Impacts of Creative-STEM Education integrated with TPACK on Grade 7 Students' Academic Achievement, Problem-solving Skills, Creative Thinking Skills and Communication Skills in Ratio, Proportion and Percentage in Mathematics

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Abstract. This article aims to: a) review the literature related to Science, Technology, Engineering and Mathematics (STEM) Education, Creativity-based Learning (CBL) and Technological Pedagogical and Content Knowledge (TPACK); b) explore mathematics teachers' and students' perspectives on the current state, problems and needs of teaching mathematics with Creativity-based STEM; and c) develop the Creativity-based STEM integrated with TPACK teaching model for teaching mathematics for Grade 7 students. The research instruments were the questionnaires for teachers and students. The data derived from questionnaires were analyzed for mean and standard deviation. The results expressed that the teachers' perspectives on the current state, problems and needs of teaching mathematics with Creativity-based STEM were high, moderate and high levels. In addition, the students had high needs of Creativity-based STEM approach. In addition, the content analysis was used to analyze common teaching steps of STEM and CBL. The researchers developed the teaching steps of Creative-STEM integrated with TPACK (TPACK-CSTEM) teaching model for teaching Grade 7 mathematics, i.e., a) Build inspiration to create; b) Identify the problem; c) Explore; d) Plan and Create product; e) Test and improve; and f) Present the creative product. At final, the authors raised one example of TPACK-CSTEM lesson plan for teaching the topic of Ratio, Proportion, Percentage in mathematics for Grade 7 students. This example may trigger other mathematics teachers in applying TPACK-CSTEM in teaching the topic or subject they aim to teach.

Keywords: STEM education, creativity-based learning, educational strategies, school achievement, teaching quality, TPACK

H. Habiddin et al. (eds.), *Proceedings of the International Conference on Mathematics and Science Education (ICoMSE 2023)*, Advances in Social Science, Education and Humanities Research 852,
https://doi.org/110.2991/978-2-38476-275-0_2

1 Introduction

The world is currently undergoing rapid and increasingly complex changes. Solving problems using traditional problem-solving methods often proves ineffective. Therefore, it is necessary to incorporate creative thinking in new ways to address these issues. The development of creative thinking is essential for all learners because it enables them to see opportunities that lead to new discoveries, inventions, and continuous innovation. Having creative thinking skills allows individuals to solve various problems quickly and excel in developing different aspects compared to others. In today's competitive world, every profession requires individuals with creative thinking skills, as the competitive nature necessitates constant development in all organizations. This is to improve their work or products, ensuring they are better than before, to be prepared for the future [1].

In order to develop students' learning skills and creativity in the 21st century, educational institutions need to improve the quality of education in Thailand. One approach is to implement STEM (Science, Technology, Engineering, and Mathematics) education, which can help develop students' problem-solving skills, creative thinking, innovation, as well as effective communication and collaboration. STEM education is an integrative approach to learning that combines four disciplines: Science, Technology, Engineering, and Mathematics, that combines the strengths and natural characteristics of each subject and blends teaching methods together. It is based on the theory of constructionism, which emphasizes self-directed learning. When students have the opportunity to generate their own ideas and create projects using appropriate media and technology, their thoughts become clear and tangible [2] [3].

The aim of mathematics education is to enable learners to solve problems, particularly those that require creative problem solving. Creative problem solving is a framework that utilizes thinking skills and thinking tools to explore various ways of finding answers or solving problems. It has a structured process of problem solving, including generating options for problem solving and evaluating the best and novel ideas [4] Problem solving and creative thinking are closely related concepts, as creative thinking is embedded throughout the thinking process. However, problem solving occurs at the final stage of thinking and is the outcome of creative thinking that can lead to solutions. [5] In summary, mathematics education aims to develop learners' problem-solving abilities, particularly through creative problem solving. This involves using thinking skills and tools to explore various ways of finding solutions. Problem solving is the end result of creative thinking and can lead to innovative solutions.

One essential knowledge for professional teachers is Pedagogical Content Knowledge (PCK), which combines content knowledge and pedagogical knowledge to effectively manage learning. PCK is an essential knowledge that should be developed in all teachers, both in-service and pre-service teachers [6]. Nevertheless, within the realm of technology, educators must possess the capability to judiciously select and adeptly implement various technologies within their teaching practices. This conceptual domain is formally recognized as TPACK, an acronym encompassing the fusion of Technological Pedagogical and Content Knowledge. TPACK is a necessary knowledge for teachers in the 21st century, as it enhances their abilities and efficiency in using technology for teaching and learning. Furthermore, TPACK is a complex integration of three main components: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). It can be seen that TK alone is not sufficient for effective teaching and learning in the 21st century, as teachers need to have CK and PK.

