

Research Article

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The Impact of Open Learning Approach on Mathematical Problem-Solving Skills and Academic Achievement in Basic Counting Principles among Grade 11 Students

Netnapa Sarakun , Yannapat Seehamongkon

Abstract

Background/purpose. This research aimed to 1) Compare mathematical problem-solving skills and academic achievement before and after learning the topic of Basic Counting Principles of Grade 11 students who were taught by traditional learning methods and open learning approach. 2) to compare mathematical problem-solving skills and academic achievement after learning the topic of Basic Counting Principles of Grade 11 students who were taught by traditional learning methods and an open learning approach. 3) to study students' satisfaction with the open learning approach on the topic of Basic Counting Principles.

Materials/methods. This research is an experimental design with a Pre-Test-Post-Test with a Real Control Group. The samples used in the study were 2 classes of Grade 11 students, 75 people, who were selected by Cluster Random Sampling. The tools used for data collection were an open learning approach plan and a traditional learning methods plan, a test to measure mathematical problem-solving skills, an achievement test, and a satisfaction survey towards an open learning approach.

Results. The research results found that 1) students in both groups had mathematical problem-solving skills and academic achievement after studying higher than before studying at a statistical significance level of 0.05 2) students in the open learning approach group had mathematical problem-solving skills and academic achievement after studying higher than the group that received traditional learning methods at a statistical significance level of 0.05 and 3) students had the highest level of satisfaction with the open learning approach, with a mean value of 4.84 and a standard deviation of 0.11.

Conclusion. The open learning approach enables learners to develop analytical thinking and problem-solving skills effectively, as well as creating greater satisfaction in learning compared to traditional learning. Therefore, it should be promoted to use this approach in managing mathematics learning in secondary schools.

1. Introduction

Mathematics plays a crucial role in the success of learning in the 21st century because mathematics helps humans to be creative, think logically, systematically, and systematically, analyze problems or situations carefully and thoroughly, and help predict, plan, make decisions, and solve problems correctly and appropriately, and can be applied in real life effectively. According to the learning standards and indicators of the Mathematics Learning Group (Revised Edition 2017), the Basic Education Core Curriculum B.E. 2551 takes into account promoting learners to have skills in thinking, analysis, critical thinking, problem-solving skills, using technology, communication, and cooperation, which will allow learners to keep up with changes in the economic, social, cultural, and environmental systems and be able to compete and live with people around the world. In addition, successful mathematics learning must prepare learners to be ready to learn various things, be ready to work after graduation, or be able to continue their studies at a higher level. Therefore, educational institutions should organize learning appropriately according to the learners' potential (Ministry of Education, 2017). Mathematics helps learners understand abstract concepts, and use logical reasoning, which are necessary skills for systematic thinking and innovation. Teaching mathematics should focus on practical work and participation in learning management to the fullest potential, not just memorizing formulas or methods for solving problems as the teacher suggests. This is to prepare learners to be able to adapt to a complex and rapidly changing world (Boaler, 2022). The OECD (2023) study stated that countries that emphasize quality mathematics education tend to have high educational achievements and strong economies. Therefore, learning mathematics is not limited to the classroom, but is also the foundation for the ability to solve real-world problems, such as financial management, data analysis, and understanding probability in various situations. Therefore, the importance of mathematics is not only in the subject content, but also in developing learners' abilities to think, analyze, solve problems, and connect knowledge to real use, which are all essential foundations for lifelong learning.

