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Fostering Mathematical Proficiency and Creative Thinking Skills in 10th Grade Students Through the 5E Inquiry-Based Learning Approach with Supplementary Media

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Abstract

This research aims to enhance mathematical proficiency and stimulate creative thinking among 10th-grade students through the implementation of the 5E Inquiry-Based Learning approach with Supplementary Media. The study explores the effectiveness of this pedagogical approach in transforming the learning experience and outcomes in mathematics education. The study focused on comparing students' performance before and after the intervention, as well as investigating their creative thinking abilities in terms of flexibility, originality, fluency, and elaboration. The participants consisted of 10th-grade students from a large-sized school in the northeastern region of Thailand, specifically one classroom comprising 40 students. The tools include Lesson plans, Mathematics Proficiency test and Creative thinking skills test. The results revealed a significant improvement in mathematical proficiency following the implementation of the 5E Inquiry-Based Learning Approach with supplementary media, with a notable increase of 37.25%. Prior to the intervention, students scored an average of 4.64 out of 20, which increased to 12.08 out of 20 post-intervention. Furthermore, the investigation into creative thinking skills indicated that students exhibited a proficient level overall, with an average score of 22.60 out of a maximum of 32 points. The analysis of specific dimensions of creative thinking revealed average scores of 5.60 for Originality, 5.78 for Fluency, 5.63 for Flexibility, and 5.60 for Elaboration.

Keywords: mathematical proficiency, creative thinking skills, supplementary media, 5E inquiry-based learning approach

1. Introduction

1.1 Introduce the Problem

Mathematics plays a crucial role in the development of human thinking, enabling individuals to think creatively, logically, systematically, and analytically. It provides a framework that allows thorough and comprehensive analysis of problems or situations. Mathematics aids in prediction, planning, decision-making, and the application of solutions in daily life accurately and appropriately. Additionally, mathematics serves as a tool for studying various scientific, technological, and other disciplines. Therefore, mathematics is beneficial for leading a well-informed life, improving the quality of life, and fostering harmonious relationships with others (Office of Academic Affairs and Educational Standards, 2008).

A range of studies have explored the multifaceted nature of mathematical proficiency, with a particular focus on the challenges faced by both teachers and students. Brijlall (2022) identified systemic, societal, and pedagogical challenges in South Africa, while Groves (2012) emphasized the need for complex changes in teachers' pedagogy to develop the full set of capabilities. In addition to developing mathematical abilities, fostering creative thinking in mathematics is crucial as it enables learners to solve problems in diverse ways. Aligned with Maharani (2014) which states Creative thinking is very important in this era of global competition, since the level of complexity problems is higher in all aspects of modern life. In the context of a mathematics classroom, critical and creative thinking skills are crucial, and teacher pedagogy plays a significant role in their development (Sanders, 2016).

Moving away from traditional lectures, we are adopting diverse methods that reshape the roles of both teachers and students. An illustration of this is the use of Inquiry-Based Learning. It is widely acknowledged that

inquiry-based teaching aims to increase students' higher-level thinking skills such as critical thinking, collaboration, and communication to meet the challenges encountered in the 21st century (Prokes, 2009). Educators employ various strategies to cultivate creative thinking in mathematics classrooms. Inquiry-based learning, problem-solving tasks, and open-ended questions are among the methods used to encourage students to explore mathematical concepts beyond routine procedures (Indarasati et al, 2019). This approach, particularly when integrated with collaborative and real-world problem-solving activities, can lead to a deeper understanding of concepts and the development of communication, collaboration, and creativity (Barron, 2010). The success of inquiry-based learning, however, is contingent on the knowledge and skills of the educators implementing it (Barron, 2010). Furthermore, the integration of inquiry skills into interesting topics and ideas can further enhance creative thinking in early years education (Michalopoulou, 2014).

