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บทคัดย่อ

การวิจัยนี้มีวัตถุประสงค์เพื่อพัฒนาความสามารถออกแบบแผนการจัดการเรียนรู้แบบสืบ-เสาะหาความรู้ตามแนวทางสะเต็มศึกษาของนิสิตครูวิทยาศาสตร์ การอบรมเชิงปฏิบัติการการประ-ยุกต์ใช้การตรวจสอบรายการของออสบอนในการสอนสะเต็มศึกษาเพื่อส่งเสริมการสอนความสร้าง-สรรค์ รวมถึงการตรวจสอบความคิดสร้างสรรค์และความมั่นใจในตนเองของนิสิตครูวิทยาศาสตร์ต่อการสอนสะเต็มเพื่อส่งเสริมความคิดสร้างสรรค์ ผู้มีส่วนร่วมการวิจัยเป็นนิสิตครูวิทยาศาสตร์ชั้นปีที่ 3 จำนวน 41 คน กำลังศึกษาหลักสูตรการผลิตครูในประเทศไทย เครื่องมือที่ใช้ในการวิจัยนี้ ได้แก่ 1) แบบประเมินแผนการจัดการเรียนรู้แบบสืบเสาะหาความรู้ตามแนวทางสะเต็มศึกษา 2) แบบทดสอบความคิดสร้างสรรค์ของกิลฟอร์ด และ 3) แบบสอบถามเกี่ยวกับความมั่นใจในตนเองต่อการสอนสะเต็มเพื่อส่ง-เสริมความคิดสร้างสรรค์ ผลการวิจัยระบุว่า คะแนนเฉลี่ยความคิดสร้างสรรค์ของนิสิตครูวิทยาศาสตร์หลังเรียนสูงกว่าก่อนเรียนที่ระดับนัยสำคัญ 0.01 การอบรมเชิงปฏิบัติการส่งผลเชิงบวกต่อความสามารถออกแบบแผนการจัดการเรียนรู้แบบสืบเสาะหาความรู้ตามแนวทางสะเต็มศึกษา ผลการวิจัยแสดงให้เห็นว่า นิสิตครูวิทยาศาสตร์ส่วนใหญ่สามารถบูรณาการสะเต็มศึกษา (80.49%) และระดับการสร้างสถานการณ์หรือบริบทสะเต็ม (65.85%) อยู่ในระดับสูง การวิเคราะห์การจัดกิจกรรมสะเต็มแสดงให้เห็นถึงสัดส่วนร้อยละของนิสิตครูวิทยาศาสตร์สามารถเสนอกิจกรรมการออกแบบเชิงวิศว-กรรมที่ท้าทายด้วยตนเอง เพื่อปลูกฝังความคิดสร้างสรรค์ โดยให้นักเรียนให้ทำงานผ่านกระบวนการทำงานที่ยืดหยุ่นและมีวิธีการแก้ปัญหาอย่างหลากหลาย (ร้อยละ 43.90) และสามารถเตรียมเครื่องมือสำหรับการประเมินความคิดสร้างสรรค์อย่างชัดเจนและเหมาะสม (ร้อยละ 73.17) นอกจากนี้นิสิตครูมีความมั่นใจในตนเองต่อการสอนสะเต็มเพื่อส่งเสริมความคิดสร้างสรรค์หลังการอบรมเชิงปฏิบัติการสูงกว่าก่อนการอบรบเชิงปฏิบัติการที่ระดับนัยสำคัญ 0.01

คำสำคัญ: ความคิดสร้างสรรค์ การสอนสะเต็ม การตรวจสอบรายการของออสบอน นิสิตครูวิทยาศาสตร์

Application of Osborn’s Checklist in STEM Teaching for Promoting Creative Thinking