In school learning management, it was found that most students are often trained to find answers and correct methods just like teachers who teach in the classroom, with repetitive teaching methods, most math teachers use the traditional teaching method, which emphasizes lecturing, giving examples and giving exercises to students. This teaching method only allows students to absorb information to remember without really understanding it, which makes Students unable to solve problems on their own. Some students often feel frustrated when faced with complex or unfamiliar problems and cannot use Learned methods to find answers efficiently, which affects their academic achievement, according to the annual report study. A school located in the northeastern region of Thailand found the Academic achievement of Grade 11 students, Semester 1, Academic Year 2023. Students have academic achievement scores. The average academic achievement score was 70.04 percent and the second semester of the academic year 2023 found that students had an average academic achievement score of 70.08 percent. Especially in the subject of Basic Counting Principles, which will be used in the 6th grade of secondary school, which will affect the O-NET exam as well. Results of the National Basic Education Test (O-NET) for Grade 12 students, academic year 2022, Mathematics subject the average score was 19.77 percent, which is less than half of the full score (National Institute of Educational Testing Service (Public Organization), 2023). Observing the students' performance in the exercises and from the mid-course test, it can be seen that most students do not understand the problem situation. Students are unable to analyze the problem situations that the teacher has given them. Students also have problems with knowledge and understanding about solving mathematical problems. Students still lack the skills and mathematical processes necessary for solving mathematical problems, resulting in incorrect answers. This results in low academic achievement and the teaching is not as successful as it should be. Due to these problems, mathematics teachers need to change their teaching methods to keep up with the times

by organizing learning to encourage students to develop skills in solving problems by themselves and for students to have better achievement than last year. Teachers must support, assist, and explain details. Student.

The open learning approach aims to enable all students to learn mathematics according to their abilities and with self-determination. Open-method teaching focuses on students' concepts or learning processes rather than teaching the content in its entirety. Noda (2000) mentioned opening up the hearts of students toward mathematics, which teachers must try their best to ensure that educational activities are in the best environment for learning and provide opportunities for students to learn to their full potential. In general, in teaching mathematics, teachers are responsible for helping students understand the content, explaining or conveying their thinking to students, and expanding mathematical concepts and positive attitudes toward mathematics and other matters. However, such mathematics teaching is based on teachers' traditional ideas and cannot open students' minds. This is different from teaching using open methods, which aims for all students to learn mathematics to their full potential with thinking process skills. Open-method teaching adheres to three principles: 1) Learning that allows students to freely express their ideas; 2) Learning that integrates the mathematical world with the real world, and 3) Learning that facilitates teachers to organize teaching and learning that is consistent with the student's context. Organizing learning activities with open methods provides students with a variety of methods that aim to stimulate their ideas so that they can construct their knowledge components and solve various problem situations. Of course, open-ended learning also creates opportunities for students to learn together, talk, exchange ideas, and listen to different perspectives. As Leikin and Levav-Waynberg (2015) pointed out, learning through open-ended questions can effectively foster creativity and cooperation among students. This type of learning also promotes critical thinking skills by asking open-ended questions that require students to interpret, analyze, and propose their solutions. Aziza (2021) studied the use of open-ended questions in the classroom and found that this method can help students develop their ability to explain their reasons and actively participate in the lesson.

From the study of academic documents and related research, it was found that the open learning approach on the subject of Basic Counting Principles for Grade 11 students can promote students to develop their ability to solve mathematical problems, resulting in better academic achievement of students. It can be applied as a guideline for teaching mathematics in other contents and at other levels to be more effective in the future.

2. Literature Review

2.1. Open Learning Approach

The use of open-ended questions in the mathematics classroom is very beneficial to students' learning experiences (Mela Aziza, 2021), such questions encourage learners to express diverse opinions, develop reasoning skills, and increase engagement. Importantly, these activities enhance higher-order thinking and positively influence students' attitudes toward mathematics (Savery, 2022) is a learner-centered approach that encourages students to explore and determine their learning paths through open-ended activities. This approach promotes critical thinking, problem-solving, and self-directed learning by avoiding fixed or one-size-fits-all answers (Murphy & Rodríguez-Manzanares, 2023) expand on the role of teachers within this approach by emphasizing that educators act as facilitators rather than traditional knowledge providers. They guide students through experiences that involve exploration, collaborative learning, discussion, and sharing of ideas, making learning more dynamic and engaging. Science education, (Wei, 2019) outlined a framework of practices for implementing open-ended learning, which includes presenting open-ended problems, working in groups to explore different solutions, and summarizing knowledge through group

discussion and reflection. This sequence effectively develops critical thinking skills and promotes peer learning.

