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Development of creativity-based learning activities to promote creative thinking of grade 6 students on the topic of polygons

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ABSTRACT

This research aimed to: i) develop creativity-based learning activities (CBL) for grade 6 students on polygons to meet the 80/80 efficiency criterion; ii) compare mathematics learning achievement before and after CBL instruction; and iii) compare creative thinking before and after CBL instruction. The sample consisted of 22 grade 6 students at Chumchon Ban Chom Sa-at School, Roi Et Province, Thailand, selected via cluster random sampling. Research instruments comprised 17 CBL lesson plans, a 20-item multiple-choice achievement test, and an 8-item open-ended creative thinking test. Data were analyzed using percentage, mean, standard deviation, and paired samples t-test. The findings revealed that: i) the CBL activities achieved an efficiency index of 83.67/83.18, exceeding the 80/80 criterion; ii) post-instruction mathematics achievement was significantly higher than pre-instruction at the 0.05 significance level; and iii) post-instruction creative thinking was significantly higher than pre-instruction at the 0.05 significance level. These results indicate that CBL is an effective instructional approach for enhancing both mathematics achievement and creative thinking among primary school students.

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1. INTRODUCTION

Mathematical creative thinking is considered a core element of 21st century learning, enabling learners to develop a genuine deep understanding of concepts rather than memorizing formulas or following conventional procedures. It also allows learners to effectively connect mathematical knowledge and apply it to real world situations [1], [2]. In a world characterized by complex problems and rapid change, creative thinking is an indispensable skill for meeting such challenges [3]. A growing body of research further indicates that creative thinking is significantly correlated with mathematics achievement and higher-order thinking abilities including analysis, synthesis, and evaluation. Therefore, fostering creative thinking in mathematics classrooms is a crucial approach to developing well rounded and sustainably capable learners [4].

Thailand's basic education core curriculum B.E.2551 (A.D. 2008) prescribes a learner-centered approach to instruction, aimed at developing analytical thinking, synthetic thinking, creative thinking, as well as critical and systematic thinking. These skills are regarded as essential foundations for quality living, decision making, and productive participation in society. However, the majority of students tend to perform well only when solving problems using teacher demonstrated methods (procedural thinking), while still lacking the ability to think flexibly and to generate novel approaches or answers (originality) [5], [6]. Both of which are key components of mathematical creative thinking [7]. When assessed against the criteria of fluency, Flexibility, and originality, many students remain at the “non-creative” or “minimally creative” levels, reflecting a persistent gap between the intentions of the curriculum and the actual outcomes achieved in classrooms [8], [9].

Research on students’ creative thinking in mathematics reveals common difficulties across different achievement levels and countries, including Thailand and Indonesia. High-achieving students tend to perform well in fluency and flexibility but struggle with novelty or originality, while average and low achievers face challenges in fluency, flexibility, understanding problems, and systematic problem-solving [4], [10], [11]. Students often rely on routine methods and trial-and-error strategies, limiting their ability to generate diverse solutions or represent problems creatively [5], [7]. Learning obstacles include a strong focus on procedural tasks in instruction, conceptual misunderstandings, and rigid perceptions of mathematics, which hinder creative thinking development [12].

A study of the mathematics instructional conditions at Chumchon Ban Chom Sa-at School, Mueang Yodwi District, Roi Et Province, Thailand, identified three major problems: the abstract nature of the content, which learners cannot visualize as clearly as in other subjects; a lack of diversity in instructional approaches; and individual differences among learners [13]. These findings align with the external quality assessment report for the primary school level, which recommended that teachers design instruction responsive to individual differences, emphasizing activities that encourage learners to think independently, solve problems, and construct their own knowledge as well as increasing the use of media, local wisdom, and appropriate technology in teaching and learning. More significantly, the report highlighted that learner have not been given sufficient opportunities to practice higher-order thinking skills including analysis, synthesis, connection, and evaluation which are fundamental to mathematical creative thinking and are directly related to long-term learning achievement.