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Abstract

This research aimed to develop science student teachers’ ability to design STEM inquiry–based lessons through 6–week workshop using Osborn’s checklist in STEM teaching to promote creative thinking. The science student teachers’ creative thinking, STEM lesson plan for promoting creative thinking, and self–confidence in STEM teaching were investigated. Research participants were 41 science student teachers who are third–year students in the Teacher Education program in Thailand. The research instruments consisted of 1) a STEM inquiry–based lesson plan assessment form, 2) Guilford’s creative assessment test and 3) a questionnaire of science student teachers’ self–confidence on STEM teaching. The research result indicated that the science student teachers’ creativity was higher after the workshop at the significant level of 0.01. The workshop has positively affected science student teachers’ ability to design STEM inquiry–based lessons. The results revealed that science student teachers was able to integrate STEM in their lesson plan (80.49%) and create STEM situations/contexts (65.85%) at high–level. Analysis of STEM activity showed that science student teachers were able to propose their own engineering design challenges that could cultivate creativity by leading students to work through the flexible process with variant solutions (43.90%). They were able to provide assessment for creative thinking clearly and appropriately (73.17%). Their self–confidence on STEM teaching after the workshop was higher at the significant level of 0.01.

Keywords: Creative thinking, STEM teaching, Osborn’s Checklist, Science student teacher

Introduction

In the world of 21st century competition, creativity is an ability that people of all careers must have for developing and improving innovations and products. Learners must be ready for the future: changes, challenges, and complexity in technology and information. Creativity development has been promoted worldwide in many countries such as Australia, Japan, Korea, New Zealand, Singapore and the United States (Guo and Woulfin, 2016). The education system in Thailand should focus on encouraging students to be more creative and able to innovate to survive in this competitive world (Bunkrong, 2017, Poon *et al*., 2014).

Using creative learning tasks/assignments to motivate students' learning is a novelty in the STEM science classroom. While science and engineering are about understanding things related to fact and calculation, creativity is something that needs to happen to learners (Larkin, 2015). Within creative learning tasks/assignments, students would have opportunities to practice their thinking to find solutions to the given real world problems. The creative learning assignments also help students to enhance creative skills leading to innovation that uses knowledge in science, mathematics, technology, and engineering design processes (Hajeekhadae, 2017). In addition, students are able to practice creativity by setting assumptions which are consistent with the real world situation. (Newton and Newton, 2010).

In this study, creativity is about making appropriate connections between unfamiliarly related concepts and the ability to come up with multiple solutions. Hence it should be an essential outcome of science and engineering studies. Introduced by Guilford (1967), which describes creativity as the ability of the brain to think in many directions, known as characteristics of divergent thinking that is the one of important thinking. There are four main characteristics of the creativity; fluency (the ability to rapidly produce a large number of ideas or solutions to a problem); flexibility (the capacity to consider a variety of approaches to a problem simultaneously); elaboration (the ability to think through the details of an idea and carry it out); and originality (the tendency to produce ideas different from those of most other people) (Csikszentmihalyi, 1992, cited in Larkin, 2015). Guilford's four divergent–production characteristics are still in wide use and influence recent divergent thinking models and assessments. For example, are the Torrance Tests of Creative Thinking, the most popular creativity assessment in education settings around the world, were originally based on The Guilford's extensive work (Plucker, Waitman and Hartley 2011). Having creative experiences will enhance knowledge of the contents because students must learn through their own experiences. Creative teaching in STEM education is evidenced through assessment and teaching practices that are challenging, confounding and multidisciplinary, focused on new and valuable processes and products, aligned to learning outcomes, proposed by Pollard, Wesson and Young (2018). Teachers should focus on providing students the opportunity to use their STEM knowledge to solve problems or create innovation without adhering to the correctness or the correct answer. Moreover, teachers should let students think freely and give students the opportunity to experiment with what they think or anticipate. Besides, teachers should try to ask questions or give suggestions about the consequences to train students how to think, analyze, reason and act on their own.

However, the processes and products of teaching and learning STEM seldom reflect tenets of creativity, suggested by Guo and Woulfin (2016). Activities used in the recent STEM classrooms are fun and present real world contexts/scenarios but not creative enough. Students can still complete the task without creative thinking. According to the study by Kruatong (2018), the STEM lessons designed by science student teachers were more about applying factual knowledge from textbooks to a situated problem. The STEM situations should be challenging, or potentially ill–defined problems, and require creative thinking processes. Osborn’s checklist is a common and useful tool to promote ideation. It composes of series of simple questions, that are based on certain verbs such as how to ‘modify’, ‘rearrange’, and ‘substitute’, designed to support creative and divergent thinking when faced by a design problem (Higgins 1996; Plucker, Waitman, and Hartley 2011, Sripanlom 2020). Therefore, this study aimed to prepare science student teachers to be able to enhance students’ creative thinking through STEM challenge activities while the Osborn's checklists were introduced to the science student teachers in order to make sure that the creative processes are involved during the challenge.

