THE DEVELOPMENT OF MATHEMATICAL CREATIVE THINKING SKILLS ON GEOMETRY TRANSFORMATION BY USING STEM EDUCATION
การพัฒนาความคิดสร้างสรรค์ทางคณิตศาสตร์ในหัวข้อเรื่อง การแปลงทางเรขาคณิต โดยใช้แนวคิดสะเต็มศึกษา

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Abstract

The purpose of this study was to study the development of mathematical creative thinking skills of students who have organizing learned by activities based on STEM Education. The research sample consisted of thirty Mathayom Suksa 2 students in Wat Tawan Ruang School and obtained by purposeful sampling. The research instruments used in this research were STEM Education leaning management plans in the topic of Geometry Transformation and a mathematical creative thinking test. The data were analyzed using mean, standard deviation, class normalized gain(g) and observation in the classroom by record from post-teaching.

The research finding; the post-learning mathematical creative thinking skills scores of students after learning under management based on STEM Education was significantly higher than their pre-learning counterpart scores. Class normalized gain equaled to 0.44, which was in the medium gain level. From observation students' behavior found that the students expressed fluency thinking as clearly as possible which was consistent with quantitative data. In overall the students were able to express their mathematics creative thinking with four aspects.

Keyword: Mathematical creative thinking skills, Geometry Transformation, STEM Education

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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์ คือ เพื่อศึกษาการพัฒนาความคิดสร้างสรรค์ทางคณิตศาสตร์ของนักเรียนชั้นมัธยมศึกษาปีที่ 2 ที่ได้รับการจัดการเรียนรู้ตามแนวคิดสะเต็มศึกษา กลุ่มตัวอย่างเป็นนักเรียนชั้นมัธยมศึกษาปีที่ 2 จำนวน 30 คน ของโรงเรียนวัดตะวันเรือง ซึ่งได้มาจากการสุ่มแบบเฉพาะเจาะจง เครื่องมือที่ใช้ในการวิจัยประกอบด้วย แผนการจัดการเรียนรู้ตามแนวคิดสะเต็มศึกษาในหัวข้อการแปลงทางเรขาคณิตและแบบวัดความคิดสร้างสรรค์ทางคณิตศาสตร์ สถิติที่ใช้ในการวิเคราะห์ข้อมูล ได้แก่ ค่าเฉลี่ย ส่วนเบี่ยงเบนมาตรฐาน ค่า Class normalized gain และการบันทึกพฤติกรรมของนักเรียนหลังการจัดการเรียนรู้ตามแนวคิดสะเต็มศึกษา

ผลการวิจัยปรากฏว่า ความคิดสร้างสรรค์ทางคณิตศาสตร์ของนักเรียนชั้นมัธยมศึกษาปีที่ 2 ที่ได้รับการจัดการเรียนรู้ตามแนวคิดสะเต็มศึกษา หลังเรียนสูงกว่าก่อนเรียน โดยนักเรียนมีคะแนนพัฒนาการความสามารถในการคิดสร้างสรรค์ทางคณิตศาสตร์ (Class normalized gain) เท่ากับ 0.44 ซึ่งอยู่ในระดับปานกลาง และระหว่างการสังเกตพฤติกรรมการจัดการเรียนรู้ตามแนวคิดสะเต็มศึกษา พบว่า นักเรียนสามารถแสดงความคิดสร้างสรรค์ทางคณิตศาสตร์ได้ครบทั้ง 4 องค์ประกอบ โดยแสดงด้านความคิดคล่องได้ชัดเจนที่สุด

คำสำคัญ: การแปลงทางเรขาคณิต ความคิดสร้างสรรค์ทางคณิตศาสตร์ สะเต็มศึกษา

Introduction

In the 21st century, people must use the knowledge and higher skills in both the production and working processes that use thought-based planning, management, design, and complex problem solving or problems that require a higher level of technology as well as creating innovations for improving the quality of human life. Therefore, each country needs to develop students and youth. To support the demand of the labor market and be able to live peacefully, there must be strengthening “New Future Skills: Learning in the 21st century”, which formed together as a network of cooperative organizations for learning skills in the 21st century (Partnership for 21st century Skills), consist of creative skills, communication skills, and collaboration skills (Vicharn Panich, 2012).

