ENHANCING MATHEMATICS ACHIEVEMENT THROUGH ONLINE PROBLEM-POSING: A STUDY DURING THE COVID-19 PANDEMIC

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ABSTRACT

Problem-posing has been recognized for enhancing students' engagement, problem-solving skills, and mathematical knowledge, which leads to higher mathematics achievement. This research is experimental research with a randomized comparison groups pre-test and post-test design, which aims to examine the effect of using online problem-posing to develop students' mathematics achievement during the outbreak of the COVID-19 pandemic in Thailand. Sixty electrical engineering students of Rajamangala University participated in this study. The research instruments included a mathematics problem-posing lesson plan and a mathematics achievement test. The participants were tested for mathematics achievement before and after attending the programs. The result indicated a statistically significant difference in the mathematics post-test mean scores between the experimental and control groups. The experimental group gained higher mathematics achievement than the control group. Therefore, it is recommended that the problem-posing be used in teaching mathematics to the students.

INTRODUCTION

Problem-posing teaching techniques have attracted the attention of educators and researchers (Cai, 1998; English, 1997; Kilpatrick, 1987; Stoyanova, 1997). Many researchers presented consistent findings that posing mathematical problems can develop problem-solving skills, mathematical knowledge, and mathematical process skills that lead to higher mathematics achievement. (Cai, 1998; 2003; Cai & Hwang, 2002; Moses et al., 1990; Silver et al., 1996; Yuan & Sriraman, 2010). Problem-posing can be used to improve the mathematics achievements of students at the university level. For instance, Radmehr, Nedaei and Drake (2020), exploring undergraduate engineering students' competencies and attitudes toward mathematical problem-posing in integral calculus, found that about 60 percent of students had positive attitudes toward mathematical problem-posing activities. Roble, Lomibao and Luna (2016) investigated the effect of pre-within-post problem-posing activities in enhancing students' achievement and mathematical flexibility in Differential Calculus. The participants of this study consisted of 36 second-year university students of Escola Naval. The finding revealed that the pre-within-post problem-posing activities helped students improve their achievement and flexibility scores in Differential Calculus. Moreover, Nedaeia, Radmehr and Drake (2022) suggested that problem-posing tasks could be used more often, alongside problem-solving tasks, as part of the teaching and mathematical achievement evaluation at the university level.

In December 2019, the world acknowledged two confirmed cases of Coronavirus patients in Wuhan, China. On 11 March 2020, the World Health Organization (WHO) officially declared the outbreak of the COVID-19 pandemic. Thailand is one of many countries experiencing this ongoing pandemic and was the first to report a case outside China on 13 January 2020. (Abuza, 2020) This severe epidemic which greatly expanded the virus in the country, had severely affected Thailand in many ways, and education was one of them. (Panyaarvudh, 2020).

In the middle of March 2020, all universities in Thailand were requested by the Ministry of Education to suspend any school activities and move to online classes (Mala, 2020). The sudden changes have caused significant impacts and disruptions to the learning progress of learners and teachers. Regarding the teachers, they had to design online learning lessons, develop learning materials and media, online measurements, and online evaluations. As for the learners, advances in information and communication technology have enabled them to access technology for learning quickly and allowed them to study anytime and anywhere according to their needs (Trifan et al., 2014). Therefore, online learning has played an essential role in higher education under globalization and borderless education. (Office of the Higher Education Commission, 2018).

The Rajamangala University of Technology Suvarnabhumi is a state university that provides higher vocational certificates, bachelor's degrees, and master's degrees under the Ministry of Higher Education, Science, Research, and Innovation. This University was established in the year 2005 with the current vision to be the leading University in professional and advanced technology and the core objective of providing professional and technological workforces that meet international standards. Mathematics knowledge is fundamental for preparing students for their profession (Rajamangala University of Technology Suvarnabhumi, 2022).

Although there are previous articles concerning problem-posing in Mathematics (Christidamayani & Kristanto, 2020; Puspitasari, et al., 2019; Suarsana et al., 2019) most of them were limited to the conventional classroom. Therefore, this study aims to investigate whether problem-posing methods can improve the performance of university students in an online mathematics classroom.

RESEARCH QUESTIONS

1. Do the students in the experimental group (learn mathematics lessons via the problem-method posing) gain a higher post-test mean score than the pre-test mean score?
2. Do the students in the experimental group gain a higher post-test mean score than the control group (learn mathematics lessons via conventional method)?