Research objectives

This research established three sub-objectives which were:

1) To study science student teachers’ ability to design STEM inquiry–based lessons after the workshop using Osborn’s checklist in STEM teaching for promoting creative thinking

2) To study science student teachers’ creative thinking before and after the workshop using Osborn’s checklist in STEM teaching for promoting creative thinking

3) To study science student teachers’ self–confidence in STEM teaching for promoting creative thinking.

Research Methodology

The methodology of this research is pre–experimental research. The research participants were 41 science student teachers who are the third year undergraduate students in the Teacher Education program in Thailand

and have already taken at least 72 credits of science and teaching profession courses, and have experiences in preparation of lesson plans and micro–teaching from the teaching method course I. They study in the department of science teacher education. They have no experience in teaching at the moment because they will teach science in elementary and middle school levels in the fifth year of the program. The participants were required to complete a 6–week workshop (3 hours per week).

The Context of the Study: A 6–weeks workshop was established for developing science student teachers' creativity and ability to design STEM inquiry–based lessons for teaching in STEM education creatively. The Osborn's checklist is a simple and well–known technique to promote creative thinking developed by Osborn (1988), the originator of classical brainstorming. The checklist was formulated as a means of transforming an existing idea, product or service into a new one by using comprehensive questions which are categorized into 9 categories; Other uses? Adapt? Modify? Magnify? Minify? Substitute? Rearrange? Reverse? Combine? Therefore, the checklist was applied in the workshop as a key strategy to provide the science student teachers opportunities to brainstorm new ideas, approaches in developing their STEM lessons. In this research, the most significant 4 categories of the checklist which are considered as important categories for STEM education; Magnify, Minify, Reverse and Substitute for STEM lessons were applied to encourage science student teachers to think creatively about their products in STEM activities. The explanation of Magnify, Minify, Reverse and Substitute questions as shown in Table 1.

Table 1 Osborn's checklist technique for promoting creative thinking in STEM education

List	Meaning
Magnify	What properties can be added to the product, such as time and durability, frequency, strength, size, length, thickness, value, ingredients?
Minify	What properties can be cut or reduced such as shortness, narrowness, and thinness, lightness, divided?
Reverse	Think of different product formats, such as shape, flavor and aroma.
Substitute	How can the original elements or forms be replaced such as replacing them with materials, steps, energy sources, locations, methods, time, emotions and sounds?

The topic of this 6–weeks workshop is shown in Table 2, it consists of: 1) Know STEM and know how to design STEM Inquiry–based instruction approach, and 2) Know and know how to enhance and assess students' creativity using Osborn's checklist technique through STEM activity.

Table 2 Outline of the 4 weeks for STEM Inquiry–based instruction

Week	Content	Implementation Process
1–3 (6 hours)	Know and know how to design STEM lesson using STEM Inquiry–based instruction approach	1) Introduce STEM Education, STEM-related content and its relatedness for the 21st century. 2) Demonstrate STEM classroom activities using a 5E inquiry-based learning by design model which includes encouraging students to learn relevant concepts through a hand–on inquiry–based method before drawing the concepts to construct a product with engineering design challenges. The products are giant bubble recipes and the maximize barge. 3) Discussion about the engineering design challenges and processes for enhancing creativity is not only the design based on the need and conditions, but also a flexible process with variant solutions. it then could be able to cultivates creativity in the STEM classroom
4–6 (6 hours)	Know and know how to enhance and assess students' creativity using Osborn's checklist through STEM activity	4) Demonstrate a chemical reaction through an inquiry–based learning by design model. Train the science student teachers using Osborn's checklist during designing the product which is slime activity. Assign science student teachers (work in groups) to utilize Osborn's checklist for assessing creativity from other science student teachers' worksheets and the products. 5) Duplicate the 4) through the electric circuit lesson and STEM activity which is an electrical power supply from the chemical cells using graphite. 6) Practice microteaching that cultivates creativity in the STEM classroom. Assign individual students to design their own STEM lesson. 7) Provide reflection and revision of the STEM lesson.