Creativity is the highest ability of humans that is a key factor in developing oneself and society to continue to progress and continue unceasingly (National Institute of Educational Testing Service (Public Organization), 2012). Creativity is considered an important thought process for students, allowing them to create ideas, fantasies and not give up on situations. It makes students face problematic situations and environments in daily life by looking for solutions to various problems and choosing the correct and appropriate solution to the issues. Therefore, education must be organized following real-life conditions in today’s society. Simultaneously, it must focus on developing and encouraging students to use knowledge to solve problems or create work related to their daily lives in various ways and to have creative and analytical thinking. It has to include the balance of knowledge and ideas, skills, ability, and social responsibility to make students live

happily with others. Creativity exists in every human (Area Phanmanee, 2004), so it is necessary to find a way to encourage humans to develop their creativity to use them in daily life.

Nowadays, learning at different mathematics levels focuses only on knowledge, memory, and understanding that cannot develop students to have advanced thinking skills, which are analysis, valuation, and creativity. The learning management is mainly lecturing; the teacher is responsible for telling knowledge while only remembering what the teacher said. The contents in mathematics are primarily abstract, causing students to be unable to apply mathematical knowledge to solve real problems (Ontida Swang, 2017). Therefore, in teaching and learning mathematics, the teachers must be the learning designer and ask questions to encourage students to think and do because learning skills obtained. Learning by doing can mean that students must apply the knowledge to their own lives.

Moreover, the teachers should not answer the students' questions immediately and do not blame them even if their answers are incorrect as that would hurt them later. Instead of that, the teachers should use questioning, narrowing to the answers, and allowing them to think or search for the answers. This kind of teaching method helps students develop their learning skills and enhance their life skills.

Apisith Thongchai and et al. (2012) concluded that STEM is an acronym for Science, Technology, Engineering, and Mathematics. STEM Education is a process that students learn through activities or projects to solve real-life problems and integrated learning management by using science, mathematics, technology, and engineering as the core. It focuses on analytical thinking by training students to think, ask questions, solve problems, and build skills. Finding information and discovering new analyses can help students to learn how to integrate knowledge from various disciplines. This will encourage students to have a deeper understanding of scientific and mathematical principles. To organize STEM Education, teachers may need to provide exciting learning media to help attract students into activities. Then, the students will gradually learn knowledge and skills from the activities involuntarily. Toys and video games are examples of allowing students to receive knowledge, skills, and fun at the same time. The model of a simulated learning experience, resulting in the educational paradigm-changing educational management at all levels, focuses on developing advanced thinking skills such as creative thinking, problem-solving, critical thinking, and communication skills. To use technology as a tool for knowledge acquisition and to have social skills, educational management is necessary to integrate both science and the integration of learning in the classroom and real life. Such can make students see the benefits and value of learning in their daily life.

As discussed above, it can be concluded that learning management based on the STEM Educational Concept can develop learners' creative thinking in mathematics, which is a concept that encourages learners to learn by practicing and integrating science into other disciplines for real-life application. Due to teaching and learning problems that focus on lectures rather than actual practice, students cannot apply knowledge in daily life and do not have enough motivation to study. Besides that, mathematics content in some topics is complicated and abstract, Geometry is one of them. Geometry used in their daily lives, such as finding areas, finding distances, lengths, height, etc. It was helps develop essential skills such as spatial or spatial skills, thinking, reasoning, creative thinking. These skills are the foundation for further learning of mathematics and other sciences (The Institute for the Promotion of Teaching Science and Technology (IPST), 2012). In Geometry teaching, almost teachers always have students learn from drawing figures on the papers. Not only the errors from the drawing can happen but this kind of teaching cannot also engage students in real-world images. Hence teachers need to design learning activities in such a way that students can apply knowledge in daily life. (Patcharin setteechaichana, 2019). Therefore, this research is interested in applying the STEM Education Concept to learning management to develop students' mathematical creative thinking skills. Geometry transformation is the topic of interest in this research since its content appropriates for integration with other sciences. Because of the geometry transformation content can be more understandable by actual practice that affects mathematical creative thinking skills. This study can also be an organizing learning activities guideline for teachers at the secondary education level.

