STEM module was to foster the scientific creativity of Fifth Graders through an integrated approach of project-based learning and STEM in science lessons. To achieve this instructional goal, the researchers performed an analysis on the needs, learner and context. During the *needs* analysis stage, the researcher interviewed five school teachers and four Fifth Graders in a primary school in Tawau, Sabah in order to gain their insight about scientific creativity and the application of PjBL and STEM in science lessons. The teachers' responses in unstructured interviews indicated that they lacked knowledge on fostering and assessing the scientific creativity of students as there are no learning modules or guidelines provided by the Ministry of Education. Teachers admitted that they had little knowledge about integrating PjBL in STEM learning.

The *learner* and *context* analysis were focused on the interest and ability of students in sketching and writing, and peer interaction as suggested by Carlton, Kicklighter, Jonnalagadda and Shoffner (2000). The findings showed that students liked drawing and doing projects but did it at home due to constraint of time and materials. Students showed pronounced differences in their writing skills and lack of interest in group work. Therefore, the instruction was developed accordingly to cater the needs of the target group.

Design and Development of the PjBL-STEM Teaching and Learning Module

The PjBL-STEM module was designed and developed as a teaching and learning material. The module consisted of six lessons and six project activities regarding Life Science, Physical Science and Material Science which are found in the contents of the Year Five Science Curriculum and Assessment Standard Document (Curriculum Development Centre, 2014b). Approximately two subsequent hours were needed to complete each activity. Activities were posed as ill-defined problems that were mostly real-life situations familiar to the students.

The principles of PjBL and STEM were incorporated into each activity, which afforded students the opportunity to design, sketch and make the prototypes. Fifth Graders were assigned to heterogeneous cooperative learning groups of 4 to 5 persons. Each activity underwent the four phases of the Directed Creative Process Model as well as incorporated the seven steps of the engineering design process.

In the Preparation Phase, teachers posed ill-defined problems in the form of open-ended questions thus allowing for many possible creative solutions (fluency). An example of ill-defined problem that guided students in group discussion is as below:

> Some residents living in squatter areas in Tawau have narrow homes and are less well-lighted. How can you help the residents to illuminate the dark space at cheap and eco-friendly costs? Your group need to design and make a home model in order to convince the residents in terms of its applicability.

The Imagination Phase involved Fifth Graders to 'put their heads together' to search for possible solutions. Through the brainstorming session within the CL 'NHT' group, students were engaged to generate a steady flow of ideas (fluency). Students then chose the best solutions for designing and developing prototypes via sketching which integrated the knowledge of science, engineering, and mathematics. Students added details upon details until the intended sketch emerged brilliantly on the worksheet provided (elaboration).

The Development Phase focused on accumulating the materials and constructing the prototypes through hands-on activities. Students were asked to consider the recyclable materials and other factors when judging their choices. Improvement was made to the prototypes based on the integrated knowledge of science, technology, engineering, and mathematics. In this stage, students were engaged to showcase their novel, unique, elaborated and completed prototypes with an abstract title (Originality, Abstractness of Title, Elaboration and Resistance to Premature Closure).

In the Action Phase, the Fifth Graders shared their work through an end-of-project presentation and collected additional information from other groups. This step enabled other students to evaluate the solutions of their peers. When students were asked to examine the solutions from other students' perspectives, they were expected to think in flexible ways. (Resistance to Premature Closure). Play factor was also infused into Action Phase when students tested their prototypes in the school compound.

Finally, students' reflections about the process of the project were carried out. Questions were formed by teachers to guide students in framing their thoughts as they worked with subjects such as mathematics, science and technology to solve problems and construct solutions. The integration of learning models in PjBL-STEM learning activities is shown in Table 1.

Table 1. Integration of learning models in the PjBL-STEM learning activities.

Engineering Design Process	CL "NHT"	Directed Creative Model	Learning Activities
• identify the problem • research the problem,	• Assign pupils to group • Ask questions	<u>Preparation Phase</u> • Identify problem • Clarify problem	• Teacher sets the stage for students with real life problems. • Pupils research and define problem. (*Technology*)
• develop possible solution(s) • select the best possible solution	• "Put heads together"	<u>Imagination Phase</u> • Search for solutions • Search for alternative solutions • Search for best solutions	• Pupils analyse problems and explore solutions by "putting heads together". • Pupils sketch their alternative solutions on the worksheet. • Pupils sketch the best solutions for designing and developing prototypes. (*Science, Engineering, Mathematics*)

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Engineering Design Process	CL "NHT"	Directed Creative Model	Learning Activities
• construct a prototype	• "Put heads together"	Development Phase • Accumulate the materials • Create their project • Improve their project	• Students accumulate the necessary materials for the project. • Pupils in groups construct their prototype. • Pupils make improvements to their prototype • (*Science, Technology, Engineering, Mathematics*).
• test and evaluate the solution. • communicate the solution	• Call on group number • pupils respond	Action Phase • Presentation • Reflect on the projects' process • Class and teachers evaluate the prototype.	• Each group presents their prototypes and students collect additional information from other groups. • Pupils reflect on the process and evaluate the projects.