Initially in week 1–3, the instructor explained about know and know how to design STEM lessons using the STEM Inquiry–based instruction approach by introducing STEM Education, STEM–related content and its relatedness for the 21st century. The instructor demonstrates STEM activities using a 5E inquiry–based learning by design model which includes encouraging students to learn relevant concepts through a hand-on inquiry-based method before drawing the concepts to construct a product with engineering design challenges. The products are giant bubble recipes and the maximize barge (Bybee 1993; Kruatong, 2018). After that, the whole class discusses the engineering design challenges and processes for enhancing creativity, not only the design based on the need and conditions, but also a flexible process with variant solutions. It then could be able to cultivate creativity in the STEM classroom.

In week 4–6, the instructor emphasized knowing and knowing how to enhance and assess students' creativity using Osborn's checklist through STEM activity. While the STEM activities were integrated in the Elaboration stage of the 5E inquiry after the big ideas of science were entirely introduced. The instructor demonstrates a chemical reaction through an inquiry–based learning by design model. Train the science student teachers using Osborn's checklist during designing the product during Slime Activity. Assign science student teachers (work in groups) to utilize Osborn's checklist for assessing creativity from the students' worksheets and the products. The science student teachers had the opportunity to think more creatively for the tasks/products such how to increase the property (Magnify), how to decrease the property (Minify), how to reverse property, and how to develop or make new things from the normal product (Substitute) in the creativity checklist before designing their solutions, the example as shown in Figure 1. Then, the instructor assigned science student teachers to utilize Osborn's checklist via demonstration of the electric circuit lesson and STEM activity which is an electrical power supply from the chemical cells using graphite. After the science student teachers gained experiences in creativity activities, they were assigned to practice microteaching that cultivates creativity in the STEM classroom by developing individual lesson plans of specific science standards and indicators. The lesson plans were submitted to the instructor at the end of the course for assessment of the effectiveness of this workshop model. Instructor provided the reflection and revision of the STEM lesson to science student teachers.

Research instruments: The research instruments consisted of 1) a STEM inquiry–based lesson assessment form, 2) Guilford's creative assessment test, 3) a self–confidence questionnaire in teaching in STEM education creatively, and 4) semi–structured interview. All instruments were reviewed by two science educators, and one professor in engineering on the items' correlation, correction, and validation, the details are described as below.