Drawing from the previously outlined rationales, it becomes evident that the principles of creativity, STEM, and TPACK hold significant advantages while seamlessly aligning with the demands of the 21st century. In light of this, the researchers express their interest in conducting a comprehensive review of the existing literature pertaining to creative thinking, STEM education, and TPACK. Subsequently, the researchers embarked on a synthesis process, aiming to distill and amalgamate relevant insights from these domains into the new teaching model so called the Creative-STEM Education integrated with TPACK. This new teaching model aims to promote Grade 7 Students' academic achievement, problem-solving skills, creative thinking skills and communication skills in the topic of Ratio, Proportion and Percentage in mathematics.

2 Literature review

2.1 STEM Education

In 2015, the Institute for the Promotion of Teaching Science and Technology (IPST) took the pioneering step of introducing STEM education to Thailand. This innovative approach seamlessly weaves together the four core disciplines of Science, Technology, Engineering, and Mathematics, entwined with the fundamental tenets of the engineering design process. Through this educational framework, students are not only immersed in acquiring knowledge and skills across science, mathematics, and technology but are also empowered to apply their learning to devise methodologies and solutions that address real-life exigencies. This dynamic approach aspires to foster a convergence of knowledge and practicality, nurturing the development of technology as an outcome of the engineering design process.

STEM education bestows a multitude of advantages in orchestrating effective mathematics instruction across diverse dimensions. In the discourse, Siripatharachai [7] underscored that the contemporary 21st-century skills framework has precipitated a paradigm shift in educational paradigms. This shift is evident as educational landscapes across all tiers underscore the cultivation of students' creative thinking and problem-solving. Simultaneously, there is an accentuation on nurturing robust communication abilities, harnessing technology as a conduit for knowledge acquisition, and fostering adept social competencies.

STEM responds well with the new trend of educational management that urges for more integrative approach as integrating various disciplines. Students can integrate their learning both in the classroom and in real life, making learning meaningful and beneficial not only for the learners themselves but also for their daily lives and the development of the country.

STEM harmoniously aligns with the contemporary shift in educational management, which ardently advocates for a more cohesive and integrative approach by integrating diverse disciplines. This methodology empowers students to seamlessly amalgamate their learning experiences, both within the classroom and in practical real-world contexts. As a result, education becomes imbued with purpose and significance, reaping benefits not solely for the learners but also for their day-to-day existence and the overarching advancement of the nation. Additionally, [8] stated that STEM education is one technique that helps students to experience real and practical learning. They can think systematically to solve problems and create new works based on their own potential, with teachers serving as advisors to enhance their qualities and apply the knowledge they have acquired in their daily lives for practical benefits.

2.2 Creativity-based Learning (CBL)

The 21st century emphasizes Creativity-based Learning as a foundation for effective teaching and learning, with a focus on student-centered approaches. In the context of mathematics education, teachers can utilize technology to facilitate learning. For example, Ruachaiphanich [9] states that creativity-based learning (CBL) is based on the framework of using creative thinking, which has been developed from the Problem-Based Learning (PBL) and Parallel Thinking approaches of Edward De Bono. This approach recognizes that traditional teaching methods may not adequately prepare students with the necessary skills to succeed in the new world. These approaches have been successful in many countries and have been used to create a new learning model known as Active Learning. This approach aims to engage students in active exploration and investigation, rather than passive listening. Students enjoy learning, develop analytical and creative thinking skills, improve communication, and enhance teamwork. Learning that focuses on creative thinking is a new method of education that promotes creative thinking, analytical thinking, and problem-solving skills in students.

Furthermore, learning that emphasizes creative thinking encourages active participation and self-confidence in students by involving them in real-life activities and open-ended problem-solving projects. Research shows that integrating learning management that focuses on creative thinking in the classroom has numerous benefits. It not only improves students' learning outcomes but also increases motivation, participation, and self-confidence. Students who experience learning that emphasizes creative thinking tend to develop a growth mindset as they learn from their mistakes. One example of learning that emphasizes creative thinking is PBL, which involves students working on real-world projects that require them to apply their knowledge and problem-solving skills. This method promotes active learning, critical thinking, and collaboration among students. Additionally, the use of technology in the classroom, such as virtual reality, augmented reality, and interactive simulations, can enhance students' learning experiences and stimulate their creativity. These tools provide opportunities for students to explore and experiment with different ideas, increasing their active participation and involvement [10] [11] [12].

In conclusion, CBL is a valuable educational approach that helps students become enthusiastic learners, critical thinkers, and problem solvers. It combines hands-on activities, collaborative projects, and technological tools to create a participatory and stimulating learning environment that fosters creativity and prepares students with essential skills for success in the 21st century.

2.3 Technological Pedagogical and Content Knowledge (TPACK)

In the current rapidly developing digital world, the concept of Technological Pedagogical and Content Knowledge (TPACK) has brought new dimensions to professional teaching. The major role of teachers is enhancing more quality education and learning experience for students. This article explores the interrelationship between knowledge, teaching methods, and technology, and effective ways to integrate them to create engaging and interactive content.