Research Objective

To study the development of mathematics creative thinking skills of students learned by activities based on STEM Education.

Research Hypothesis

After learning by activities based on STEM Education, Mathayom Suksa 2 students have higher mathematical creative thinking scores, than before using the activities. Moreover, the students can express their mathematics creative thinking with four aspects of fluency, flexibility, originality, and elaboration.

Target Group

This research took model of classroom action research with STEM Education to develop mathematics creative thinking skills. The participants in this study were thirty students Mathayom Suksa 2 students in the second semester of academic year 2019 at Wat Tawan Rueng School was selected by purposeful sampling. The reason for this choosing are 1.) Wat Tawan Rueang School is an opportunity expansion school, 2.) there are a large number of students in this school who come from various districts in Pathum Thani Province, 3.) the students are in mixed-abilities of high, medium and low academic achievement, and 4.) students are from different family backgrounds such as government officials, state enterprises, farmers, etc. Therefore, the participants is a good representative of the population.

Variables

1. Independent variable is organizing of learning activities base on STEM Education.
2. Dependent variable is scores of mathematical creative thinking skills.

Research instruments

The instruments used in this study were consisted of learning plans, Mathematics creative thinking skills test and students' behavior.

1. Learning Plans

There were six learning plans on Geometry Transformation applied mathematics creative thinking skills. The contents were 1) Introduction of Geometry Transformation 2) Translation 3) Tessellation (Activity about tracery designed) 4) Reflection 5) Activity about "Party" and 6) Tessellation (Activity about create tracery from reflection). The evaluation of the learning plan based on STEM Education was measured by 3 experts. The values obtained then interpreted according to the criteria according to (Chantana Sonkongdang(2008)) as detail below.

Mean range	Interpretation
4.51-5.00	Appropriate
3.51-4.50	Slightly appropriate
2.51-3.50	Neutral
1.51-2.50	slightly inappropriate
1.00-1.50	inappropriate

The assessment results of plans 1 to 6 were an average of 4.45, 4.51, 4.61, 4.68, 4.56, and 4.68, respectively. This result means that plan 1 was slightly appropriate while plans 2-6 were appropriate.

2. Mathematics creative thinking skills test

Mathematics creative thinking sill test was developed by the researcher. There are four items for 24 points, this test covered all the contents. The quality of the mathematics creative thinking test components the index-objective congruence (IOC), Difficulty (p), Discrimination (r), and Reliability. The index-objective congruence (IOC) was used to evaluate the congruence between learning objective and the test items. The value of IOC was 0.67-1.00. The difficulty (p) and discrimination (r) of the items were 0.54-0.6 and 0.20-0.47 respectively. The reliability value was calculated by using Cronbach's alpha to ensure that the responses collected though the instruments was reliable and consistent. The value of this test was 0.74.

Data Collection

This research collected data by using the pre-experiment (One group Pretest-Posttest Design) which has the following steps.

1. The data collection of this research was performed during ten periods of teaching on geometry transformation as explained in the last section. During the period, participants received learning instruction based on STEM Education.

2. After the experiment, the samples were examined their mathematical creative thinking skills by the post-test.

3. The students' mathematical creative thinking skills were assessed after they have learned through STEM Education; the data were collected from students' post-test scores.

4. The researcher observes student's behavior during the period and records information to analyze expression mathematics creative thinking skills.

Data Analysis

Data analysis of this research can be described as follows.

1. Quantitative data

The data from mathematics creative thinking skills test was analyzed by mean, percentage, standard deviation and class normalized gain. Class normalized gain as a measure of change when the same concept test is used to gauge student understanding at the beginning and again at the

end (Hake, 1998). The normalized gain <g> values obtained then interpreted according to the criteria according to (Hake, 1998) are shown in detail below.

"High gain" the value is (g)

"Medium gain" the value is (g)

"Low gain" the value is (g)

2. Qualitative data

The researcher analyzed student's behavior by using information from classroom observation records.