1) A STEM inquiry-based lesson assessment form was used to capture science

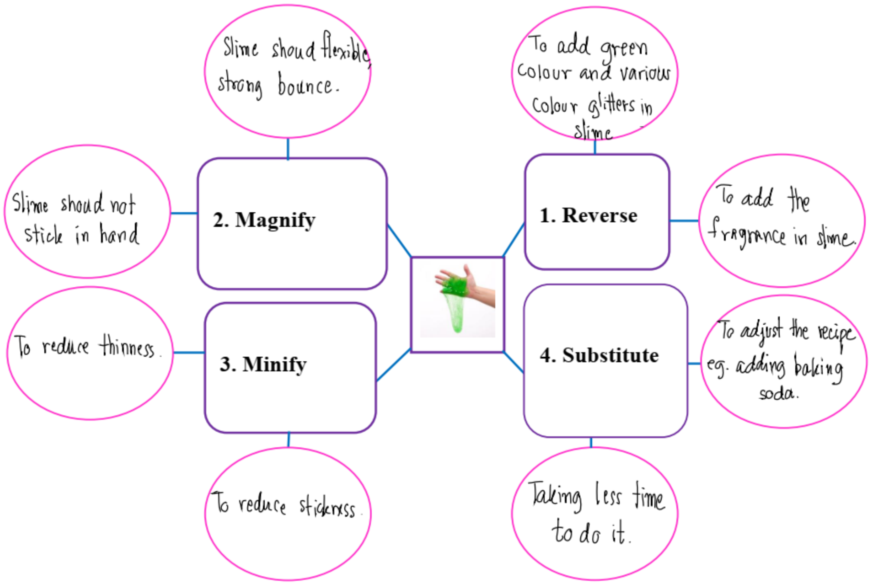


Figure 1 Checklist for the slime activity

student teachers' ability to design STEM inquiry–based lessons for enhancing creative teaching in STEM education. The criteria and rubrics were constructed, corresponding to the definition of teaching in STEM education creatively as had been proposed by Pollard, *et al*. (2018), as shown in Table 3. Criteria 1) STEM Integration and 2) STEM situations aim to check whether the lesson is incorporated through a realistic context, STEM content, and engineering design process. Criteria 3) creative thinking activity and 4) assessment aim to check whether the engineering design challenges could lead students to work through the flexible process with variant solutions. Each criteria is rated on three levels; good, moderate and need to improve. The lessons are checked by the researcher and a science educator and the inter–rater agreement is 85 percent.

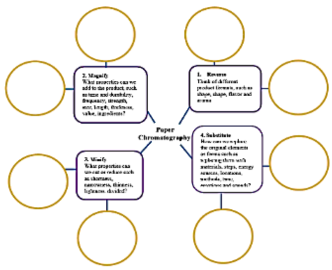
2) Guilford's creative assessment test is used for creativity assessment. The pre and post parallel tests consisted of 3 items each, totaling 6 items. Fluency, flexibility, elaboration and originality were graded using different scoring methods, rated on a creative-quality scale, a 5-point "not at all creative" to "very creative" response format (Silvia *et al*., 2008). So a total score of test 0–4, 5–8, 9–12,13–16 were considered to be poorly, fairly, quite highly, and highly creative respectively. The internal reliability of the test is high (Cronbach's alpha = 0.86).

3) A self–confidence questionnaire in teaching in STEM education creatively was administered to science student teachers. The ten statements based on a five point scale were

Table 3 A criteria and rubrics of science student teachers' ability to design STEM inquiry–based lesson to enhance teaching for STEM education promoting creative thinking

Criteria	Levels			Examples
	Good *(GL)*	Moderate *(ML)*	Need to improve *(NIL)*	
1. STEM integration	Integrate all four disciplines in activities, leading to use of main knowledge in science content and apply other disciplines, appropriately.	Integrate 2–3 disciplines in activities leading to use of main knowledge in science content and apply other disciplines, appropriately.	No integration with other disciplines except science content.	**Science**: Standard SC2.1 Gr.8/1 **Technology**: Standard OT 4.1 Gr. 8/3,Standard OT 4.1 Gr. 8/4 **Mathematics**: Standard M 2.1 Gr. 3/11, Standard M 2.1 Gr. 3/12 **Integrating knowledge with engineering**: ability to specify design criteria for appropriate problems, build and develop prototypes or models, test, and improve appropriate solutions under the rules and limitations. *[science student teacher No.8: GL]* **Science**: Standard SC2.1 Gr.8/1 *[science student teacher No. 6: NIL]*
2. STEM situations/ contexts	Writing the situation clearly and appropriately. Define criteria and constraints appropriate to the activity.	Writing the situation clearly but not appropriately. Define criteria and constraint partially but not appropriate to the activity.	Writing the situation unclearly and inappropriately. Cannot define criteria and constraint of the activity.	"Mr. Tong wants to buy a birthday gift for a friend which is colorful, unique and easy to find materials in the house such as alum, salt, and picture frames. So Mr. Tong wants to make a gift by himself to get the gift he wants." *[science student teacher No. 9: GL]* "Let students make a mixture of cleaning products.*" [science student teacher No.2: ML]* "The teacher gives examples using the knowledge of substance separation that affects everyday life" *[science student teacher No.16: NIL]*
3. Creative STEM activity	Propose the activity that makes associations between STEM concepts which come up with multiple solutions.	Propose the activity that makes associations between STEM concepts which come up with multiple solutions but it repeats	Unable to design an activity or propose an activity which comes up with only one solution.	- Cleaning products *[science student teacher No.1: GL]* - Miracle Christmas tree*[science student teacher No.15: GL]* - Natural soap *[science student teacher No.20: GL]* - Bright handkerchief*[science student teacher No.25: GL]*