TPACK is a concept that was introduced in 2008 by Koehler and Mishra [13]. It builds upon the idea of Pedagogical Content Knowledge (PCK) proposed by Shulman (1986), which focuses on the integration of knowledge and teaching methods. What is newly added to the Pedagogical Content Knowledge is Technological Knowledge (TK). This is because in the 21st century, technology has increasingly played a significant role in learning and education.

The three dimensions of TPACK are interconnected and reinforce the integration of technology with teaching practices. To achieve effectiveness, there needs to be a balance between Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK) when teachers have a strong foundation in all three dimensions. Teachers can leverage technology to enhance teaching strategies, support content presentations, and promote student-centered learning. For example, teachers can use technology tools to create interactive multimedia presentations, facilitate virtual discussions, or provide personalized feedback, which promotes increased student engagement and deeper understanding of the content. CK, PK and TK are intertwined and demonstrate the complex interactions of knowledge in the TPACK framework as Fig. 1 illustrated. Content Knowledge (CK) refers to the teacher's knowledge of the subject matter to be taught. Teachers must have knowledge of the content as defined by the educational curriculum without deviation. Pedagogical Knowledge (PK) refers to the teacher's knowledge of teaching methods and strategies, which vary depending on the subject area and individual preferences. Technological Knowledge (TK) refers to the teacher's knowledge of technology to enhance learning and instructional management, including hardware (such as projectors, visualizers, and interactive whiteboards) and software (such as Microsoft programs or various applications).

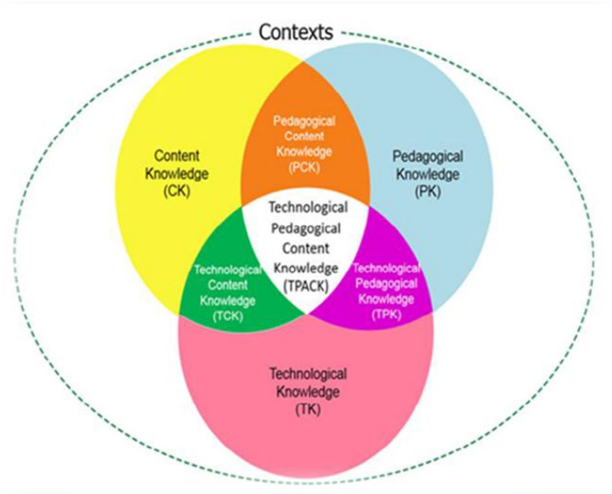

Fig. 1. TPACK Model [13]

From Fig. 1, it can be seen that CK, PK and TK as separate knowledge are not sufficient for effective learning management. When teachers integrate CK and PK together; they form a type of knowledge called Pedagogical Content Knowledge (PCK). PCK is the integration of CK and PK, which involves managing learning with appropriate instructional techniques specific to a particular content, in order to enable learners to communicate in language. Activities suitable for this teaching approach include the Communicative Teaching Approach, which focuses on listening and reading from authentic materials, sentence construction practice, and using role play or information gap activities for training, and so on. In the integration of CK and TK, this knowledge is called Technological Content Knowledge; TCK), which is the knowledge of using various technologies to facilitate learners' understanding of the content according to the objectives of the lesson. The integration of PK and TK forms Technological Pedagogical Knowledge (TPK), which is the knowledge of using technology for learning and managing learning in various appropriate ways specific to a particular teaching method.

Consequently, TPACK is a framework that emphasizes the integration of CK, PK and TK in teaching practice. By considering the interactions between CK, PK and TK, teachers can utilize TPACK to improve their teaching practices and promote meaningful student engagement. When teachers combine their CK, PK and TK, they can develop a comprehensive understanding of teaching methodologies and effectively incorporate technology into their instruction. This results in efficient learning management as teachers align the use of technology with teaching methods and content, creating a seamless learning experience. Through dynamic teaching methods, teachers can foster critical thinking and curiosity among students. Additionally, by incorporating relevant and contextual content, learners can make connections between theories and real-world applications. Technology also serves as a motivator, as teachers provide innovative tools and platforms that enhance the learning experience for students. By encouraging learners to actively seek and create knowledge from teacher-generated content, teachers can cultivate enthusiasm and a lifelong desire for learning.

3 Methodology

The researchers employed survey research to explore the teachers' and students' perspectives on the current state, problems and needs of mathematics teaching and learning through STEM education and CBL. The sample were 149 in-service mathematics teachers and 109 Grade 7 students in Chiang Rai Province, the North region of Thailand. The research instruments were the questionnaires on the current state, problems and needs of mathematics teaching and learning through STEM education and CBL for teachers and students. The data derived from both questionnaires were analyzed for mean and standard deviation (SD). In addition, the researchers reviewed the literature related to STEM Education, CBL and TPACK. The data was analyzed by using content analysis. After that, the authors created the Creative-STEM Education integrated with TPACK or TPACK-CSTEM teaching model and sent it to a panel of five experts to validate its Suitability, Feasibility and Usefulness. The results from experts were calculated for mean and SD and interpreted according to the set criteria.