2.2. Traditional Learning Methods

Traditional learning methods, sometimes referred to as traditional learning methods, is a teaching style that emphasizes one-on-one learning between a teacher and students in a classroom setting, where the teacher primarily lectures and students listen, take notes, read books, and do exercises (Moore, 2020; Bates, 2021). This style has a fixed learning structure, such as a specific time and place for teaching, and assessments often focus on memory tests and quizzes. However, traditional learning methods also have the advantage of creating direct interaction between teachers and students, allowing immediate communication and problem-solving (Bates, 2021). On the other hand, it lacks flexibility and is less responsive to individual students' needs or learning speed (Moore, 2020). A study by Alessa and Hussein (2023) compared teachers' perspectives on traditional learning methods and modern teaching methods, finding significant differences between the two. Traditional learning methods have clear limitations and advantages when used in a real classroom context. Teachers plan and prepare instructional materials according to the curriculum and learning objectives, such as books, exercises, and lecture slides (Bates, 2021), before conveying knowledge through lectures and having students listen and take notes sequentially (Moore, 2020). This process emphasizes the direct transfer of knowledge from teachers to students.

2.3. Mathematics Problem-Solving Skills

Mathematical problem-solving skills are an important process that directly affects students' academic achievement. Many studies have clearly defined and described the steps involved in this skill (Schoenfeld, 2021). It is explained that the process of mathematical problem-solving skills consists of the following main steps: understanding the problem, planning a solution, applying mathematical problem-solving skills, and checking the correctness of the answer. This is consistent with the study of (Wang and Lin, 2023), who divided the problem-solving process into 4 main steps: understanding the problem, in which students must interpret the problem correctly and clearly understand the data and goals of the problem; planning and selecting a strategy (Devising a Plan), which is a systematic plan and selecting appropriate methods, such as setting up equations or drawing illustrations; implementing the plan, in which students will use mathematical skills and basic knowledge to find the answer; and looking back/checking, in which students review and evaluate whether the answer is correct and consistent with the problem, and correct errors if found. In addition, (Wang and Lin, 2023) emphasized the importance of perseverance and motivation. This will help students not to give up and face obstacles in the mathematics problem-solving process (Melawati et al., 2022) emphasized the importance of understanding the problem and problem-solving steps that affect students' mathematics achievement, while (Cai and Hwang, 2023) defined mathematics problem-solving skills as the process in which learners develop mental models to deal with tasks with diverse contexts and objectives.

2.4. Academic Achievement

Academic achievement refers to the level of knowledge, understanding, or skills that a learner can demonstrate by the objectives of a course or unit of study, often measured by test scores, assessments, or tangible educational outcomes (Ormrod, 2022). (Slavin, 2022) added that academic achievement is an "educational outcome" that reflects the learner's learning performance and is an important indicator of the quality of teaching and learning. This achievement is influenced by many factors, such as teaching methods, motivation, and learner background. In Mathematics (Kadir, 2023), mathematics achievement is defined as the level of student achievement, as measured by standardized test scores, grades, and learning assessments, that reflect students' understanding and mathematical skills. For a systematic assessment of academic achievement, a popular testing tool is

the Wechsler Individual Achievement Test – Fourth Edition (WIAT-4), 2020, a standardized test that assesses academic achievement in several areas, such as listening, speaking, reading, writing, and mathematics, covering learners from childhood to adulthood. In the latest version, new subtests, such as pronunciation ability, have been added, as well as an automatic scoring system for essay writing.

2.5. Satisfaction

Satisfaction is an important indicator of the quality of teaching and learning. (Zhu et al., 2023) explained that learning satisfaction refers to the degree to which learners feel satisfied with the learning process, such as content, teaching, engagement, and outcomes. This is consistent with the concept of (Kotler and Keller, 2023), who defined “satisfaction” as a positive or negative feeling resulting from comparing expectations with actual outcomes. (According to the study by Cole, Shelley, and Swartz, 2014), Factors affecting the satisfaction of undergraduate and graduate students studying in online courses include the convenience of online learning, interaction with instructors and classmates, course structure, and technical support, all of which play an important role in the learner’s learning experience.

3. Methodology

3.1. Research design

This research is experimental. The research design is Pre-Test-Post-Test with a Real Control Group (Faculty of Educational Research and Development, Faculty of Education, Mahasarakham University, 2015).