Table 3 A criteria and rubrics of science student teachers' ability to design STEM inquiry–based lesson to enhance teaching for STEM education promoting creative thinking (continued)

Criteria	Levels			Examples
	Good *(GL)*	Moderate *(ML)*	Need to improve *(NIL)*	
		from the textbook.		- Fabric dyes *[science student teacher No.33: GL]* - Crystal production *[science student teacher No.41: ML]* - Paper chromatography *[science student teacher No. 16: ML]* - Waste water filter *[science student teacher No.7: ML]* - Earth Structure Model *[science student teacher No.7: NIL]*
4. Creative Thinking assessment	Provide instruments for creative thinking assessment clearly and appropriately.	Provide instruments for creative thinking assessment but not clear or appropriate.	No instruments for creative thinking assessment.	Creativity checklist form  *[science student teacher No.16: GL]*

used. They were modified from Joseph *et al.* (2011); Kruatong (2018), Kruatong *et al.* (2017) and Tsupros, Kohler and Hallinen (2008). The internal reliability of the questionnaire is high (Cronbach's alpha = 0.81). The data was analyzed using mean, standard deviation and comparing mean difference using dependent sample *t*–test.

Additionally, the qualitative data were collected. Participant classroom observation was used for investigating science student teachers' views about developing STEM inquiry–based lesson plans, semi-structured interview was conducted after the course was completed, and 16 science student teachers were randomly selected for a 20–30 minute individual interview. The semi–structured interview questions are: What are difficult parts of developing creativity STEM inquiry-based lesson plans? What are problems in developing lessons (For example; content, teaching method and material)? How to solve the problems? What is the advantage of developing a creativity STEM inquiry–based lesson plan? Are you willing to recommend using STEM inquiry–based instruction in the future?

Results

Science student teachers' ability to design STEM inquiry–based by promoting creative thinking in STEM education

After the workshop, the science student teachers' lesson plans were analyzed as shown in Table 4. They reveal that most science student teachers were able to identify STEM integration, create a STEM situation/ context, and use creative thinking assessment, appropriately. In terms of designing STEM activities for enhancing creative thinking, 43.90 percent of them were able to create their own STEM activity that possibly cultivates creativity in the STEM classroom. While 14 activities (34.15%) were identified as a creative STEM activity, they seem like STEM activities which were introduced in the textbook. The 9 STEM activities (21.95%) needed to improve, considering the dimension of cultivating creativity only. For example, the earth structure model and solar system model because students might be able to complete the task without creative thinking.

Table 4 science student teachers' ability to design STEM inquiry–based for 4 criteria of STEM education for promoting creative thinking

Criteria	Frequency (percent) of science student teachers		
	Good	Moderate	Need to improve
STEM integration	33 (80.49)	3 (7.32)	6 (14.63)
STEM situations/contexts	27 (65.85)	6 (14.63)	8 (19.51)
Creative STEM activity	18 (43.90)	14 (34.15)	9 (21.95)
Creative thinking assessment	30 (73.17)	3 (7.32)	8 (19.51)

A science student teacher [No. 11] designed a lesson of meaning and techniques for separation of mixtures. Students inquire through common separation techniques for example chromatography, distillation, evaporation, filtration, solvent extraction and simple distillation by setting up a station rotation model. After that the science student teacher used "eco dyeing with flowers activity" as a STEM product to lead students applying their understanding in the elaboration. Engineering design processes is focused, the teacher assigns students to (1) identify the problem; the teacher raise issues to enhance students to identify problem for further inquiry, (2) analyze needs, conditions and limitations related to possible products, (3) explore information; the teacher motivate students to search related knowledge such science, mathematics, art, culture, and others, (4) model solution; students apply their knowledge for developing model solution by brainstorming ideas for the production step by step using a creativity checklist (magnify, minify, reverse and substitute), (5) planning and development; students develop ideas and find materials to make the products, (7) test and evaluate the solution, (8) present the solution, and (9) reflection and revise: students work more from reflection and revise their products for better version. The Osborn's checklist is identified as a tool for assessing the creativity during the development process and the product. Considering the STEM activity and learning process revealed the science student teacher [No. 11] was able to design a STEM inquiry–based lesson for promoting creative thinking in STEM education.