Research Results

The results of this study can be divided into two parts.

1. Quantitative data

Results are shown in Table 1, Table 2, Table 3, Table 4, and Table 5. The Table 1, Table 2 ,and Table 3 are the comparison of student's scores before and after learning activities based on STEM Education. The next tables are the results of student's score in each aspect of mathematics creative thinking skills. The results of data analysis are as follows.

Table1: Mean and Standard deviation of mathematical creative thinking skills test

Group of Experiment	Total Score	Mean	*S.D.*
Pre-test	24	7.33	3.15
Post-test	24	14.60	2.91

From the Table 1, it was found that mean after students' scores who receives learning activities based on STEM Education higher than before receives learning activities. Therefore, the students have developed mathematics creative thinking skills.

Table 2: The class normalized gain of mathematics creative thinking skills test on geometry Transformation

% Pre-test	% Post-test	Actual gain	Maximum possible gain	Normalized gain<g>
7.33	14.60	7.27	16.67	0.44

The development of mathematics creative thinking skills was analyzed based on the results of the students' pretest and posttest by using class normalized gain. From the Table 2 found that the students were developed mathematics creative thinking skills at medium gain level, the value of class normalized gain was 0.44 form thirty students.

Table 3: The class normalized gain of individual students in mathematics creative thinking skills

No.	Pre-test	Post-test	Normalized Gain	Level
1	3	9	0.40	Medium
2	6	17	1.57	High
3	8	13	0.45	Medium
4	14	17	0.43	Medium
5	10	14	0.40	Medium
6	9	15	0.67	Medium
7	11	17	0.86	High
8	11	18	1.17	High
9	9	17	1.14	High
10	8	12	0.33	Medium
11	5	14	0.90	High
12	8	17	1.29	High
13	8	13	0.45	Medium
14	6	13	0.64	Medium
15	11	16	0.63	Medium
16	4	14	1.00	High
17	10	15	0.56	Medium
18	1	10	0.64	Medium
19	5	12	0.58	Medium
20	9	18	1.50	High
21	7	18	1.83	High
22	0	10	0.71	High
23	6	12	0.50	Medium
24	8	16	1.00	High
25	11	22	5.50	High
26	7	12	0.42	Medium
27	4	13	0.82	High
28	6	15	1.00	High
29	5	12	0.58	Medium
30	10	17	1.00	High

(n=30)

From the Table 3, it was found that the normalized gain can be divide into two part 1) fifteen students were classified as high gain level (50 percentage) and 2) fifteen students were classified as medium gain level (50 percentage). The student no.5 has higher level than another person. Therefor, the students were developed mathematics creative thinking skills.

In this part, the researchers analyzed the mean values of mathematical creative thinking skills scores by decomposing the creativity into four aspects of thinking: fluency, flexibility, originality, and elaboration. The results shown in Table 4.

Table 4: Mean and standard deviation of pre-test and post-test in four aspects of mathematics creative thinking skills

Creativity	Experiment	Full Score	Mean	*S.D.*
Fluency	Pre-test	6	2.60	1.04
	Post-test	6	4.53	0.97
Flexibility	Pre-test	6	1.80	1.03
	Post-test	6	3.20	0.89
Originality	Pre-test	6	2.37	1.29
	Post-test	6	4.30	1.02
Elaboration	Pre-test	6	0.57	0.73
	Post-test	6	2.57	1.19

Form Table 4, when comparing the differences of mean value of mathematical creative thinking skills scores in four aspects of creativity collected before and after learning activities based on STEM Education, it was found that mean value of post-learning higher than pre-learning, so the students were developed four aspects of mathematics creative thinking skills.

Table 5: Mean and Standard deviation in four aspects of mathematics creative thinking skills

Aspect of creativity	Mean	*S.D.*
Fluency	4.53	0.97
Flexibility	3.20	0.89
Originality	4.30	1.02
Elaboration	2.57	1.19

When compare the mean value in four aspects of mathematics creative thinking skills, it was found that fluency was different from flexibility, originality, and elaboration. Fluency has higher development than flexibility, originality, and elaboration respectively.