Evaluation Phase

It is essential to collect data and information during the development of instruction to assess the effects of instructional materials (Ellington & Aris, 2000). According to Rusell (1974), the content validity and reliability must be determined before a module is being used. Hence, an evaluation was undertaken that included content validity, reliability and appropriateness of the module.

A panel of seven experts were involved to ascertain the content validity of the module. The experts were university and college lecturers as well as educators from the primary school science field. Two creativity and STEM experts were from two public universities, three were Master Trainers from primary schools specializing in primary science and science pedagogy, and one science lecturer from a teacher training institute specializing in Project-Based Learning and STEM.

A module evaluation form adapted from Russell (1974) was used which required experts to give candid feedback on the pedagogy content (PjBL, NHT and STEM), activity overview, relevance of each lesson plans, learning standard, overall flow of the project activities, integration of the five trait dimensions of scientific creativity, and written comments to improve the module. The PjBL-STEM module was produced in the Malay language to ensure the understanding of the module's content among primary school teachers. It was proof-read by two language experts.

The first questionnaire aimed to capture a holistic view on tracking students' perceptions on the appropriateness of PjBL-STEM activities. The questionnaire used a 5-point Likert scale with the value of 1 (strongly disagree) to 5 (strongly agree). The 10-item questionnaire was developed from ideas gathered from an instrument used in a research by Othman (2015) which required students to give their overall feeling, their gains in the five trait dimensions of scientific creativity, cooperative learning and interest.

To ascertain the internal consistency reliability of the PjBL-STEM module, a set of questionnaires adapted from Ahmad (2002) were given to students. According to Mohd Noah and Ahmad (2005), questionnaires based on activities showed a higher reliability index as compared to objectives in the module. There were six activities in the PjBL-STEM module. Each activity in the module was evaluated by five items employing a Likert scale with the value of 1 (strongly disagree) to 5 (strongly agree) to each item. The items asked if each activity conducted would help Fifth Graders to nurture the 5-trait dimension of scientific creativity in accordance with the learning outcomes of the module. All 30 items were presented in simple Malay language which consisted of short sentences that catered to the level of Fifth Graders. The two questionnaires were administered to 30 Fifth Graders in the PjBL-STEM group after an intervention using the module.

A paper-based open-ended question was administered after the intervention to obtain students' written feedback regarding the appropriateness of the module activities. Students were asked to reflect on their learning experiences and feelings following their participation in the PjBL-STEM intervention, and how their participation impacted their creative abilities, by responding to these questions: *'I like/dislike the methods in which the science project were carried out because …', 'The science project enabled me to be creative by……', and 'Something new I learned from the science project was……'*

Quasi-Experimental Research

The Implementation Phase involved the delivery of the PjBL-STEM teaching and learning module and assessed the effects of instructional delivery in the actual classroom. Thus, a pre- and post-test non-equivalent control group quasi-experimental design was employed. A total of 60 Fifth Graders were randomly selected from two primary schools in the Tawau district and assigned to one of the conditions as intact groups: the treatment group (PjBL-STEM, n=30), or control group (CG, n=30). The PjBL-STEM module was administered in six separate lessons and six project activities for 12 weeks throughout January - March 2017. A total of 60 minutes was given at the first phase of the lesson and the second phase of the project activities was revisited in the following weeks. This gap enabled students to find extra relevant materials and information to design their projects. The Fifth Graders in the CG group were exposed to traditional project activities.

The Scientific Creativity Test (SCT) which was developed by researchers (Ambo & Siew, 2017) and has been proven as a reliable and valid instrument, was used as an instrument to assess scientific creativity among the Fifth Graders. The SCT test was constructed based on the three dimensions of SCSM. There are six items in the SCT test which reflect technical product. All the items require responses in the form of a sketch. A small amount of writing was required from the students to label or name the sketches they had drawn. The same SCT was used during the pre-test and post-test. The scores obtained were analyzed using a scoring criterion adapted from Torrance, Ball and Safter (2008). All instruments used in this research were prepared in Malay; these were reviewed by a Malay language teacher.