The science student teacher [No. 41] designed the lesson for teaching techniques for separation of mixtures as well. The teacher demonstrates how to separate flour mixed with metal filings using magnetic power and assigns students (work in groups) to separate other mixtures themselves. After that, "constructing a handy water filter" activity is assigned. It seems to be an interesting product for encouraging students' creative thinking, but the teacher does not provide a given situation related to real life, criteria and constraints. Without any critical issues, this activity is not challenged and has not met the key features of STEM activities. Another meaning and techniques for separation of mixtures lesson developed by a science student teacher [No. 16] identifies "activity of finding out the number of substances in the pen ink" as a STEM activity. The lesson might address science and mathematics contents incorporated with the engineering design process, but missing cultivates creativity. The activity emphasizing the engineering design process is seemingly limited with only one correct procedure and answer.

Science student teachers' creativity before and after the workshop using Osborn's checklist in STEM teaching for promoting creative thinking

Data from the Table 5 data indicates that the least and the highest scores belong to flexibility and elaboration respectively. The workshop can enhance science student teachers' creativity subscales at originality which is a strange idea different from ordinary and unique ideas that exist. (t = 7.422, p < 0.001), fluency which is the ability of a person to come up with quick, fluent, and large volumes of answers in a limited amount of time. (t = 8.081, p < 0.01), flexibility which is the ability of a person to come up with different types of answers and in many different directions. (t = 3.612, p < 0.01) and elaboration which is the ability to provide details to decorate or expand the main idea to have a more complete meaning (t = 8.204, p < 0.01) were well developed. The data of science student teachers' creative thinking generally showed an increase in creative thinking skills. Science student teachers' pre–test score of creative thinking is 6.95, was considered to be fairly creative and post–test score of 12.59, and was considered to be highly creative. The science student teachers' creative thinking after STEM inquiry–based learning is significantly higher than before learning (t = 9.896, p < 0.01).

Science student teachers' confidence on STEM education for promoting creative thinking

After the 6–week creativity STEM inquiry–based learning workshop, the science student teachers' response to the 5–point scale statements as shown in Table 6 regarding their confidence in conducting STEM education with creativity reveals that the science student teachers are confident in their ability for teaching in STEM education creatively significantly changed in post–test.

Table 5 Comparison of science student teachers' average and standard deviation of creativity between pre–test and post–test

Creativity subscales	Pre–test		Post–test		*t*
	Means	SD	Mean	SD	
Originality	1.50	1.38	3.33	0.76	7.422**
Fluency	1.69	0.58	3.11	0.98	8.081**
Flexibility	2.41	0.72	2.84	0.96	3.612**
Elaboration	1.44	1.34	3.42	0.69	8.204**
Total	**6.95**	**3.23**	**12.59**	**2.47**	**9.896****

**Significance level of 0.01

Table 6 Comparison of science student teachers' average of confidence score on creative teaching in STEM education

Statement	Pre–test		Post–test		*t*
	Means	SD	Means	SD	
1. I have a basic skill and can create artifacts/tools/ materials to develop my teaching activities creatively.	2.97	0.49	3.42	0.6	3.33**
2. I have a basic knowledge of engineering to motivate students to learn creatively.	2.2	0.60	2.82	0.61	3.582**
3. I have a basic knowledge of science to help students to complete creative activities in the classroom.	3.11	0.45	3.34	0.48	2.161*
4. I have basic knowledge of mathematics to help students to complete creative activities in the classroom.	2.76	0.59	3.05	0.61	2.223*
5. I have basic knowledge of mathematics to develop my own creativity teaching.	2.61	0.55	2.95	0.57	2.76**

*Significance level of 0.05 and ** significance level of 0.01

Table 6 Comparison of science student teachers' average of confidence score on creative teaching in STEM education (continued)