4 Results and Discussion

4.1 Teachers' perspectives on the current state, problems, and needs of teaching with STEM education and CBL

There were 149 in-service mathematics teachers (31 males, 118 females) responded to the questionnaire of perspectives on current state, problems and needs of teaching mathematics with creative-based STEM. 54 respondents aged between 25-30 years (36.20%), 49 respondents aged between 41-45 years (32.90%), 19 respondents aged between 51-55 years (12.80%). 17 respondents aged between 36-40 years (11.40%), and 10 of them aged between 31-35 years (6.70%). In addition, there were 65 K 1 Teachers (43.60%), 30 Professional Level Teachers (K 2 Teachers) (20.10%) and 54 Senior Professional Level Teachers (K 3 Teachers) (36.20%). Most of the respondents had teaching experience less than six years (54 persons or 36.20%). There were 35 respondents had 21-25 years of teaching experience (23.50%), 29 respondents with 11-15 years of teaching experience (19.50%), 25 respondents with 6-10 years of teaching experience (16.80%) and six respondents with 16-20 years of teaching experience (4.00%).

The teachers' perspectives on the current state, problems, and needs of teaching with STEM education and CBL can be shown as Table 1.

Table 1. Teachers' perspectives on current state, problems, and needs of teaching with Creative-based STEM

Item	Statement	Mean	SD	Interpretation
Current state				
1.	You understand the Creative-based STEM approach.	3.66	0.78	High
2.	The Creative-based STEM approach is suitable for your school.	3.40	0.72	Moderate
3.	The Creative-based STEM approach is suitable for your students.	3.40	0.67	Moderate
4.	You are satisfied with the Creative-based STEM approach.	3.58	0.75	High
5.	The school is equipped with facilities, environment, and infrastructure to support Creative-based STEM approach.	3.91	0.65	High
6.	The school is equipped with media and tools to support Creative-based STEM approach.	3.70	0.65	High
7.	The learners are ready for Creative-based STEM approach.	3.54	0.73	High
	Average of current state	3.59	0.70	High
Problems				
8.	There is a lack of support from school for organizing Creative-based STEM approach.	3.61	1.16	High
9.	Implementing Creative-based STEM approach is challenging in your classroom context.	3.38	0.99	Moderate
10.	Creative-based STEM approach demands too many materials/equipment.	3.53	1.00	High
11.	Creative-based STEM approach demands too complex materials/equipment.	3.18	0.94	Moderate
12.	The implementation of Creative-based STEM approach takes too much time.	3.87	0.92	High
13.	The outcomes of Creative-based STEM approach do not match with its investment of resources, time, and effort.	3.03	1.00	Moderate
14.	Students' knowledge and skills are insufficient for learning with Creative-based STEM approach.	3.10	0.98	Moderate
	Average of problems	3.38	0.99	Moderate
Needs				
15.	You want to implement Creative-based STEM approach in your classroom.	4.11	0.61	High
16.	You want to develop more understanding of Creative-based STEM approach.	4.48	0.51	High
17.	Your students want to learn with Creative-based STEM approach.	3.75	0.66	High

18.	Creative-based STEM approach is suitable for developing students' problem-solving skills.	4.46	0.51	High
19.	Creative-based STEM approach is suitable for developing students' creative thinking skills.	4.52	0.50	Very high
20.	Creative-based STEM approach is suitable for developing students' academic achievement.	4.03	0.60	High
21.	Creative-based STEM approach is beneficial for education.	4.48	0.50	High
22.	Creative-based STEM approach should be recommended for other teachers.	4.52	0.50	Very high
23.	Creative-based STEM approach should be widely disseminated.	4.48	0.50	High
	Average of needs	4.31	0.54	High

In overall, the teachers had a high level (mean = 3.59, SD = 0.70) of perspectives on current state of creative-STEM education. The teachers had a moderate level (mean = 3.38, SD = 0.99) and high level (mean = 4.31, SD = 0.54) of perspectives on problems and needs of creative-STEM education, respectively. There were three high level of problems in three items: Item 8: There is a lack of support from school for organizing Creative-based STEM approach (mean = 3.61, SD =1.16); Item 10: Creative-based STEM approach demands too many materials/equipment (mean = 3.53, SD = 1.00); and Item 12: The implementation of Creative-based STEM approach takes too much time (mean = 3.87, SD = 0.92). In addition, there were two major needs from teachers' perspectives in implementing Creative-based STEM approach: Item 19: Creative-based STEM approach is suitable for developing students' creative thinking skills (mean = 4.52, SD = 0.50); and Item 22: Creative-based STEM approach should be recommended for other teachers (mean = 4.52, SD = 0.50).