Data Analysis

Quantitative data were collected from two questionnaires. Descriptive statistics were calculated for each item as proposed by Boone and Boone (2012) for percentage, means and standard deviations. The formula used to calculate means was:

[(number of respondents who selected response 1(weighting of response 1) + (number of respondents who selected response 2*(weighting of response 2)... (number of respondents who selected response n)*(weighting of response n)] / (total number of respondents)*

Inferential statistics were carried out using SPSS for Windows (Version 22). The Alpha value was set at .05 level of significance.

To analyze written data in open-ended questions, the researchers used interpretive methods (Erickson, 1986) to explore common themes that emerged out of 30 participants' statements and words. An iterative process of coding, memo writing, focused coding, and integrative memo writing (Emerson, Fretz & Shaw, 1995) was followed.

Results of Research

Content Validity

The PjBL-STEM module was reviewed by subject matter experts to ascertain the content validity. In accordance with the experts' suggestions, three amendments were made to the activities in the STEM module; 1) the title of Activity Five was changed to Light-Friendly House; 2) the duration of the Development Phase was extended to 20 minutes as more time was required for making and improving the prototype; and 3) The description of Activity 5 was explained in accordance with the learning standard of 1.3.1 and 1.3.2. Overall, experts established the opinion that the PjBL-STEM module is a suitable module to foster scientific creativity among Fifth Graders.

Reliability

The Cronbach's Alpha coefficient of internal consistency was computed to determine the activities' degree of measure with a similar module and construct to produce a consistent result (Cohen, Manion, & Morrison, 2007). Most researchers suggest that the Alpha value of 0.8 and greater is typically a high level of reliability (Cohen, Manion, & Morrison, 2000; Sekaran & Bougie, 2010)). However, according to scholars (Abd Ghafar, 1999; Konting, 2000), the

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Alpha Cronbach value of 0.6 is also sufficient for instruments developed in the social science field of education. Table 2 showed the obtained Alpha Cronbach's value of the PjBL-STEM module was .75 based upon scores gained from the 30 students in a 10-item questionnaire, while the range was within 0.65 to 0.87. Consequently, the Alpha values of the PjBL-STEM module were considered to have an acceptable reliability in the context of measurement.

Table 2. Cronbach's Alpha Coefficient of the Learning Activities in the PjBL-STEM Module.

Activity	Cronbach's Alpha (Overall alpha = .75)
Animal of my Imagination	.66
Bird Cage	.70
Floating Seeds	.65
Balloon-Powered cars	.79
Light-Friendly house	.85
Mini Ice Box	.87

Students' Perception Regarding PjBL-STEM Activities

The results of the questionnaire (Table 3) show students had an overall mean of 4.37 regarding PjBL-STEM activities, which was rated as a 'moderately high positive' perception. Overall, 35.3% agreed and 48% strongly agreed on the scientific creativity and collaboration aspect of the PjBL-STEM module. According to Inas, Harry, Yugo, and Andika (2015), criteria with the mean level equal or more than 3.50 is acceptable. From the results, the mean scores ranging from 4.03 to 4.73 indicated that the fifth graders agreed that the module was appropriate to foster scientific creativity in primary schools.

Table 3. Percentage, means and standard deviations of students' perception regarding PjBL-STEM activities.

……………………..after learning with PjBL-STEM	1 Strongly Disagree	2 Disagree	3 Neutral	4 Agree	5 Strongly Agree	Mean	*SD*
	f (%)						
I enjoyed the learning process.	0(0)	1(3)	0(0)	5(17)	24(80)	4.73	.640
My STEM knowledge has increased.	0(0)	1(3)	5(17)	14(47)	10(33)	4.10	.803
The cooperation among group members is enhanced.	0(0)	2(7)	5(17)	16(53)	7(23)	4.53	.681
I am able to generate many ideas.	0(0)	3(10)	5(17)	2(7)	20(67)	4.23	1.104
I am able to produce unique ideas	0(0)	2(7)	1(3)	13(43)	14(47)	4.30	.837
I am able to develop diverse ideas.	0(0)	1(3)	3(10)	15(50)	11(37)	4.50	.777
I am able to give a special title for the sketch.	0(0)	0(0)	6(20)	15(50)	9(30)	4.03	.669
I am able to make a detailed sketch.	0(0)	0(0)	5(17)	15(50)	10(33)	4.26	.980
The quality of the group prototype is enhanced.	0(0)	2(7)	5(17)	6(20)	17(57)	4.40	.932
I am looking forward to future science projects.	0(0)	1(3)	2(7)	5(17)	22(73)	4.60	.770
Overall	0(0)	13 (4.3)	37 (12.3)	106 (35.3)	144 (48)	4.37	.819