Creativity-based learning (CBL) is one form of active learning that has been studied and researched in the context of Thai students. It is grounded in problem-based learning (PBL), integrated with Edward de Bono’s concept of developing creative thinking through lateral thinking. The primary goal of CBL is to develop both academic content knowledge and 21st century skills in learners particularly creative thinking, analytical thinking, problem-solving, and independent knowledge seeking. In this learning process, the teacher’s role is not limited to that of an instructor, but extends to that of a learning coach who provides guidance, a learning travel agent who leads learners in exploring knowledge from diverse contexts, and a learning designer who can effectively create activities that promote creative thinking [14]. The CBL process consists of five main stages: stimulating interest, posing problems and grouping students according to their interests, researching and developing ideas, presenting learning outcomes, and evaluating learning outcomes. Implementing this process in mathematics education allows students to learn subject content while concurrently and concretely developing their creative thinking skills and aligns with the goal of preparing learners to contribute creatively to the nation’s future development. The CBL process is therefore an instructional approach that promotes learners’ development of analytical thinking, communication, collaboration, and creative thinking through authentic, hands-on practice [15], [16].

For the reasons outlined above, the researcher was interested in studying the development of CBL activities to enhance the creative thinking of grade 6 students on the topic of polygons. It is anticipated that the development of such learning activities will help elevate the effectiveness of student learning and lead to increasingly appropriate instructional practices going forward. The novelty of this study lies in its contextual integration of the CBL model within the specific mathematical domain of polygons at the primary school level in Thailand, empirically demonstrating that CBL simultaneously enhances both mathematics learning achievement and creative thinking two outcomes that are rarely measured together in a single quasi-experimental study at this grade level. This dual-outcome design, combined with the 80/80 efficiency criterion validation, provides a replicable instructional framework applicable to other mathematical topics and underserved primary school contexts in Southeast Asia.

2. LITERATURE REVIEW

CBL is an approach to learning activity design that helps learners transition from existing knowledge toward new ways of thinking and practice, ultimately generating new understandings that hold personal meaning and can create value for others [17]–[19]. This perspective holds that creativity is not separate from content learning, but rather emerges from the integration of creative expression such as designing, producing work, or devising new solutions with regular academic learning, enabling learners to understand content across various disciplines more deeply and connectedly [18]. CBL is underpinned by at least four key principles: i) learners have agency over their own learning (creative agency); ii) learning engages both emotion and the body through direct experience (affective/embodied); iii) learning occurs within relational systems and social contexts (relational ecologies); and iv) learning takes place through doing and making (learning by doing and making) [20].

Mathematical creative thinking refers to the capacity to reason logically and think divergently in order to generate diverse and novel mathematical ideas or solutions. Its primary indicators include fluency, flexibility, originality, and elaboration [21], [22]. This concept emphasizes skill development through context-rich learning approaches such as PBL and science, technology, engineering, and mathematics (STEM)/science, technology, engineering, arts, and mathematics (STEAM), which have evolved into CBL an approach that fosters deep creative thinking and problem solving [22], [23]. Key principles of mathematical creative thinking include providing students with opportunities to experiment with new approaches, build confidence, and make connections across different perspectives [2], [24]. Designing activities that encourage questioning, problem-posing, and independent problem-solving is also an important strategy for promoting creative thinking in mathematics classrooms [25]. Research further indicates that developing creative thinking requires teacher support and an environment conducive to experimentation and reflection [2], [23].

3. RESEARCH METHOD

3.1. Objectives

This study employed a one-group pretest–posttest quasi-experimental design, which is an appropriate framework for evaluating instructional interventions without a control group when ethical or logistical constraints make random assignment difficult. The study pursued three objectives: i) to develop CBL activity management for grade 6 students on the topic of polygons to meet the efficiency criterion of 80/80; ii) to compare the mathematics learning achievement of grade 6 students who received CBL activities on the topic of polygons between pre-instruction and post-instruction; and iii) to compare the creative thinking of grade 6 students who received CBL activities on the topic of polygons between pre-instruction and post-instruction. The 80/80 efficiency criterion is a well-established standard in Thai educational research for evaluating instructional materials, where E_1 (process efficiency) and E_2 (outcome efficiency) must each reach at least 80% to confirm that a set of learning activities meets acceptable quality thresholds.