In addition, the responding teachers provided these recommendations for improving the implementation of creative-based STEM: Students should have positive attitudes towards self-directed learning that is one important factor in learning with creative-based STEM. Teachers should select content and context that were suitable for creative-based STEM. Also, schools should support sufficient media, materials and technology for teachers teaching with creative-based STEM as well as provide a creative-based STEM professional development for teachers.

4.2 Students' perspectives on problems, and needs of learning with STEM education and CBL

There were 23 males (21.10%) and 86 females (78.90%) Grade 7 students responded to the current state, problems and needs of teaching mathematics with STEM education and CBL questionnaire. The students' perspectives on the problems and needs of learning with STEM education and CBL were as Table 2.

Table 2. Students' perspectives on current state, problems, and needs of learning with Creative-based STEM

Item	Statement	Mean	SD	Interpretation
Problems				
	Education			
1.	Creative-based STEM approach is not suitable for local context.	1.73	0.84	low
2.	Creative-based STEM approach is not suitable for school context.	2.11	0.85	low
3.	School administrator does not support Creative-based STEM approach.	1.79	0.71	low
4.	School administrator does not support integration of local context in teaching with creative-based STEM.	1.71	0.74	Low
	Total	1.83	0.78	Low
	Curriculum			
5.	The school lacks curriculum using creative-based STEM.	2.47	0.51	Low
6.	The school lacks instructional plans using creative-based STEM.	2.65	0.49	Medium
7.	Creative-based STEM is not widely used in the school.	2.25	0.67	Low
	Total	2.45	0.55	low
	Teacher			
8.	Teachers are not yet well prepared for creative-based STEM.	2.02	0.71	Low
9.	Teachers lack understanding of creative-based STEM.	2.19	0.60	Low
10.	Teachers lack awareness of the importance of creative-based STEM.	2.34	0.47	Low
11.	Teachers lack teaching skills in implementing creative-based STEM.	2.39	0.49	Low
12.	Teachers lack an ability to incorporated local contexts into creative-based STEM.	2.82	0.55	Medium
13.	Students are not yet well prepared for creative-based STEM.	2.02	0.73	Low
14.	Students are not accustom in learning by integrating local contexts.	2.34	0.59	Low
15.	Students lack development of creative thinking skills.	2.22	0.60	Low
16.	Students lack development of problem-solving skills.	2.22	0.60	Low
17.	Students lack development of communication skills.	2.22	0.60	Low
	Total	2.27	0.59	Low

	Needs			
	Education			
18.	The local community needs creative-based STEM.	4.50	0.50	High
19.	The school needs creative-based STEM.	4.50	0.50	High
20.	School administrators should support creative-based STEM.	4.55	0.49	Very high
21.	School administrators should support the utilization of local context in creative-based STEM.	4.07	0.58	High
	Total	4.40	0.51	High
	Curriculum			
22.	Schools should develop curriculum using creative-based STEM.	4.55	0.49	Very high
23.	Schools should promote teachers to construct creative-based STEM instructional plans.	4.50	0.50	Very high
24.	Schools should enhance the dissemination of creative-based STEM.	4.55	0.50	Very high
	Total	4.51	0.49	Very High
	Teacher			
25.	Teachers should enhance their readiness for teaching with creative-based STEM.	4.02	0.49	high
26.	Teachers should improve their understanding of creative-based STEM.	4.04	0.53	high
27.	Teachers should develop skills in using creative-based STEM.	3.93	0.83	high
28.	Teachers should utilize local contexts in teaching with creative-based STEM.	3.54	0.76	High
	Total	3.88	0.65	High
	Student			
29.	Students should be prepared for learning with creative-based STEM.	3.58	0.70	High
30.	Students should develop readiness for learning with local contexts.	4.13	0.60	High
31.	Students should be developed their creative thinking skills.	4.53	0.50	Very High
32.	Students should be developed their problem-solving skills.	4.52	0.58	Very High
33.	Students should be developed their communication skills.	4.50	0.50	Very High
	Total	4.25	0.57	High

Although students had a low level of problems in learning mathematics with creative-based STEM, they had a high level of needs of learning with creative-based STEM regarding School (mean = 4.40, SD = 0.51), Curriculum (mean = 4.51, SD = 0.49), Teacher (mean = 3.88, SD = 0.65), and Student (mean = 4.25, SD = 0.57). They had a very high level of needs regarding these aspects: Item 20: School administrators should support creative-based STEM (mean = 4.55, SD = 0.49); Item 22: Schools should develop curriculum using creative-based STEM (mean = 4.55, SD = 0.49); Item 23: Schools should promote teachers to construct creative-based STEM instructional plans (mean = 4.50, SD = 0.50); Item 24: Schools should enhance the dissemination of creative-based STEM (mean = 4.55, SSD = 0.50). In addition, the students highly perceived that they need to be developed in creative thinking skills (mean = 4.53, SD = 0.50), problem-solving skills (mean = 4.52, SD = 0.58) and communication skills (mean = 4.50, SD = 0.50).