2. Qualitative data

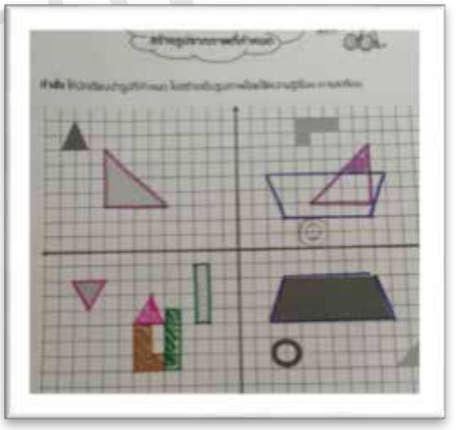
From observation students' behavior, the researcher found that the students had developed mathematics creative thinking skills after organizing learning activities based on STEM Education.

1) Fluency thinking

From first activity, the students could not show example about translation in real life with limit time. After the students do "design tracery activity", the students could design various patterns with limit time and different form another group. In activity, the researcher using questions to motivate the students. According to the definition of fluency refers to the number of unique answers received from thinking within a limited time.

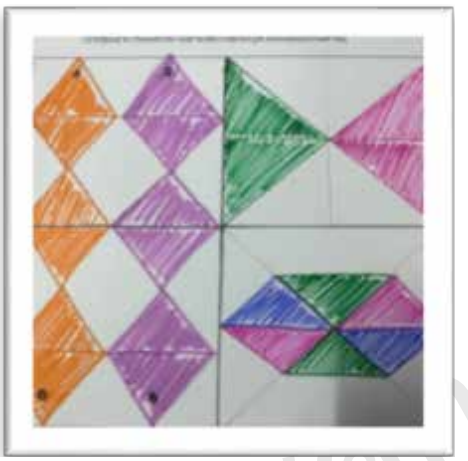
2) Flexibility thinking

The students were developed flexibility after organization learning activities based on STEM Education which corresponds to flexible thinking that they can think in many directions and can be used to match the situation or condition by organized into categories with rules. As can be seen from the last activity, the pattern's design using the knowledge of translation and reflection by GSP program shows that after the exercise, each group of students can think in various ways and can be classified.



3) Originality thinking

Originality thinking; students were developed originality after organization learning activities based on STEM Education which is consistent with the definition of originality thinking. It refers to the ability to think differently from ordinary ideas. As can be seen from the creation a picture from given shape by using translation and reflection. After doing activity, the students could create unusual picture and different other people. In this activity, the researcher using pictures that have been cut into different shapes for students to trial and error.



4) Elaboration thinking

After organization learning activities based on STEM Education, the students were developed elaboration with correspond to the definition of elaboration thinking: the ability to think to obtain a variety of details. Think in response to stimuli or problems and provide features to make it visual or clear, and complete ideas contribute to creative success. As can be seen from “design tracery activity”, the students could create the patterns variety and explain about thinking process.

The comparison each aspect of mathematics creatives thinking skills, from observer student's behavior in classroom; the researcher found that the students had developed their fluency thinking more than flexibility thinking and elaboration thinking in each period, respectively. This result was shown in the "Party" (Christmas Tree Moving) activity that the students able to move Christmas trees according to specified conditions. The students have many approaches for moving Christmas trees, but they could not explain their approaches. Some students have many ways to solve problems, but students take the wrong approach. From student's behavior were consistent with definition of fluency that the number of unique answers obtained from thinking within a limited time. It is useful to solve problems because problem-solving must seek several answers or solutions. Hence these results correspond with the quantitative analysis that fluency thinking has mean value higher development than flexibility, originality, and elaboration respectively in the Table 5.

Discussions and Conclusion

The students have developed mathematics creative thinking skills on geometry transformation by using STEM Education. The development of mathematics creative thinking skills was analyzed based on the results of the pre-test and post-test. The normalized gain (g) value than interpreted according to (Hake,1998) was 0.44 which medium level. Furthermore, the development of individual found that can be divide into two groups where 1) fifteen students were classified as high gain level and 2) fifteen students were classified as medium gain level.