3.2. Methodology

The population in this study consisted of 185 grade 6 students from 11 schools within the M Yodwi educational quality development cluster, Moeiwadi District, Roi Et Province, under the Roi Et Primary Educational Service Area Office 3, Thailand, in the academic year 2025. The sample comprised 22 grade 6 students enrolled in the second semester of the 2025 academic year at Chumchon Ban Chom Sa-at School, Moeiwadi District, Roi Et Province, under the Roi Et Primary Educational Service Area Office 3, constituting one classroom. The sample was obtained through cluster random sampling. This is because this group of students is similar to the majority of students in Thailand and the ASEAN region.

3.3. Research instruments

Three research instruments were employed in this study. The first instrument consisted of 17 CBL lesson plans on the topic of polygons for grade 6 mathematics, developed based on the basic education core curriculum B.E. 2008 and validated by five mathematics experts, who rated the lesson plans at an appropriate level of quality with mean scores ranging from 4.44 to 4.93, confirming readiness for implementation. The second instrument was a 20-item multiple-choice achievement test with discrimination indices ranging from 0.35 to 0.82 and an overall reliability coefficient of 0.93, analyzed using the Lovett method. The third instrument was an 8-items open-ended mathematical creative thinking test with difficulty indices ranging from 0.47 to 0.64, discrimination indices ranging from 0.56 to 0.74, and an overall reliability coefficient of 0.96, calculated using Cronbach's alpha method.

3.4. Data analysis

Data analysis proceeded in two stages following standard procedures for educational research. First, the efficiency of the CBL activity plans was evaluated against the 80/80 criterion, with process efficiency (E_1) derived from student worksheets, classroom behavior assessments, and quizzes, and outcome efficiency (E_2) derived from the posttest scores. Second, paired samples t-tests were used to compare students' mathematics learning achievement and creative thinking scores before and after instruction.

4. RESULTS

Efficiency of CBL activities on the topic of polygons for grade 6 students. The efficiency of the learning activities was determined by measuring the process efficiency (E_1) through students' activity worksheets, in-class learning behavior assessments, and in-class quizzes, weighted at a ratio of 30:30:40

respectively, and the outcome efficiency (E_2) measured through the learning achievement test, compared against the 80/80 criterion, as presented in Table 1.

Table 1. Efficiency of CBL activities on the topic of polygons for grade 6 students

Item (N=22)	Pretest (20)	Activity worksheets (30)	Classroom behavior (30)	Quizzes (40)	Total (100)	Posttest (20)
Total	248	595.94	562.5	682.36	1840.79	366
Mean ($\bar{x}$)	11.27	27.09	25.57	31.02	83.67	16.64
S.D.	1.32	1.31	3.17	2.77	6.01	1.80
Percentage	56.36	90.29	85.23	77.54	83.67	83.18

Note: S.D.=standard deviation; efficiency of CBL mathematics learning activities (E1/E2)=83.67/83.18.

As shown in Table 1, the mean score during instruction was 83.67% of the total score, and the mean posttest score was 16.64 out of a possible 20 points, representing 83.18% of the total score. Therefore, the CBL activities on the topic of polygons for grade 6 students achieved an efficiency index (E_1/E_2) of 83.67/83.18, meeting the established criterion. These results indicate that the instructional materials were well-designed and successfully facilitated both the learning process and the achievement of learning outcomes, consistent with the 80/80 efficiency standard used in Thai educational research.