Effects of the PjBL-STEM Module

Paired Sample T-Test. A paired sample t-test was performed to determine if there were any significant differences between the pre- and post-test mean scores in the PjBL-STEM group in the five trait dimensions of scientific creativity. The result of this analysis (Table 4) indicates that the post-test mean scores were significantly higher than the pre-test mean scores of Fluency, Originality, Elaboration, Title Abstraction and Resistance to Premature Closure respectively ($t(29) = -6.608$, $p < .05$; $t(29) = -10.433$, $p < .05$; $t(29) = -19.078$, $p < .05$; $t(29) = -7.067$, $p < .05$; $t(29) = -21.650$, $p < .05$ respectively). These results indicated that the PjBL-STEM group performed significantly better on the post-test compared to the pre-test in all trait dimensions of scientific creativity.

On the other hand, the result of the paired sample t-test analysis on the CG group (Table 4) indicated that the post-test mean scores were significantly higher than the pre-test mean scores of Fluency, Originality, Elaboration, Title Abstraction, and Resistance to Premature Closure respectively ($t(29) = -6.430$, $p < .05$; $t(29) = -5.393$, $p < .05$; $t(29) = -5.288$, $p < .05$; $t(29) = -3.844$, $p < .05$; $t(29) = -4.284$, $p < .05$ respectively). These results indicated that the CG group performed significantly better on the post-test compared to the pre-test in all trait dimensions of scientific creativity.

Table 4. The result of paired sample *t*-test

Dimension	Group	Pre-test	Post-test	Difference	*t*	*df*	*p*
		Mean (SD)					
Fluency	PjBL-STEM	9.80 (2.007)	12.03 (2.141)	–2.23 (– .134)	–6.608	29	p< .05
	CG	6.80 (1.472)	8.33 (1.747)	–1.53 (– .275)	–6.430	29	p< .05
Originality	PjBL-STEM	9.03 (2.356)	11.87 (2.515)	–2.83 (– .159)	–10.433	29	p< .05
	CG	7.87 (1.737)	9.63 (2.428)	–1.76 (– .691)	–5.393	29	p< .05
Elaboration	PjBL-STEM	20.87 (4.337)	24.0 (4.511)	–3.13 (–.174)	–19.078	29	p< .05
	CG	9.433 (2.374)	11.70 (2.693)	–2.27 (–.319)	–5.288	29	p< .05
Title Abstraction	PjBL-STEM	17.40 (4.731)	20.67 (5.738)	–3.27 (–1.007)	–7.067	29	p< .05
	CG	7.77 (2.837)	8.97 (2.760)	–1.20 (.077)	–3.844	29	p< .05
Resistance to Premature Closure	PjBL-STEM	11.27 (3.107)	14.00 (3.184)	–2.73 (–.077)	–21.650	29	p< .05
	CG	7.03 (1.650)	8.57 (1.716)	–1.54 (–066)	–4.284	29	p< .05

Note: Significant level at p = .05

Independent-Samples T-test. An independent-samples t-test was conducted to compare the mean scores of the pre-test in five trait dimensions of scientific creativity between the PjBL-STEM group and the CG group. The result of this analysis (Table 5) revealed that there were no significant differences in the pre-test mean scores between the PjBL-STEM group and the CG group in Fluency ($t(58) = 1.94$, $p = .057$), Originality ($t(58) = 1.22$, $p = .227$), Elaboration ($t(58) = 1.12$, $p = .268$), Title Abstraction ($t(58) = 1.34$, $p = .184$) and Resistance to Premature Closure ($t(58) = 3.34$, $p = .185$).