The 5E Inquiry-Based Learning Approach, explained by Duran and Duran (2004), is a helpful method for encouraging inquiry in science education. This approach consists of five stages: engagement, exploration, explanation, elaboration, and evaluation. Research by Chen (2021) suggests that this method is successful in developing students' communication skills and collaborative mindset in the workplace. Goldston et al. (2013) also back the effectiveness of the 5E model, conducting a detailed examination of a scoring tool for inquiry-based teaching. In addition, teaching using multimedia aids allows learners to visualize concepts clearly, resulting in a faster understanding of the content. This aligns with the statement made by Kirkwood (1996) that the use of media in education is a growing trend, driven by technological and economic factors. This trend has led to the development of transmedia approaches, which aim to expand the reach and impact of educational media (Fisch, 2016). Integrating technology and real-world applications further enhances the creative aspects of mathematical thinking (Silver, 1997).

Due to the reasons mentioned above, the researcher was motivated to enhance learning outcomes and foster creative thinking skills in mathematics through the implementation of Inquiry-Based Learning (5E) along with supplementary media. The chosen media include the GeoGebra program and lessons from the Mathigon web application, specifically focusing on the topic of Geometric Transformations for 10th-grade students in Thailand.

1.2 Research Objectives

- To compare the mathematical proficiency regarding geometric transformations of 10th-grade students before and after implementing the 5E Inquiry-Based Learning Approach with supplementary media.
- To investigate the creative thinking skills, specifically focusing on flexibility, originality, fluency, and elaboration, among the students.

2. Method

2.1 Target Group

The target group for this research comprises 10th-grade students from a large-sized school in the northeastern region of Thailand. Specifically, one classroom with a total of 40 students will be involved in the study.

2.2 Variables

2.2.1 Independent Variable

The independent variable in this research is the implementation of Inquiry-Based Learning (5E) approach with supplementary media. This variable focuses on the instructional method employed during the research.

2.2.2 Dependent Variables

Mathematical proficiency: The content scope for Geometric Transformation includes translation, reflection, and rotation.

Creative thinking skills: The component consist of Originality, Fluency, Flexibility and Elaboration

2.3 Research Tools

The tools utilized in this research include:

1) Lesson plans: Developed based on the 5E Inquiry-Based Learning Approach with supplementary Media - the GeoGebra and lessons from the Mathigon web application, ensuring its quality through expert reviews. The lesson examples from both platforms can be found in Figure 1 and Figure 2.

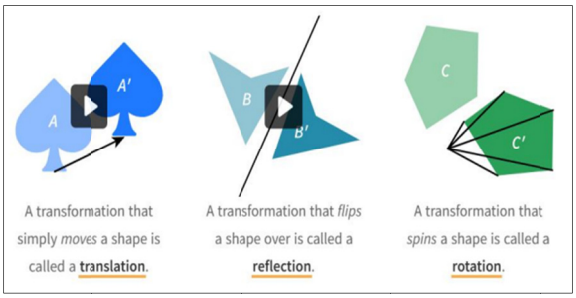

Figure 1. Example lessons from the Mathigon web application

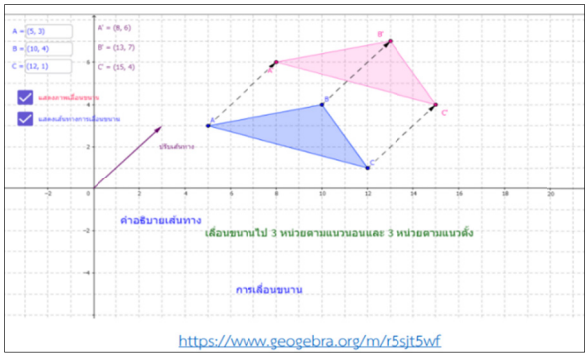

Figure 2. Example from the GeoGebra

The 5E Inquiry-Based Learning Approach with supplementary media involves the following steps:

Engagement:

This is the entry point into the lesson, which may generate interest through the use of supplementary media, such as the Mathigon web application, which presents colorful and engaging content.

Exploration:

This step involves understanding the topic of study by using GeoGebra to create geometric transformations to explain various transformation processes, enhancing students' understanding and visualization.