Comparative analysis of mathematics learning achievement of grade 6 students who received CBL activities on the topic of polygons: pre-instruction vs. post-instruction in Table 2. As shown in the Table 2, students' post-instruction learning achievement was significantly higher than pre-instruction achievement following the CBL activities on the topic of polygons for grade 6 students, at the .05 level of statistical significance. The mean posttest score (16.64) was notably higher than the mean pretest score (11.27), yielding a mean paired difference of 5.36 points (t=20.04, p=0.00). This result confirms that the CBL instructional approach effectively improved students' mathematics learning achievement on the topic of polygons, consistent with evidence from comparable learner-centered interventions at the primary school level.

Table 2. Comparison of students' learning achievement before and after the learning activities

N	Pretest $\bar{x}$	Pretest S.D.	Posttest $\bar{x}$	Posttest S.D.	Paired Diff. $\bar{x}$	Paired Diff. S.D.	t-test	P
22	11.27	1.32	16.64	1.84	5.36	1.26	20.04*	0.00

Note: S.D.=standard deviation and Diff= difference. *Statistically significant at the 0.05 level.

Comparative analysis of creative thinking of grade 6 students who received CBL activities on the topic of polygons: pre-instruction vs. post-instruction in Table 3. As shown in the Table 3, students' post-instruction creative thinking was significantly higher than pre-instruction creative thinking following the CBL activities on the topic of polygons for grade 6 students, at the 0.05 level of statistical significance. The mean post-instruction creative thinking score (19.27) was substantially higher than the mean pre-instruction score (11.50), with a mean paired difference of 7.77 points (t=20.59, p=0.00). These findings demonstrate that CBL activities not only improved mathematics learning achievement but also cultivated higher-order creative thinking abilities in students, underscoring the dual academic value of this instructional approach.

Table 3. Comparison of students' creative thinking before and after the learning activities

N	Pretest $\bar{x}$	Pretest S.D.	Posttest $\bar{x}$	Posttest S.D.	Paired Diff. $\bar{x}$	Paired Diff. S.D.	t-test	P
22	11.50	1.60	19.27	1.75	7.77	1.73	20.59*	0.00

Note: S.D.=standard deviation and Diff= difference. *Statistically significant at the 0.05 level.

5. DISCUSSION

The CBL activities on the topic of polygons for grade 6 students achieved efficiency at the criterion of 83.67/83.18, meeting the established standard. This was attributable to the systematic design of the learning activities and the appropriately written lesson plans, which were developed by reviewing mathematics learning area documents aligned with the basic education core curriculum B.E. 2008, mathematics textbooks and teacher manuals, and clearly defined learning objectives. The researcher also studied documents on learning standards, indicators, learning content, core content, key competencies, and desirable characteristics of learners, and conducted curriculum and content analyses to ensure learners could achieve the learning objectives. The lesson plans underwent validation by five experts for accuracy, language appropriateness, content coverage, and alignment of learning objectives and activities, and were subsequently revised in accordance with the experts' recommendations. This aligns with the concept that a well-designed lesson plan should have clear and measurable learning objectives to guide instruction and assessment, along with a structure comprising an introduction, main content, and conclusion, with appropriate time management consistent with the curriculum [26], [27]. The lesson plan development process should begin with an analysis of the learner context and environment, followed by the appropriate determination of content, objectives, and assessment methods [28]. Good lesson plans also include seating arrangements and monitoring of classroom activities to enhance learning effectiveness. This is consistent with the research of Phon-Yiam [29], who studied the development of CBL mathematics learning activities integrated with technological pedagogical content knowledge (TPACK) to develop learning achievement and creative thinking on the topic of circles for grade 6 students. That study found the CBL-TPACK lesson plans achieved an efficiency of 87.15/83.89, exceeding the established criterion. This also aligns with the research of Koonkor *et al*. [30], who developed CBL activities to promote creative thinking and learning achievement on three-dimensional geometric shapes for grade 6 students, yielding an efficiency index (E1/E2) of 73.13/77.11, likewise exceeding the established criterion.