According to Gay and Airasian (2003, p. 467), if there is no significant difference between the two pre-test means, then a t-test can be computed on the post-test means. An independent sample t-test was therefore performed to compare the mean scores of post-tests in the five trait dimensions of scientific creativity between the PjBL-STEM group and CG group. The result of this analysis revealed that students in the PjBL-STEM group scored significantly higher than the students in the CG group in Fluency ($t(58) = 9.93$, $p < .05$), Originality ($t(58) = 8.76$, $p < .05$), Elaboration ($t(58) = 10.81$, $p < .05$), Title Abstraction ($t(58) = 8.798$, $p < .05$), and Resistance to Premature Closure ($t(58) = 11.90$, $p < .05$). This result indicated that there was a significant difference in post-test mean scores between students in the PjBL-STEM group and CG group in the five trait dimensions of scientific creativity.

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Table 5. The result of independent-samples *t*-test

Dimension	Test	PjBL-STEM Mean (*SD*)	CG Mean (*SD*)	Group Difference	*t*	*df*	*p*
Fluency	Pre	7.77 (2.06)	6.87 (1.48)	.90 (.58)	1.94	58	.057
	Post	12.40 (1.40)	8.3 (1.75)	4.10 (– .35)	9.93	58	p < .05
Originality	Pre	8.93 (2.24)	8.30 (1.74)	0.63 (.50)	1.22	58	.227
	Post	18.40 (4.85)	9.6 (2.60)	8.8 (2.25)	8.76	58	p < .05
Elaboration	Pre	11.67 (1.95)	11.13 (1.74)	.54 (.21)	1.12	58	.268
	Post	21.6 (4.02)	12.1 (2.67)	9.50 (1.35)	10.81	58	p < .05
Title Abstraction	Pre	9.40 (3.34)	8.43 (2.09)	.97 (1.25)	1.34	58	.184
	Post	21.57 (7.34)	8.97 (2.76)	12.6 (4.58)	8.80	58	p < .05
Resistance to Premature Closure	Pre	8.27 (1.44)	7.73 (1.64)	0.54 (▯.20)	3.34	58	.185
	Post	15.83 (2.85)	8.60 (1.71)	7.23 (1.14)	11.90	58	p < .05

Note: Significant level at p = .05

Open-ended Questions

Several themes emerged from participants' extended views from the open-ended questions about the PjBL- STEM approach. They are as follows:

I like/dislike the methods in which the science project was carried out because …

Felt excited. The students expressed excitement and were eager to carry out the project and test the prototype.

"I like the testing of the prototype (the) most.... amazing ..." (S3)
"Everyone is eager to know what project our group will be doing ..." (S2, S6)
"We feel most excited *(when) our project is ready for presentation." (S11)*
"I'm looking forward to awaiting sconce class next week; about what STEM project the teacher will ask us to do ..." (S8)

Experienced positive competition. Although the objective of the PjBL- STEM is not to inculcate competition, each group strived to produce the best design and creation. Additionally, teachers would reward the group that produced unique, quickly created and complete designs. This also enhances motivation and healthy competition in nurturing the students' scientific creativity.

"Often we (were) the most awesome group ..." (S1, S16, S22, S23)
"Our project got the best result among all (the) groups, we are not going to lose ..." (S25, S24)
"We are targeting to beat other groups in the creations..." (S26, S29)

Enjoyed the testing of prototype. This is the nature of children who like to play. Hence, the prototype testing activity was the most anticipated activity.

"I like most the testing of the 'floating seed' project.' (S3, S6, S8)
'We float the 'floating seed' project in the water of the school fish pond …fantastic ... "(S4, S17)
"I like to play the balloon-powered car…when the balloon bec(a)me big, we release(d) the balloon, eventually the car move(d) ..." (S11, S22, S26)

Enjoyed the chance of making a model. Creative students were eager to construct prototypes according to their sketches. The collaboration shown by each team member is also a factor to the success of producing a good project.

"I like to do project activities because I can build something based on our sketches..." (S16, S22, S17)
"The most wonderful time of doing the project is (when) we're working together to create something." (S2, S11)
"Making the mini fridge is the most fun activity…our juices slowly become liquid ..." (S1, S3)

Enjoyed the chance of doing a presentation. Students enjoyed making presentations because it was a chance for them to tackle various questions and criticisms during the question and answer session. In fact, this activity trained students to communicate clearly and wisely.

"I was afraid (for my) first presentation, but I was OK with various questions and criticisms after a few trials..." (S18)
"It's not a tough job anymore because we can just explain what's done ..." (S4, S7)
"I like to present (to) other groups how we solve the problems..." (S30)

The science project enables me to be creative by......

Generating many ideas (Fluency). Generally, the students acknowledged that the PjBL-STEM activities engaged them to generate many ideas.