4.3 Creative-STEM Education integrated with TPACK Model

The researchers created the Creative-STEM Education integrated with TPACK Model aimed to teach mathematics for Grad 7 students. This involves utilizing knowledge of teaching methods, specifically knowledge of STEM education and CBL. Through this synthesis, it has been discovered that there are six steps in the teaching process, and the use of technology aids in learning and learning management, which in turn helps develop problem-solving skills, creative skills, math communication skills, and academic achievement.

The Creative-STEM Education integrated with TPACK Model demonstrates the relationship between CBL, STEM and TPACK as shown in Table 3.

Table 3. Relationship between the Creative-STEM Education and the TPACK.

Teaching steps of creative-STEM education	TPACK
Step 1 Build inspiration to create The teacher presents problem situations that require the integration of mathematical knowledge with science, engineering, and technology to solve problems presented through interesting and modern learning materials. This stage aims to inspire creativity in students.	Google form YouTube.com Wordwall Kahoot
Step 2 Identify the problem The student first identifies the problem they encountered in Step 1 individually. Then, they form groups of 4-6 students with mixed abilities. The group discusses and modifies the problem to determine one that interests them. The instructor will gradually assist and facilitate the students in this process.	Spi http://th.rakko.tools
Step 3 Explore Students work together to search for information, science, mathematics, engineering, and technology concepts related to a given problem in order to understand the problem. They analyze the conditions or constraints of the problem and determine the scope of the problem that will guide their work.	Spin YouTube.com Google.com Mentimeter Canva Capcut
Step 4 Design and create product	

The students collaborate to develop an innovative plan. They solve problems in step 2 by utilizing information and ideas from step 3 to create projects in accordance with the planned steps.	
Step 5 Test and improve Learners engage in testing and evaluating solutions and creative projects to assess their ability to solve the given problem. They analyze the effectiveness of these solutions and utilize the evaluation results to enhance and refine their problem-solving techniques or create improved work pieces. They strive for increased efficiency until they develop the most appropriate solution or work piece. Teachers play a supportive role by guiding and offering feedback to aid in the improvement of the work piece.	
Step 6 Present the creative product Students showcase their innovative solutions or projects to their peers utilizing diverse creative methods and media. Subsequently, the teacher facilitates a platform for critiquing, critiquing, and evaluating the work, while also providing constructive suggestions for further enhancing the solutions or projects.	Facebook Google Capcut

The researchers presented the Creative-STEM Education integrated with TPACK Model (TPACK-CSTEM) model to a panel of five experts for assessment of its Suitability, Feasibility, and Usefulness. The Index of Item-Objective-Congruence (IOC) of Suitability, Feasibility, and Usefulness of the TPACK-CSTEM model was analyzed, and the results ranged between 0.60-1.00 as Table 4, which is considered acceptable.

Table 4. Experts' evaluation of quality of the TPACK-CSTEM model.

Item	Statement	IOC		
		Suitability	Feasibility	Usefulness
1.	The model can develop problem-solving skills in mathematics.	0.80	1.00	1.00
2.	The model can develop creative skills in mathematics.	1.00	0.80	1.00
3.	The model can develop communication skills in mathematics.	0.60	0.80	1.00
4.	The model can be developed to be a model for other subjects.	0.60	0.80	1.00
5.	The model was created according to the STEM education.	0.60	0.80	1.00
6.	The model was created based on CBL.	1.00	1.00	1.00
7.	The model is created based on TPACK framework.	0.80	0.80	1.00
8.	The model can be practically applied in the classroom.	1.00	1.00	1.00
9.	The model can be used to develop students' technology skills.	0.80	0.87	1.00

In order to comprehend the practical implementation of the TPACK-CSTEM model into classroom practice, the researchers presented a sample instructional plan for the topic of Ratio in mathematics in Grade 7 students that took seven teaching hours. The details of TPACK-CSTEM lesson plan are as follows.

Learning objectives

Students should be able to:

1. Explain the proportions of a mixed portion of rice preparation (M);
2. Determine and apply ratios in a constant quantity of rice preparation (M);
3. Describe the changing states of matter in the process of rice preparation (S);
4. Design and create innovative and suitable shapes of rice preparation (E);
5. Utilize online resources for mathematical research and communication (T); and
6. Collaborate creatively with others, expressing opinions and working together.