The learning achievement of students taught using CBL activities on the topic of Polygons for grade 6 was significantly higher after instruction than before, at the .05 level of statistical significance. This was due to the nature of CBL as a learner-centered instructional approach that provides students with opportunities to think, analyze, design, and solve problems independently through meaningful activities and situations, resulting in systematic self-constructed knowledge. This is consistent with the key principle of encouraging deep student engagement in problem-solving through activities that promote fluent, flexible, and creative thinking, with an emphasis on learning connected to real contexts and fostering learner autonomy [31]–[33]. This finding also aligns with research at the primary level clearly demonstrating that CBL-based instruction significantly improves students' creative thinking and mathematics achievement compared to traditional teaching [31], [34]. and with the research of Khalid *et al.* [35] and Hu and Wang [36], which found that non-lecture-based mathematics instruction involving student creative construction leads to markedly higher achievement outcomes.

Comparing the creative thinking of grade 6 students before and after CBL instruction on the topic of Polygons, the mean pre-instruction creative thinking test score was 11.50, while the mean post-instruction score was 19.27. It can be concluded that students' creative thinking after instruction was significantly higher than before, at the 0.05 level of statistical significance. This was because CBL is a learner-centered instructional model that promotes student participation in the learning process through collaboration, interaction, and the exchange of ideas among learners, resulting in an enthusiastic learning atmosphere conducive to sustained engagement. Learners were able to utilize their full potential in thinking, analyzing, and making independent decisions, with opportunities to express opinions and collaboratively solve problems within their groups, leading to self-constructed knowledge. This is consistent with the principle that mathematical creative thinking arising from creative construction emphasizes developing students' higher-order thinking through diverse and deep thought processes. Creative thinking is classified into three levels: imitation, modification, and construction with the construction level being the highest, at which students can solve problems independently and innovatively. Another key principle is the integration of mathematical content knowledge with questioning and logical problem-solving skills, along with learning approaches that allow students to experiment with new strategies and reflect on their own outcomes in order to genuinely foster creative thinking [37]. Research further indicates that developing creative thinking requires adequate time and an appropriate context such as open-ended problem design without fixed answers to stimulate broader and deeper thinking [38]. The emergence of mathematical creative thinking through creative construction is therefore a process that integrates knowledge, skills, and attitudes in independent and innovative problem-solving, enabling students to develop stronger analytical and complex problem-solving abilities [35], [38].

6. CONCLUSION

Based on the research findings, it can be concluded that CBL on the topic of polygons is an effective instructional model for promoting the creative thinking of grade 6 students, producing statistically significant improvements in both mathematical creative thinking and learning achievement. Theoretically, these results support the view that integrating problem-posing, lateral thinking, and collaborative inquiry within a structured five-stage CBL process creates cognitive conditions favorable to both content mastery and divergent thinking development. Practically, CBL activities can be further applied to develop mathematics instruction at the primary level across related content areas, and it is recommended that mathematics teachers receive targeted professional development in CBL design principles so that this approach can be systematically scaled across schools in similar underserved rural contexts in Thailand and the broader Southeast Asian region.

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Suphatta Thong Bo	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓
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C : **C**onceptualization	I : **I**nvestigation	Vi : **Vi**sualization
M : **M**ethodology	R : **R**esources	Su : **Su**pervision
So : **So**ftware	D : **D**ata Curation	P : **P**roject administration
Va : **Va**lidation	O : Writing - **O**riginal Draft	Fu : **Fu**nding acquisition
Fo : **Fo**rmal analysis	E : Writing - Review & **E**diting	

CONFLICT OF INTEREST STATEMENT

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. The authors state no conflict of interest.

INFORMED CONSENT

Not applicable. This study did not involve the collection or publication of any identifiable personal information (e.g., names, photographs, or videos) of participants

DATA AVAILABILITY

The data presented in this study are available on request from the corresponding author, [CC]. The data are not publicly available due to privacy or ethical restrictions.

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