"Sure, I have many ideas ..." (S1)
"Many ideas can be shared with friends ..." (S5, S16, S24)
"Yes, we can draw many designs until we do not have enough time to complete the prototypes." (S1, S2, S5)
"Of course, we share ideas to do what we want ..." (S7, S19)
"Every member contributes her/his ideas…. ideas are so many!" (S4, S13, S28)

Prototypes construction activities through projects within groups developed the students' inventive skills. Students recognized that many prototypes were constructed which indirectly trained them to produce various designs.

"Yes, the more models(were) created, the more inventive skills we developed..." (S7, S21)

Expanding original ideas (Elaboration). The activities carried out also stimulated the minds of the students to think outside the box. However, sometimes pupils needed to be encouraged by giving examples, situations or explanations before could think of their own ideas.

"Yes, my idea expan(ded) in the drawing ..." (S1, S2, S5)
"I can think more, for example ..." (S16, S22, S17)
"At first, it is hard to think, but eventually more and more ideas came. I got them by exploring the given examples and situations." (S18, S28, S30)

Generating a special and unique idea (Originality). Students were aware that the activities were able to sharpen their minds to generate special and unique ideas. Although the same materials were provided, each group found originality in their design and prototype.

"Yes, my ideas are unique and special..." (S1)
"My idea is not the same as anyone else ..." (S24, S25)
"Yes, my idea is better than anyone else ..." (S6, S12)
"Although the materials provided by the teachers are similar, we managed to produce unique sketches which are different from other groups ..." (S12, S25, S30)

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Thinking of a special title (Title Abstraction). Almost 50% of the students could not give a special title to their illustrated sketches.

"It's hard to write a special title to all the sketches I've made ..." (S14, S18, S25)
"I do not know what title is appropriate for each title I am going to give..." (S7, S11, S15)

However, another 50% of students were able to give a special title.

"All the titles I give in my design are unique and special ..." (S1, S24, S25)
"We got the title first, just love to give it a headline..." (S5, S16, S24)
"We are happy to find (a) special title ..." (S23, S30)

Obtaining information from various sources to produce detailed sketches (Resistance to Premature Closure). Students strove to gain information from various sources to produce detailed sketches.

"Yes, I use(d) information from various sources to produce good and interesting inventions" (S2, S7, S12, S16, S23)
"They are my own ideas based on my daily experiences" (S7, S9, S15, S17, S22, S24)
"Information obtained is through reading, experience and what has been taught by parent(s) and teachers" (S1, S3, S8, S10, S20)

Something new I learned from the science project are......

Awareness of the interdisciplinary nature of STEM. STEM learning, which integrates Science, Technology, engineering and Mathematics in an activity indirectly increases the students' awareness of the interdisciplinary nature of STEM.

"All activities involve sketches. We learn ways to calculate the cost of a project. It needs explanation using science and technology in the unique design ... "(S1, S3)
"STEM learning is good, because I learned science, math, technology and sketching ..." (S11, S19, S30)
"I like to calculate. The cost we used to make the project is just a small amount ..." (S1, S6)

Mastering skills in STEM. Students agreed that the activities carried out helped them to master a variety of STEM skills.

"Yes, through this activity, we can design, draw stretches, calculate project costs, and invent prototypes using science knowledge and appropriate materials..." (S1, S7, S22, S30)

The PjBL-STEM learning not only engaged students to learn about Science and Technology but also familiarized them with smart calculations in a project which indirectly enhances their motivation to learn mathematics.

" There will be always an approximate budget in every project we made..." (S1, S17, S19, S27))
" Estimating cost is important so that the project does not require much spending..." (S3)
"We make projects out of recycled materials. So, it cost(s) very little "(S11, S26.S29)
"This activity trains us to be smart in planning in order to produce a good output" (S4)

Increased confidence to share ideas. The activities carried out also provided an opportunity for students to boldly express their ideas and respond to the issues raised in the presentation.

"I used to be afraid to present in front of classmates, but now I feel ok ..." (S16, S22, S17)
"I'm not feeling shy anymore (in) being asked to make a presentation ..." (S2, S13, S16
"I'm not afraid to say something wrong because the teacher will correct me ..." (S1, S14)

Nurturing teamwork. PjBL-STEM activities through 'Numbered-heads together' engaged students to practice teamwork. Students realised that producing a good quality product required cooperation among members. Furthermore, group members strived to help one another which fostered team spirit and satisfaction.