Explanation and Summarization:

This step involves analyzing, interpreting, and summarizing the gathered information. The results are presented in the form of drawings, tables, or graphs. PowerPoint presentations are used in this step to present the summarized knowledge systematically.

Elaboration:

Students collaborate to answer questions and consolidate the knowledge they have gained.

Evaluation:

Students complete exercises to assess their understanding of the material learned.

2) Mathematics Proficiency test: This test is employed to evaluate mathematical abilities using a multiple-choice format consisting of 20 questions. It focuses specifically on geometric transformations, which involve the movement of geometric shapes through translation, reflection, and rotation. Examples of questions are as follows:

Which transformation preserves both shape and size?

a) Translation

b) Reflection

c) Rotation

d) Dilation

If a triangle is reflected over the x-axis, what happens to its vertices?

a) They move vertically downward.

b) They move vertically upward.

c) They move horizontally to the left.

d) They remain unchanged.

What is the result of a 180-degree rotation of a rectangle about its center?

a) A congruent rectangle

b) A square

c) A parallelogram

d) A trapezoid

3) Creative thinking skills test: This test assigns tasks to students to solve a variety of Mathematics problems and assesses their responses using a rubric scoring system. Details as presented in Table 1.

Table 1. Scoring rubric for creative thinking

Criteria	Excellent (4 points)	Good (3 points)	Fair (2 points)	Poor (1 point)
1. Flexibility	Can find answers that address the issue. Responses are correct and appropriate 90% or more of the time within the given time limit.	Can find answers that address the issue. Responses are correct and appropriate 70% or more of the time within the given time limit.	Can find answers that address the issue. Responses are correct and appropriate 50% or more of the time within the given time limit.	Can find answers that address the issue. Responses are correct and appropriate less than 50% of the time within the given time limit.
2. Originality	Can find answers according to the given situation with a variety of methods.	Can find answers according to the given situation with relatively diverse methods predominantly.	Can find answers according to the given situation with some diversity.	Can find answers according to the given situation with limited diversity.
3. Fluency	Can find answers that stand out, are unusual, and differ from others' responses. Uses knowledge-based thinking methods effectively and can apply them correctly.	Can find answers that stand out, are unusual, and differ from others' responses. Uses knowledge-based thinking methods and can apply them correctly mostly.	Can find answers that stand out, are unusual, and differ from others' responses. Uses knowledge-based thinking methods and can apply them partially.	Can find answers that stand out, are unusual, and differ from others' responses. Uses knowledge-based thinking methods and applies them correctly to a lesser extent.
4. Elaboration	Answers are within the scoring criteria. Can describe various details and link them together with proper planning. Can explain accurately.	Answers are within the scoring criteria. Can describe various details and link them together with proper planning. Can explain accurately mostly.	Answers are within the scoring criteria. Can describe various details and link them together with some planning. Can explain accurately partially.	Answers are within the scoring criteria. Can describe various details and link them together with some planning. Can explain accurately to a lesser extent.

2.4 Data Analysis

The analysis aimed to provide insights into the effectiveness of the implemented approach by examining average scores, percentages, and standard deviations related to mathematics proficiency and creative thinking skills among the student.

3. Result

The results of comparing the mathematical proficiency in geometric transformations among 10th-grade students before and after implementing the 5E Inquiry-Based Learning Approach with supplementary media revealed a notable increase of 37.25%. Prior to the learning intervention, students scored an average of 4.64 out of 20, while post-intervention, the average score increased to 12.08 out of 20. Details as presented in Table 2.

Table 2. Mathematics proficiency progress of students using 5E inquiry-based learning with supplementary media

Learning Approach	Pre-test Average Score	Post-test Average Score	Progress Percentage
5E Inquiry-Based with Supplementary Media	4.63 (23.13% of 20 points)	12.08 (60.40% of 20 points)	37.25%

Results of the investigation into the creative thinking skills in mathematics reveal that, overall, students are at a proficient level with an average score of 22.60 out of a maximum of 32 points. Examining each aspect, with a full score of 8 points for each dimension, the findings indicate the following average scores: Originality 5.60, Fluency 5.78, Flexibility 5.63, and Elaboration 5.60. Details as presented in Table 3.