3.2. Population and sample

The population consisted of Grade 11 students at A school in the northeastern region of Thailand during the second semester of the 2024 academic year, totaling 444 students across 12 classrooms. The school arranged students in each classroom with mixed abilities. The sample consisted of 75 Grade 11 students selected by cluster random sampling due to the dispersed nature of the population and the difficulty in organizing a comprehensive population framework. The sampling process involved studying the basic characteristics of the population and grouping students into subgroups based on similarities and differences within and between groups. Specifically, Grade 11, and Section 3 students had an average pre-test score of 1.650 in mathematical problem-solving skills and 1.075 in academic achievement, whereas Grade 11, and Section 12 students had average scores of 0.486 and 8.200, respectively. The sample was randomly selected by drawing lots, resulting in an experimental group of 40 students from Section 3, who studied using the open learning approach, and a control group of 35 students from Section 12, who received traditional learning methods on the topic of Basic Counting Principles.

3.3. Instruments Used for Data Collection

The instruments used for data collection consisted of the following: lesson plans based on the open learning approach and traditional learning methods on the topic of Basic Counting Principles, totaling 12 plans with 12 hours of instructional time; a mathematics problem-solving test comprising 5 open-ended questions; an academic achievement test on Basic Counting Principles containing 30 multiple-choice questions, each with 5 options; and a 20-item satisfaction survey designed to evaluate students’ satisfaction with the open learning approach.

3.4. Creation and qualitative development of research instruments

In developing the research instruments, the researcher followed systematic steps to ensure validity and reliability. Twelve open learning approach lesson plans and twelve traditional learning

method lesson plans on the topic of Basic Counting Principles (totaling 12 hours each) were constructed based on the Basic Education Core Curriculum B.E. 2551 and the school's curriculum for Grade 11 mathematics. Both sets were evaluated by experts, yielding scores ranging from 4.70 to 5.00, indicating the highest level of appropriateness, and were revised according to expert recommendations. A mathematics problem-solving skills test was developed using five out of seven initially constructed subjective items aligned with the learning content. After piloting with 37 non-sample students, five items were selected based on acceptable difficulty (0.432–0.568), discrimination (0.273–0.477), and reliability (0.614). A 30-item multiple-choice achievement test was developed from 37 initial items, validated through expert review (IOC = 0.80), and tested with non-sample students. The selected 30 items demonstrated suitable difficulty (0.22–0.67), discrimination (0.22–0.72), and reliability (0.79 using Lovett's method). Additionally, a 15-item student satisfaction questionnaire was created to assess satisfaction with the open learning approach in three dimensions: learning activity organization, learning atmosphere, and assessment. The instrument was validated by experts (IOC = 1.00) and yielded high reliability (0.924) and discrimination indices ranging from 0.548 to 0.852. All instruments were finalized for implementation with the sample group.

3.5. Data Collection

This study employed a true experimental research design using a post-test control group design to examine the development of mathematical problem-solving skills on the topic of basic counting principles among Grade 11 students. The intervention was conducted over a total of 12 hours using both traditional learning methods and an open learning approach. The data collection procedures were as follows: A pre-test was administered to assess students' prior knowledge using a 30-item multiple-choice achievement test (60 minutes) and a mathematics problem-solving skills test comprising 5 subjective written questions (60 minutes). The learning intervention was implemented with 75 Grade 11 students from a school in northeastern Thailand during the second semester of the 2024 academic year, divided into an experimental group (40 students from Grade 11, Section 3) who received instruction through the open learning approach, and a control group (35 students from Grade 11, Section 12) who received traditional instruction. Upon completion of the intervention, a post-test was conducted using the same 30-item achievement test and the 5-question problem-solving skills test. A satisfaction questionnaire was administered to the experimental group immediately after the teaching activities and All collected data were analyzed in accordance with the research objectives.

3.6. Data Analysis

The researcher analyzes comparative data on mathematics problem-solving skills and academic achievement before and after studying the topic of Basic Counting Principles among Grade 11 students who received an open learning approach, using statistics to test the research data. Specifically, the Paired Hotelling's T2 statistical method is employed. Analyze the comparative data on mathematics problem-solving skills and academic achievement after studying the topic of Basic Counting Principles among Grade 11 students who received traditional learning methods and an open learning approach, as measured by statistics using Two Samples Hotelling's T2 statistical method. And to study the satisfaction of students with an open learning approach on the topic of Basic Counting Principles.