> *"We're working together in all the activities in order to produce a good group product." (S1, S16, S22, S23)*
> *"If all the experts work together, the final product will be (the) best ..." (S7, S19, S21)*
> *"More ideas are collected to produce good prototypes ..." (S2, S15, S28)*
> *"If the activities are organized in groups, members will help each other until everyone is satisfied with (the) final product." (S15, S28)*

Expanding ideas outside the school. Learners were aware that the project activities can not only be carried out at school but also anywhere outside of school. Armed with the existing experience and knowledge while pursuing learning in school, the idea can be developed and applied according to the availability of the material in the environment.

> *"We can make various models at home..." (S6, S21)*
> *"Yes, I'll do it again at home with my brother ....," (S6)*
> *"Of course, now I understand how to make a project, even at home..."(S2, S24, S27)*

I dislike the methods in which the science project was carried out because …

Lack of cooperation. There is no doubt that feelings of discontent arose due to lack of positive attitudes and cooperation among group members. The attitude of some bossy ones and the lack of responsibility shown by group members is the cause of dissatisfaction.

> *"I do not like group activities because some friends like to scramble." (S7, S15)*
> *"Some friends do not cooperate ... I myself need to do a lot of work." (S18, S30)*
> *"Some friends do not want to help and lazy to work." (S4, S9, S14)*

Lack of materials and interest in sketching and presentation. Students who were less creative and disliked sketching and making presentations showed boredom. Normally, they tried to avoid engaging in those activities. However, they were bound to the tasks given during the Numbered-heads together with cooperative learning. If the specific task given during the week was not their preference, then the pupil would show a sense of boredom and was less cheerful, *"I feel bored with sketching and presentation." (S7, S11, S15)*. Apparently, most pupils prefer 'hands on' activities rather than sketching activities. Some students were reluctant to present their work because *"I'm afraid of being told that my drawings are bad ..." (S5, S10)*. Similarly, if the provided materials were inadequate, boredom will arise because good ideas and sketches cannot be completed due to lack of materials, *"Bored if there is no more material to use for the project ..." (S9, S14, S18).*

Discussion

This research was an attempt to design and develop a PjBL-STEM teaching and learning module and to evaluate its reliability, validity, appropriateness and effects. The PjBL-STEM teaching and learning module was developed based on an integrated instructional design and theoretical model for assessing the trait dimension of scientific creativity among Fifth Graders.

The analysis on internal consistency reliability shows that the PjBL-STEM module was in an acceptable range for Cronbach alpha test of reliability. Each appointed expert greatly approved the pedagogy content (PjBL, NHT and STEM), activity overview, relevance of each lesson plan, learning standard, and overall flow of the project activities. Some revisions needed to be made to improve the description of the activities, project titles and duration of the Development Phase. Overall the findings suggest that the PBL-CL module was with an acceptable reliability and good content validity in fostering scientific creativity of Fifth Graders. This

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research has demonstrated that the principle of integrating the constructivist learning theory, engineering design process model, directed creative process model, scientific creativity structure model, cooperative learning (Number-Heads Together), and the ADDIE instructional design model offers educators the potential to develop an integrated PjBL-STEM teaching and learning module that is valid and reliable. Donnelly and Fitzmaurice (2005) also agree with the importance of a planned integrated approach to the process with the focus on the students' learning when designing modules.

Students rated PjBL-STEM activity as a kind of enjoyable learning which could promote knowledge about STEM, group cooperation and the quality of group prototypes, which in turn promotes their interest in learning science. Students agreed that this approach gears them towards developing the five trait dimensions of scientific creativity. In the stage of "putting heads together", all the group members were engaged to cooperate and come up with many new ideas. Each member of the group was involved in the thinking as they worked collectively to produce group prototypes. This supportive atmosphere is conducive for the development of many original responses from a wider perspective. Previous research (Siew, Chin, & Sombuling, 2017) have reported that cooperative learning 'NHT' created conducive environments for developing the trait dimensions of scientific creativity.

The response captured from the open-ended questions further supported and elaborated students' moderately high positive perception in questionnaire. The Fifth Graders agreed that the methods in which the PjBL-STEM project was carried out made them feel excited; experienced positive competition; enjoyed the chance of making and testing prototypes and doing a presentation. The Fifth Graders expressed that the PjBL-STEM project provided an avenue for them to be creative by: generating many ideas, expanding original ideas, generating special and unique ideas, thinking of a special title, and obtaining information from various sources to complete sketches. Their views justified designing and creating technical products as catalysts to foster the trait dimension of scientific creativity. This research's findings are supported by Siew, Goh and Sulaiman (2016) who found that integrating STEM in an engineering design process contributed positively to student development of creativity. Cavas, Kesercioglu, Holbrook, Rannikmae, Ozdogru and Gokler (2012) also found that scientific creativity of students enhanced when hands-on and minds-on activities were emphasized in project design and development.