Table 3. Creative thinking skills in mathematics proficiency

Dimension	Full Score	Average Score	*SD*
Originality	8	5.60	0.89
Fluency	8	5.78	0.95
Flexibility	8	5.63	0.85
Elaboration	8	5.60	0.99
Total	32	22.6	0.88

4. Discussions

The 5E Inquiry-Based Learning Approach has been shown to improve mathematical proficiency in several ways. Bakri (2021) found that it enhances conceptual and procedural knowledge, as well as flexibility in problem-solving. This is further supported by Mujtahid et al. (2018), who demonstrated that inquiry-based learning through lesson study can improve students' problem-solving abilities. Cartilla and Rondina (2020) also noted that the 5E model can enhance teachers' pedagogical practice, leading to improved student performance. Finally, Chowdhury (2016) found that the constructivist approach, which underpins the 5E model, significantly improves student achievement in mathematics. These studies collectively suggest that the 5E Inquiry-Based Learning Approach can enhance mathematical proficiency through improved problem-solving abilities, pedagogical practice, and student achievement. Furthermore, the use of supplementary media plays a crucial role in enhancing mathematical proficiency after learning aligned with previous research findings, which demonstrate that the use of visual and animated media can significantly enhance mathematical problem-solving skills (Widodo et al., 2019; Luzón & Letón, 2015). However, the effectiveness of these media is contingent on their appropriateness and alignment with the learners' characteristics (Widodo et al., 2018).

From the research findings, it can be elucidated that students, after undergoing the 5E Inquiry-Based Learning Approach with supplementary media in the topic of geometric transformations, exhibit a proficient level of creative thinking skills in mathematics. This indicates that the teaching method effectively promotes creative thinking skills in mathematics among 10th-grade students. The previous research studies are consistent in demonstrating that the 5E Inquiry-Based Learning Approach, when combined with supplementary media, significantly enhanced creative thinking skills in mathematics. Indarasati (2019) found that this approach, which involves engagement, exploration, explanation, elaboration, and evaluation, is effective in promoting creative problem-solving and mathematical creativity. Aziz and Suparman (2020) further supports this, emphasizing the importance of stimulating creative thinking skills in 21st-century learning and the potential of the inquiry learning model to achieve this. Brown et al. (2007) provides a practical example of the successful use of an inquiry approach to develop mathematical thinking, demonstrating its potential to enhance creative thinking skills.

5. Research Recommendations

5.1 Teacher Preparation and Implementation

Teachers should undergo thorough training and preparation before implementing the Inquiry-Based Learning (5E) approach. Emphasis should be placed on prioritizing student-centered activities, focusing on the components of knowledge construction, interaction, physical participation, procedural learning, and application of knowledge.

5.2 Clarification and Documentation

In each instructional medium used to support teaching, educators should provide clear explanations and ensure comprehensive documentation of various student activities. This documentation serves as valuable data for analysis, evaluation, and continuous improvement of the learning process in future lesson plans.

5.3 Post-Lesson Reflection and Discussion

After each session of the Inquiry-Based Learning (5E) approach, there should be a collaborative post-lesson reflection. This reflection should encompass a summary of the conducted activities, how students responded, and their feelings about the activities. It is essential to open opportunities for students to express their thoughts and experiences gained through hands-on activities, with the teacher acting as a facilitator rather than a sole authority.

6. Limitation

The research has certain limitations due to its experimental nature with a small sample size, which might not fully represent the entire population. Hence, careful consideration is needed when applying the research outcomes.

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Authors contributions

Asst. Prof. Dr. Tatsirin Sawangboon was responsible for study design and revising. Chanoknan Kwangpukieo was responsible for conducting teaching activities according to the lesson plans and collecting data in the school while she was a student teacher. Asst. Prof. Dr. Tatsirin Sawangboon drafted the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.