4. Results

4.1. Data Analysis Results

Section 1: Comparative analysis of mathematics problem-solving skills and academic achievement before and after studying the topic of Basic Counting Principles of Grade 11 Students who received Traditional Learning Methods and Open Learning Approach.

The researcher compared the mathematics problem-solving skills and academic achievement before and after studying with the target group of 40 students, who were Grade 11 students. The mean and standard deviation were analyzed.

Table 1. Problem-solving skills before and after open learning approach

Experiment	n	Full Score	Mean	S.D.	df	t	Sig
Pre-Test	40	10	1.650	2.007	39	-18.715	0.000*
Post-Test	40		7.375	2.371			

* Statistically significant at the 0.05 level.

The analysis results in the table showed that the mathematics problem-solving skills of Grade 11 Students who received an open learning approach had a mean score after learning that was significantly higher than the mean score before learning, at a statistical significance level of 0.05.

Table 2. Academic achievement before and after open learning approach

Experiment	n	Full Score	Mean	S.D.	df	t	Sig
Pre-Test	40	30	10.075	3.682	39	-9.266	0.000*
Post-Test	40		17.200	3.911			

* Statistically significant at the 0.05 level.

From the analysis results table, it was found that in the comparison of academic achievement before and after studying Grade 11 students who received an open learning approach, the average score after studying was significantly higher than the average score before studying at the statistical level of 0.05.

Table 3. Problem-solving skills before and after traditional learning methods

Experiment	n	Full Score	Mean	S.D.	df	t	Sig
Pre-Test	35	10	0.486	1.245	34	-5.258	0.000*
Post-Test	35		2.114	2.398			

* Statistically significant at the 0.05 level.

The analysis results table showed that in the comparison of mathematics problem-solving skills of Grade 11 students who received traditional learning methods, the average score after learning was significantly higher than the average score before learning at the statistical level of 0.05.

Table 4. Academic achievement before and after traditional learning methods

Experiment	n	Full Score	Mean	S.D.	df	t	Sig
Before Learning	35	30	8.200	3.692	34	-5.580	0.000*
After Learning	35		12.457	5.118			

* Statistically significant at the 0.05 level.

From the analysis results table, it was found that in comparing academic achievement before and after studying Grade 11 students who received traditional learning methods, the average score after studying was significantly higher than the average score before studying at the statistical level of 0.05.

The researcher checked the preliminary agreement of the data analysis using the multivariate analysis test statistic, as shown in Table 5.

Table 5. Relationship between dependent variables after open learning approach

Variables	Mathematical Problem-Solving Skill (Post-Learning)	Academic Achievement (Post-Learning)	Sig
Mathematical Problem-Solving Skill (Post-Learning)	1.00	0.514	0.001*
Academic Achievement (Post-Learning)		1.00	

* Statistically significant at the 0.05 level.

The analysis results table found that the correlation coefficient between mathematics problem-solving skills after learning and academic achievement after learning with the open learning approach on the topic of Basic Counting Principles for Grade 11 students had a statistically significant positive relationship at the 0.05 level.

Table 6. Relationship between dependent variables after traditional learning methods

Variables	Mathematical Problem-Solving Skill (Post-Learning)	Academic Achievement (Post-Learning)	Sig
Mathematical Problem-Solving Skill (Post-Learning)	1.00	0.365	0.001*
Academic Achievement (Post-Learning)		1.00	

* Statistically significant at the 0.05 level.

From the analysis results table, it was found that the results of the analysis of the correlation coefficient between mathematics problem-solving skills after learning and academic achievement after learning by organizing traditional learning methods on the topic of basic counting principles of Grade 11 students were positively related with statistical significance at the 0.05 level.

From Tables 5-6, it was found that mathematics problem-solving skills and academic achievement after learning were positively related, with statistical significance at the 0.05 level, for Grade 11 students who received the traditional and open learning methods. Therefore, the researcher analyzed and compared the data using Hotelling's T^2 statistical method.

Table 7. Using Hotelling's T^2 statistical method, open learning approach

Test Statistic	Value	F	Hypothesis df	Error df	Sig
Hotelling's trace	448.83	218.66	2.000	38.000	0.000*

* Statistically significant at the 0.05 level.