The results in this study found that the learning management process based on STEM Education guidelines can encourage students to use mathematics creative thinking skills from analyzing a given situation with various questions helps students practice and develop mathematics creativity thinking skills. In which each group of students tries to create work by brainstorming and exchanging ideas. For the work to be unique and unique practical according to the conditions and limitations of the specified situation and the learners are in an atmosphere of non-pressure learning activities, students are allowed to demonstrate their potential in initiating self-learning activities freely. Design according to the imagination, not blocking students' thoughts, and will enable students to express themselves their ideas in various ways under the concepts of which are, according to Aree Phanmanee (2014, P.121), in other words, show that the atmosphere that creates creativity is the atmosphere is full of acceptance and the urge to express freely. Providing opportunities for students to explore and study by themselves is a classroom that supports students' creativity. Also, this activity is a learning process that encourages learners to participate in activities. The learners have acted by themselves. According to real conditions, learners take action to solve the real problem: Brainstorming ideas and imagination Choose the best and most

suitable model and improve the workpiece. Students can solve problems by themselves. They were resulting in a learning process in line with Pornthip Siriphatratchai (2013), which states that learning management, according to STEM Education, teaches students to develop various aspects such as creative skills Critical thinking skills in working as a group, etc. It is also consistent with Sirinapa Kitkueak (2015) that says that learning management is based on the concept of STEM Education. Is learning management that focuses on promoting all students who can create workpieces. Have design skills and think of ways to solve problems in real conditions. The students work together as a group. Solve the actual question of the work created during the study. With exact assessment measurements with a teacher to help raise issues and suggest ideas.

Moreover, the research found that fluency has the best development. Next is originality thinking, flexibility, and elaboration, respectively. It may be due to organizing STEM Educational activities in which the learners practice thinking from analyzing the given situation with various questions in the event leading to the lesson. Activities for developing learners to identify problems and activity summary. Activities encourage students to practice and build creativity, especially fluency thinking but neglecting and giving less importance to flexible thinking, originality, and elaboration thoughts. It can observe behavior from the study of all groups of students. Most students are still unable to come up with a variety of answers. And even cannot explain the answer clearly from participating in learning activities based on the STEM Educational concept Students have the development of flexible thinking, originality and elaboration thought accordance with Prapaporn Urai (2006). They were developing math learning activities that focus on the mathematics creativity of Prathom Suksa 2 students. The development of learning activities focuses on organizing learning experiences. Students solve problems creatively so that knowledge can be summarized. As well as helping one another under the atmosphere of using media students practice first, change learning by explaining reasoning to each other. The activities found that mathematics creative thinking has an average score equal to 61.11 percent, divided by each aspect. Fluency thinking, flexible thinking, and originality with an average rating of 46.18, 61.11, and 76.04 percent, respectively, found that fluency thinking has the best development, and the second is the initiative, respectively.

Recommendations

In doing this research, the researcher has suggested being a guideline for teaching and learning by using the concept of STEM Education on the topic of Geometric transformation to develop mathematics creative thinking skills as follows;

1. Activity learning should be organized for the students to participate in the teaching and learning activities and allow them to do group and individual activities. To train leadership and followers, students should have the courage to show comment and listen to others' opinions.

2. Teachers have to study materials equipment to be suitable, safe, harmless, and under the activities specified in each matter.

3. Allowing students to leave presenting in front of the class will help improve spoken language, Assertiveness of students, and self-confidence. Observed by explaining students's work in the first period, do not dare to say, do not dare to tell their work. Because it's embarrassing to have to talk but many times have passed, Students are more developed, dare to speak, express themselves, and have confidence in explaining their work better.

Future Research

1. There should be a study of learning management results based on the STEM Education concept to develop other skills, such as analytical thinking skills, critical thinking skills, group work skills, invention ability, and self-confidence.

2. There should be a study of learning management according to the STEM Education guidelines that relate to local knowledge to solve problems in the community.

3. They should study the effect of learning activities using STEM Educational approaches on mathematical achievement and mathematical creative ability with other grade students, other subject content, and learning content knowing others to study the effects students have had.

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