Teaching and learning process

Step1: Build inspiration to create

1.1) The teacher instructed the students to complete a pre-test on Ratio using a Google Form. The teacher shared the link https://docs.google.com/forms/d/e/1FAIpQLScEydS7ivvxpJ-QGAwvu1s9JGkGLUG-sweNcKNYKzYLqOgjnvA/viewform or students can scan the QR Code to access it. Additionally, the teacher prepared a hard copy of pre-test for students who are unable to use the application.

1.2) The teacher opens a 5-minute YouTube video on the topic of "Khao Kaep" (in Thai) (Narrow Rice) using the following link: https://www.youtube.com/watch?app=desktop&v=T49k17Qptzs&t=18s or scan QR Code

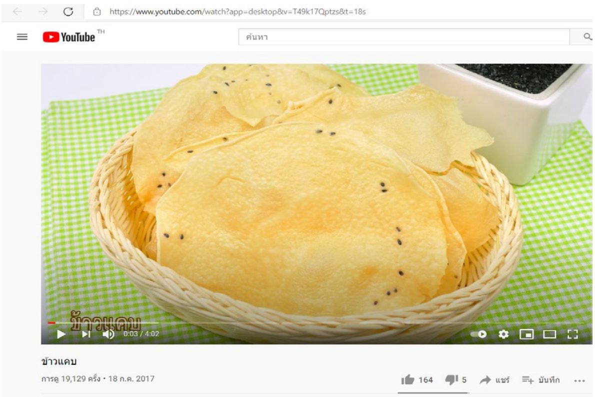

Fig. 2. YouTube video clip of "Khao Kaep" (in Thai) (Narrow Rice)

Then, the teacher inspires students by asking individual students questions after watching the YouTube video on "Khao Kaep" as follows:

Question: From the YouTube video on "Khao Kaep," does the ratio of ingredients play a significant role in making Khao Kaep or not?

Answer: *The ratio is important in the process as using too much or too little of any component may result in Khao Kaep losing its shape and may affect its taste.*

Question: Have you ever eaten dried Khao Kaep and then fried it?

Answer: *Yes/No*

Question: What ingredients do you think are used in the Khao Kaep you have eaten?

Answer: *Glutinous rice, salt, black sesame seeds, white sesame seeds, sugarcane juice.*

Step2: Identify the problem

2.1) The teacher divides the students into groups of 5, according to their abilities. The students are grouped into "advanced," "average," and "weak" based on their academic performance. This grouping aims to facilitate peer assistance and knowledge exchange among the students. (5 minutes)

The criteria for grouping based on academic performance are as follows:

- Advanced: students with an average score of 3.00 - 4.00
- Average: students with an average score of 2.00 - 2.99
- Weak: students with an average score below 2.00

2.2) The students are asked to discuss and calculate the ratio of the components of narrow rice, and then write down the steps and draw a colored diagram of the narrow rice formula chosen by their group. (20 minutes)

- How can the ratio of narrow rice components be written?
- If there is a clear ratio, how many sheets of narrow rice can be produced?
- If more narrow rice needs to be made, how should the mixing ratio be determined to calculate the components of narrow rice?

2.3) The students participate in the Gallery Walk activity by presenting their group's findings to the class and sticking the blue paper on the classroom wall. This allows each group to have the opportunity to learn about the details and ideas of their peers' groups. (25 minutes)

2.4) The teacher stimulates the students' thinking about the diversity of narrow rice components presented by the students and highlights the use of ratios or different components to establish connections between the topics. (15 minutes)

Step 3: Explore

3.1) The teacher instructs students to explore information from Knowledge Sheet 1.1 on the topic of ratios and complete Worksheet 1.1 on ratios. This foundational knowledge will be used for the constructivist learning activity on the subject of rice preparation ratios. The objective of this activity is for students to explain ratios, find ratios, and determine ratios of mixed portions in rice preparation.

3.2) Student's research information from Knowledge Sheet 1.2 regarding changes of state in matter and complete Worksheet 1.2 on changes of state in matter. This fundamental knowledge will be employed for the constructivist learning activity on the subject of rice preparation ratios. The goal of this activity is for students to describe changes of state in matter and apply them in the process of rice preparation.

3.3) Students search the internet for relevant topics related to the posed problems. This enables students to comprehend the problem, analyze its conditions or limitations, and define the problem's scope to lead to a problem-solving and creative process in designing various shapes of rice preparation.

Mathematics:

Ratio - A ratio is a relationship that illustrates a comparison between two quantities, which can have the same or different units. A ratio of the quantity A to the quantity B is represented as A: B.

Science:

Changes of State in Matter - When a liquid receives heat, the particles of the liquid move rapidly. This results in particles near the liquid's surface gaining enough energy to escape and become gas, causing the liquid to evaporate. This process is known as vaporization.

Engineering Design:

The design process for creating various shapes of rice preparation, which can be used as a promotional product for local snacks, to be recognized globally.

Technology:

Using computer-based presentation methods through the Menti-meter program, the teacher provides further explanation on the topic of ratios.