Statement		Pre–test		Post–test		*t*
		Means	SD	Means	SD	
6.	I have the competency of STEM inquiry–based learning to develop creative thinking	2.86	0.48	3.14	0.59	2.044*
7.	I have good knowledge and understanding about STEM education to develop creative thinking.	2.55	0.65	2.92	0.49	2.676*
8.	I have frequent corporate discussions about STEM education with peers.	2.57	0.55	3.24	0.55	5.252**
9.	I can design lesson plans based on the STEM education concept to develop creative thinking.	2.55	0.60	3.97	0.64	7.273**
10.	I can measure and evaluate learning based on STEM education.	2.58	0.50	3.79	0.58	6.651**
Total		**2.69**	**0.54**	**3.26**	**0.57**	**4.304****

*Significance level of 0.05 and ** significance level of 0.01

Science student teachers' thoughts about STEM education for promote creativity thinking

The data from the semi–structured interview of 16 science student teachers revealed that the science student teachers realized the benefit of STEM lessons. The STEM activities focus on solving real–life problems, including the development of new processes or products that benefit students' creative thinking. As a science teacher, the ability to integrate knowledge in science, technology, engineering and mathematics is needed. The interview data revealed that they would apply the inquiry–based STEM instruction to their future classrooms as follow:

"I will definitely apply STEM in future classrooms because STEM education allows learners to learn and act on their own more than listening to teachers only. Nowadays, most students like fun learning and gaining knowledge at the same time." [Science student teacher, 16]

"I will definitely apply STEM in the future classroom because it is one of very good ways of learning that helps students to develop their ability to learn from real experiences, have fun, and helps them to think and solve problems creatively." [Science student teacher, 13]

"Osborn's checklist technique would help the students to think about the product step by step, and would be easier for the teachers to check what they have been thinking in their team." [Science student teacher, 11]

A half of science student teachers thought that the most difficult part of designing a STEM inquiry–based lesson plan to enhance creative thinking is determining learning outcome correlated to learning standard. The learning objectives, activities and assessments have to relate to learning indicators. Another difficulty is the STEM inquiry–based learning approach introduced in the workshop itself. The science student teachers mentioned that the activities must be well organized for covering all related concepts and at the same time cultivating creativity seems to be an important issue.

Although most science student teachers' were able to design a STEM inquiry–based lesson plan, the limitation of pedagogy, STEM content, time and available material still are identified as issues to be concerned in their future STEM instructional practices. The science student teachers have to organize activities which must not only incorporate STEM content, scientific inquiry practices, and engineering design practices, but also figure out the STEM activity that attract students' interest and cultivate their creativity. They have to spend a period of time searching related guidelines from the internet and more support after the workshop is needed.

Conclusions and Implementation

This research aimed to develop science student teachers' ability to create STEM activity that promotes creative thinking by applying the Osborn's checklist technique into the lesson planning and teaching processes. Based on the research result, it is indicated that the science student teachers' creativity is significantly higher after the workshop at the significance level of 0.01. The application of Osborn's checklist technique can successfully integrate with real life situations and STEM activities and can promote science student teachers' creative thinking. Guo and Woulfin (2016) proposed that teachers should understand how to provide resources and guidance for their students to come up with creative ideas and solutions but they do not necessarily need to be idea creators. This study found that while the science student teachers gained creativity skill, most of them were able to create a good level of 4 criteria of creative teaching in STEM education; STEM integration, create STEM situation/context, provide creative STEM activity and used creative thinking assessment.

Before the workshop, most of the science student teachers thought that students' reproduction models or painting pictures about scientific subjects was being scientifically creative. After the workshop, obviously, most of them were able to provide more creative STEM activities/tasks and creative processes are involved both by searching/creating activity themselves and just repeating from the textbook. The science student teachers were able to recognize and assess creative thinking in students by using Osborn's checklist or at least know how students think and do things creatively through STEM activity. This finding corresponds to Newton and Newton (2010) since teachers' conceptions of creativity may be adequate, they are likely to recognize significant opportunities for creativity involving.

This study was limited since the researchers did not probe more deeply into science student teachers' views of creative teaching in STEM education and their understanding of creative STEM activity. Thus, the data would provide an in–depth understanding of whether, and how strongly, their understandings related to their STEM lessons.

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