The analysis results table showed that mathematical problem-solving skills and academic achievement in Basic Counting Principles among Grade 11 students who received an open learning approach were significantly higher after studying compared to before studying, with a statistical significance level of 0.05.

Table 8. Using Hotelling's T^2 statistical method, achievement traditional learning methods

Test Statistic	Value	F	Hypothesis df	Error df	Sig
Hotelling's trace	29.318	14.228	2.000	33.000	0.000*

* Statistically significant at the 0.05 level.

The analysis results table found that mathematical problem-solving skills and academic achievement in the subject of Basic Counting Principles of Grade 11 students who received traditional learning methods after studying were significantly higher than before studying at a statistical level of 0.05.

From Table 5-8, the distribution characteristics of the analyzed data tend to follow a multivariate normal distribution. The examination of the relationship of the dependent variable between mathematical problem-solving skills and academic achievement on the topic of Basic Counting Principles of Grade 11 students who received traditional learning methods and an open learning approach found a relationship. Therefore, it is considered appropriate to analyze multiple variances or use the Hotelling T^2 statistical method.

Section 2: Comparative Analysis of Mathematical Problem-Solving Skills and Academic Achievement After Studying the Topic of Basic Counting Principles Among Grade 11 Students Who Received Traditional Learning Method and Open Learning Approach

The researcher compared mathematical problem-solving skills and academic achievement after studying 75 Grade 11 students who received either the traditional or open learning methods. The analysis was conducted to determine the mean, standard deviation, and percentage.

Table 9. Comparison of problem-solving skills between learning methods

Open Learning Approach	n	Full Score	Mean	S.D.	df	t	Sig
Traditional Learning Method	35	10	2.114	2.398	73	-9.534	0.000*
Open Learning Approach	40		7.375	2.371			

* Statistically significant at the 0.05 level.

The analysis results table showed that in the comparison of mathematical problem-solving skills of the Grade 11 students, the post-learning scores of the open learning approach were significantly higher than the post-learning scores of the traditional learning methods at the statistical level of 0.05.

Table 10. Comparison of academic achievement between learning methods

Learning Management Approach	n	Full Score	Mean	S.D.	df	t	Sig
traditional learning method	35	30	12.457	5.118	73	-4.445	0.000*
open learning Approach	40		17.150	3.991			

* Statistically significant at the 0.05 level.

From the analysis results table, it was found that the comparison of academic achievement of Grade 11 students showed that the post-learning scores of the open learning approach were higher

than the post-learning scores of the traditional learning methods at a statistical significance level of 0.05.

Table 11. Relationship of Dependent Variables Principles between learning methods

Variable	Mathematical Problem-Solving Skill (Post-Learning)	Academic Achievement (Post-Learning)	Sig
Mathematical Problem-Solving Skill (Post-Learning)	1.00	0.613	0.000*
Academic Achievement (Post-Learning)		1.00	

* Statistically significant at the 0.05 level.

From the analysis results table, the correlation coefficient between mathematical problem-solving skills after learning and academic achievement after learning, based on both traditional learning methods and open learning Approaches, in the topic of Basic Counting Principles among Grade 11 students showed a positive relationship with statistical significance at the 0.05 level.

Table 12. Box's test of equality of covariance matrices

Box's M	F	df1	df2	Sig
4.129	1.335	3.000	73	0.261

From the analysis results table of Box's M test (Box's Test of Equality of Covariance Matrices), it was found that the $F = 1.335$ and the $Sig = 0.261$, indicating that the variance-covariance matrices of the populations are equal. This confirms the assumption of homogeneity of variance-covariance matrices.

Table 13. Using Hotelling's T^2 statistical method, between learning methods

Test statistics	Value	F	Hypothesis df	Error df	Sig
Hotelling's trace	96.407	47.543	2.000	72.000	0.000*

* Statistically significant at the 0.05 level.

From the analysis results table, mathematical problem-solving skills and academic achievement after studying the topic of Basic Counting Principles of Grade 11 students who received traditional learning methods and an open learning approach were found to be significantly higher than the post-learning scores of the traditional learning method at a statistical level of 0.05.