Step 4: Design and Create product

4.1) Students engage in the Constructivist Learning Activity Set 1 on the topic of rice preparation ratios. Together, students collaborate to plan problem-solving and create outcomes stemming from the problem-solving process. They utilize data and ideas obtained through research, using relevant information and considering resources, limitations, and conditions. Following this, the teacher prepares the following equipment for the students:

1. Pre-soaked sticky rice	1 kilogram
2. Salt	2 teaspoons
3. Water	1 liter
4. White cloth	1 piece
5. Various-sized pots	2 pieces
6. String (for tying cloth)	2 strands
7. Paddle for flattening rice dough	1 piece
8. Measuring cup	1 piece
9. Ladle	1 piece
10. Digital scale	1 piece

4.2) The teacher sets the conditions for the experiment, where students design a study to investigate the ratios of the components in rice preparation.

a) Ratios of rice preparation components.

b) Design the desired shape of the rice preparation and create a mold based on the designed shape.

c) The change of state of matter that turns water into steam and the use of steam to transform the rice dough into sheets.

d) If additional components are introduced to the rice preparation, such as flavoring or coloring, it will alter the ratios. Therefore, it's necessary to calculate the appropriate ratios for the desired rice preparation once again.

4.3) Each group of students collaborates to plan, design, and calculate the ratios of the components in their own rice preparation, following the outlined steps.

Step 5: Test and improve

Each group of students tests and evaluates their own work from Constructivist Learning Activity Set 1 on the topic of rice preparation ratios. If the results are not satisfactory, such as needing to increase or decrease the ratios of the rice preparation components, students can make adjustments to their work.

Step 6: Present the creative product

6.1) The teacher instructs each group of students to take suggestions from their peers and make improvements. If each group of students accepts the suggestions and makes changes to the ratios in their rice preparation formula, they are encouraged to think and innovate further. During this phase, students document the activity by recording the steps and explaining the process, including the ratios, in a video clip. They then post the video clip in the designated Facebook group, where both the teacher and peers can provide feedback by liking, offering suggestions, or giving positive comments in the comment section. Additionally, students share the rice preparation they've adjusted based on the suggestions with their classmates for tasting.

6.2) The teacher and students collaborate to summarize the activities. The teacher connects all the activities, allowing students to learn about Ratios in mathematics.

Ratio refers to the relationship that illustrates a comparison between two quantities, which can have the same or different units.

The ratio of quantity A to quantity B can be represented as A: B or $\frac{a}{b}$ by $b \neq 0$

Equal Ratios:

The principle of finding ratios that are equal to a given ratio involves the principles of multiplication and division:

Multiplication Principle: $\frac{a}{b} = \frac{a \times c}{b \times c}$ when $c \neq 0$

Division Principle: $\frac{a}{b} = \frac{a \div c}{b \div c}$ when $c \neq 0$

6.3) After the lesson, each group of students takes a post-lesson test on the topic of ratios, consisting of 10 questions (as provided in the attached documents in the learning management plan), to assess their understanding after the learning session.

The significance of learning mathematics in our daily lives cannot be overstated, as it lays the groundwork for cultivating a range of essential skills, including problem-solving, creative thinking, and effective mathematical communication. These proficiencies bear immense importance across diverse professions and advanced education. The incorporation of technology into educational management substantially elevates teaching effectiveness and pertinence. Consequently, the Creative-STEM Education integrated with TPACK Model offers a potent strategy for nurturing students' problem-solving abilities, fostering creative thinking, and enhancing their aptitude for mathematical communication.

5 Recommendations

5.1 Recommendations for implications

1. Mathematics educators can readily adopt the Creative-STEM Education integrated with TPACK Model, as expounded in this study, and seamlessly implement it within their respective subject areas.
2. Educators across different subjects are encouraged to embrace the delineated methodologies and activities encapsulated within the Creative-STEM Education integrated with TPACK Model. This adoption seeks to cultivate a conducive environment for nurturing essential proficiencies such as problem-solving, creative thinking, and effective mathematical communication skills.
3. Some students may struggle with new teaching approach, as the Creative-STEM Education integrated with TPACK Model, and time constraints. Therefore, instructors should allocate more time and prepare students to accustom with the new model.

5.2 Recommendations for future research

1. The exploration of using the Creative-STEM Education integrated with TPACK Model in teaching other topics and/or subjects based on contextual relevance and student interests.
2. The investigation of application of the Creative-STEM Education integrated with TPACK Model in developing other cognitive skills in mathematics such as reasoning and linking skills.
3. The use of different research methodology and design to study the effects of the Creative-STEM Education integrated with TPACK Model.

Acknowledgments. This research was supported by Boonruang Wittayakhom School. I would like to express my sincere thanks to my research advisor, Assoc. Prof. Dr. Khajornsak Buaraphan, for their valuable comments, suggestions and encouragement through-out the process of this research.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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