Another aspect of the findings is that students value the interdisciplinary nature within the PjBL-STEM projects. Students described how the PjBL-STEM project has advanced their knowledge and skills in STEM, such as designing, calculating, sketching, and inventing a project. Moreover, as students worked in a group, they built confidence in sharing ideas and endeavoured to help each other to produce a good quality product. The abovementioned responses highlight the good face validity of the PjBL-STEM module, consequently establishing its appropriateness in science lessons.

Despite the many positive views of students on the STEM-PjBL learning activities, there are however some negative feedbacks which need to be addressed in future research work. One negative view highlighted is the lack of positive attitude and cooperation among group members while carrying out projects. This challenge has also been described in the works of Koh, Tan, John Wang, Ee and Liu (2007). In addressing this challenge, teachers should emphasize the role of 'putting heads together' so that each group member performs tasks accordingly. The research also highlighted that the lack of materials could be a hindrance for a student to produce more unique prototypes. Undeniably, students need to experiment with different materials and work out the best materials to create a unique product. In addressing this challenge, students are encouraged to take their own initiative in getting the necessary material for their science projects. Another challenge highlighted by students in this research was lack of interest in activities such as sketching and end-project presentations. In future research work, students will be given guidance in sketching and motivation in presenting their prototypes.

The result of the paired sample T-test indicated that Fifth Graders taught in both PjBL-STEM and CG groups performed significantly better in their five trait dimensions of scientific creativity in the post-test compared to the pre-test. However, Fifth Graders taught in the PjBL-STEM group were found to have significantly greater improvement scores compared with their peers taught in the CG learning group. That is, the opportunity to learn with the PjBL-STEM teaching and learning module had a profound effect on the Fifth Graders' scientific creativity. As for the result of the independent sample T-test, it suggested that the use of a reliable and valid PjBL-STEM teaching and learning module by Fifth Graders in learning science is effective in fostering their scientific creativity. This research confirms earlier research (Lou, Chou, Shih, & Chung, 2016; Siew, Amir, & Chong, 2015) that PjBL-STEM can foster learners' scientific creativity.

In the PjBL-STEM learning process, the Fifth Graders were presented with ill-defined and real life problems to be solved in their CL 'NHT' group. The authentic nature of these problems triggered students to brainstorm and draw on knowledge across STEM disciplines to design and create science-based prototypes. Students were engaged in the directed creative process as well as engineering design process to develop and practise the creative traits of being fluent, original, and elaborative. In addition, students were advocated to produce an abstract title and give greater depth of thought in producing detailed sketches. This type of learning environment eventually leads students to be scientific creative. This is further supported by Lewis (2009) who asserts that imposing some structure to open-ended problems may assist in encouraging more creative thinking. Hynes, Portsmore, Dare, Milto, Rogers and Hammer (2011) on the other hand noted that engineering design process provides students an opportunity to practice creative and outside-the-box thinking.

Conclusions

This research ascertained that the developed PjBL-STEM teaching and learning module has an acceptable reliability and good content validity. Overall, PjBL-STEM module is appropriate and effective for fostering the trait dimension of the scientific creativity among Fifth Graders. This research has highlighted the pivotal role of the principle of integrating explicitly the constructivist learning theory, engineering design process model, directed creative process model, scientific creativity structure model, cooperative learning (Number-Heads Together), and the ADDIE instructional design model in developing an integrated PjBL-STEM teaching and learning module that is valid, reliable, appropriate and effective in fostering Fifth Graders' scientific creativity. These empirically proven integrated models can be further upgraded or improved to serve as a reference model for those who are interested in developing a learning module which fosters the five-trait dimension of scientific creativity.

This research suggests that a carefully crafted interdisciplinary approach to PjBL-STEM teaching allows students to experience ill-defined problems and provide them with avenues to solve these through designing and making science-based prototypes. When students were trained to be more fluent, flexible, original, and elaborated at developing the technical products within the four disciplines of STEM, they were encouraged to become more scientifically creative. The scientific creativity that PjBL-STEM approach builds would place students at an advantage in making the best use of their potential, especially after post-primary education.

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