From Tables 11-13, the distribution characteristics of the analyzed data tended to be a multivariate normal distribution. The results of the examination of the relationship of the dependent variable between mathematical problem-solving skills and academic achievement in the topic of Basic Counting Principles of Grade 11 students who received traditional learning methods and an open learning approach found that they were related. Therefore, analyzing multiple variances or using the Hotelling T^2 statistical method is considered appropriate.

Section 3: Analysis of Student Satisfaction Toward the open learning approach on the Topic of Basic Counting Principles

Table 14. Students' satisfaction with the open learning approach

No.	Items	Satisfaction level			
		Mean	S.D.	Interpretation	
Aspect: Learning Activity Management					
1	The learning activities were appropriate to the learning content.	4.80	0.50	Highest	
2	The learning activities encouraged students to think creatively to solve problems.	4.70	0.61	Highest	
3	The learning activities promoted student collaboration and knowledge exchange.	4.80	0.41	Highest	
4	The learning activities helped students understand the content better.	4.68	0.62	Highest	
5	The learning activities provided opportunities to think from different scientific perspectives.	4.73	0.51	Highest	
Aspect: Learning Atmosphere					
1	The atmosphere of the activities allowed students to participate willingly.	4.90	0.30	Highest	
2	The atmosphere encouraged students to express opinions independently and in groups.	4.88	0.33	Highest	
3	The atmosphere encouraged students to express ideas creatively.	4.88	0.33	Highest	
4	The atmosphere allowed students to engage in activities with enjoyment.	4.90	0.30	Highest	
5	The atmosphere encouraged students to think from various viewpoints.	4.88	0.40	Highest	
Aspect: Assessment and Evaluation					
1	The assessment reflected the actual learning performance of the students.	4.90	0.30	Highest	
2	The explanation of learning objectives, teaching activities, and evaluation was clear and consistent.	4.85	0.36	Highest	
No.	Items	Satisfaction level			
		Mean	S.D.	Interpretation	
3	The evaluation method matched the learning activities appropriately.	4.90	0.38	Highest	
4	The evaluation reflected student development and learning achievements.	4.93	0.27	Highest	
5	The evaluation matched the subject’s goals and learning objectives.	4.85	0.36	Highest	

The analysis found that for students who were satisfied with the open learning approach, the opinions of the 5th-grade secondary students were at the highest level of satisfaction overall, with a mean of 4.84 and a standard deviation (S.D.) of 0.11.

5. Discussion

From the study of the results of the open learning approach that affects mathematical problem-solving skills and academic achievement on the topic of Basic Counting Principles of Grade 11 Students, the researcher presented the discussion as follows: The results of the comparison of mathematical problem-solving skills and academic achievement before and after studying the topic of Basic Counting Principles of Grade 11 students who received the traditional learning methods and the open learning approach found that the mean score after studying was higher than the mean score before studying at a statistical significance level of 0.05, which is consistent with the first hypothesis because this result is consistent with the concept of Novotná, Who stated that open learning approach allows students to have the opportunity to ask questions and solve problems systematically. And develop mathematical abilities through discussion and collaborative thinking in the classroom (Novotná et al., 2014). In addition, Research shows that using problem-posing and metacognition learning approaches helps students develop problem-solving skills (Kadir, 2023). Traditional learning still helps students develop basic skills steadily (Johnson & Smith, 2018), while the open learning approach promotes students to develop critical thinking and problem-solving skills in depth, which directly affects academic achievement (Lee, 2019). open learning approach also stimulates student engagement in learning through activities that emphasize communication and exchange of ideas, resulting in students having a deeper understanding of the content and being more motivated to learn (Brown, 2020). In addition, the development of mathematical problem-solving abilities also benefits from practicing systematic thinking skills and applying knowledge to solve real-world problems. Both learning methods can support the development of these skills (Garcia & Martinez, 2021).

The results of the comparison of mathematical problem-solving skills and academic achievement after studying the topic of Basic Counting Principles of Grade 11 students who received the traditional learning methods and the open learning approach found that the post-learning scores of the open learning approach were significantly higher than the post-learning scores of the normal learning management at a statistical level of 0.05, which is consistent with the open learning approach that encourages students to participate in learning more and think analytically by themselves. Stated that the open learning approach emphasizes that learners have the freedom to explore their ideas and connect their knowledge to real-life contexts, resulting in more meaningful learning than memorizing content (Munroe, 2015). Also showed that learning that stimulates critical thinking and mathematical communication helps promote confidence and efficiency in solving problems (Appiah et al., 2022). The research of Novotná, Stehlíková, and Tichá (2014) studied teachers' beliefs about the use of open-ended tasks in teaching mathematics and found that open-ended tasks can stimulate higher-level thinking. It promotes learners' active participation and results in deeper learning. In addition, it is consistent with Liljedahl's (2016) research that emphasizes the use of open-learning approaches in mathematics lessons. It was found that when learners are allowed to explore mathematical concepts by themselves under various situations, it will result in solid understanding and the ability to apply knowledge to solve problems effectively. The open learning approach emphasizes learners' participation, asking questions, finding answers by themselves, and exchanging ideas, which can develop both problem-solving skills and deep understanding, leading to better academic achievement. Therefore, the results of this research support the idea that designing learning using open problem-based learning can effectively develop mathematical skills and enhance students' academic achievement.

The results of the study on student satisfaction with the open learning approach on the topic of Basic Counting Principles found that Grade 11 students were satisfied with the open learning approach. Overall, it was at the highest level of satisfaction, with a mean of 4.84 and a standard deviation (S.D.) of 0.11, which is consistent with the study (Safarini & Kusumah, 2022). It was found that students were highly satisfied with learning using Open Educational Resources (OER). Cole et al. (2014) also confirmed that important factors affecting learner satisfaction in open-learning approach systems include learning freedom, teacher support, and classroom interaction (Cole et al., 2014). Panaoura, G. (2017) found that using an open-ended approach helps build learner confidence, increase satisfaction, and promote active participation in mathematics classes, especially when students feel that they are free to think and can express their opinions openly. In addition, Rahman, Roslan, & Badusah (2019) also found that the use of learner-centered learning activities, such as open learning approach helps increase students' intrinsic motivation and results in significantly higher levels of satisfaction with learning, especially in mathematics, which is often perceived as difficult and boring. Therefore, open learning, which allows students to express their opinions, explore on their own, and interact freely in the classroom, is an approach that can effectively increase satisfaction and enhance positive learning experiences.

6. Conclusion

6.1. Mathematical problem-solving skills and academic achievement before and after studying the topic of Basic Counting Principles of Grade 11 students who received the traditional learning methods and open learning approach found that students who received the traditional learning methods and students who received open learning approach could mathematical problem-solving skills and academic achievement after studying higher than before studying with statistical significance at the 0.05 level, which accepted the research hypothesis that was set.

6.2. Mathematical problem-solving skills and academic achievement After studying the topic of Basic Counting Principles of Grade 11 students who received the traditional learning methods and open learning approach found that students who received the open learning approach could have mathematical problem-solving skills and academic achievement higher than students who received traditional learning methods with statistical significance at the 0.05 level, which accepted the research hypothesis that was set.

6.3. The satisfaction of students with an open learning approach on the topic of Basic Counting Principles found that Grade 11 students were at the highest level of satisfaction overall with a mean value of 4.84 and a standard deviation (S.D.) of 0.11.

7. Suggestion

The open learning approach is a learning management that uses open-ended problem situations that are relevant to students and learner-focused. Each grade level has different content. Therefore, teachers should adjust the open-ended problem situations to be appropriate for the content and their students, to have a variety of problem-solving methods that are appropriate for that context, and to stimulate students to be more interested. Teachers should plan for organizing open-ended learning to be appropriate for students' learning time. Teachers choose interesting teaching media in addition to activity sheets, such as having a video of a problem situation to attract more interest in students' learning.

Declarations

Author Contributions. All authors have read and approved the published on the final version of the article.

Conflicts of Interest. The authors declare no conflict of interest.

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Ethical Approval. This study was conducted in compliance with ethical standards and was approved by the Mahasarakham University, under approval number 036-753/2568. All participants provided informed consent prior to participation, and their privacy and confidentiality were protected throughout the study.

Data Availability Statement. The data supporting this study's findings are available on request from the corresponding author. However, due to privacy or ethical restrictions, the data are not publicly available.

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