REVIEW OF LITERATURE

Problem-posing

The definition of problem-posing varies among researchers ' perspectives. For instance, Silver (1994) and English (1997) stated that problem-posing was a process of defining a math problem from a conditional context, information, or situation in which the original problem was made using conditional modifications. At the same time, Leung (2013) defined problem-posing as the process of defining a problem or question at each step of mathematical problem-solving. In this case, problem-posing was used to find solutions for the problems (Leung, 2013). Mathematical problem-posing is a guideline for designing and organizing mathematical learning activities. The characteristics and the uses of mathematics problem-posing are as follows (Silver, 1994; Leung, 2013):

1. Mathematical problem-posing can be performed in parallel with problem-solving.

There are three ways to implement mathematical problem-posing. The first feature is problem-posing followed by problem-solving, which is the technique that focuses on learners raising problems or asking questions from a given context which could be information, daily situations, charts, pictures, and so forth. These activities encourage students to use mathematical knowledge to analyze and find relationships between information in a given context, create problems or questions, and then solve the problems.

Another technique of problem-posing requires students to set problems during the problem-solving process. This activity focuses on students' creation of the questions at each stage of the problem-solving to consider the condition of the problem and determine the problem-solving approach that leads to the answers to the problem.

The third approach is the problem-posing after one problem has been solved. This method focuses on students' problem creation after the previous question has been resolved. This kind of problem-posing activity encourages learners to expand their ideas about problem-solving results into new problems that may come from modification or information of the problem that has been answered.

In this study, the researchers used the first techniques to enable the students to create the mathematical problem-posing from the given context, condition, and situation to find the proper method to solve the problem.

2. Context of the problem- posing

The context of problem-posing refers to information, conditions, situations, or problems that students use to create problems that should be diverse and cover both mathematics and everyday contexts. The problem-posing context can be divided into three types. The complete structural context is the setting of a new problem that focuses on adjusting initial problem conditions. The second type is a conditional context which focuses on a required specific question. The third one is an independent context to set new problems from context based on the unconditional interest (EI Sayed, 2002; Leung, 2013; Silver, 1994).

3. Problems arising from problem-posing activities depend on each learner's knowledge and experience of problem-posing.

The problems set by the students can be diverse from the easy level to the complex level, not to mention whether those problems can be solved or not. Generally, the solution can be found in a given problem. However, if the students' problems are inconsistent with the setting context, the teachers' roles are needed to guide the students to adapt the problem set to the context. (Kwek, 2015).

The concept of mathematical problem-posing has received interest and support from mathematics educators to use it to manage mathematics learning concretely and continuously to help develop knowledge and skills in mathematical processes in the learners (Suarsana et al., 2019).

Online Learning

The COVID-19 pandemic has changed how people work and students conduct their studies. During national lockdowns, working and studying at home has become the norm, with some classes permanently moving to online-based learning to continue the study and maintain interaction between the teachers and the students (Carolan et al., 2020). Online learning has become a topic of interest in the 21st century (Hurlbut, 2018). It was defined as the delivery of instruction via digital resources since this kind of learning is delivered through electronic devices (Kennedy & Archambault, 2012). It was also called by other names, such as distance education, computerized electronic learning, and internet learning. The debut of online learning denotes that students can access their learning materials online at any place and anytime (Santos et al., 2019).

According to Reushle et al. (1999), online learning comprises critical components which are:

Cognitive skills: Teachers and students who engage in online teaching and learning environments require a complex range of skills to achieve their teaching and learning goals (Jonassen et al., 1995).

Content structure: The design of the content structure in the website is essential for the learners. The websites must organize the materials into manageable sizes. Moreover, concept maps and graphic organizers will help learners navigate materials and observe the relationships between the concepts.

Learner control: A 'learner-centered' approach requires teachers to be facilitators (Jonassen, 1993) rather than lecturers and view learners as active participants in the learning process. The high level of learner control in a flexible online environment may encourage not only learning of new content but also improve personal learning strategies.

Ease of use: Excellent interface design is determined by simple site navigation and the ability to present the users with friendly, self-evident, and predictable pathways through the site content.

Online learning skill: The online learning skill is pivotal to the learners' achievement of online learning. Therefore, helping to improve learners' skills in learning online is essential.

Online evaluation: Evaluation is integral to all aspects and levels of any educational design and development process. A reliable and validated evaluation instrument will ensure that students receive feedback from the instructor's point of view. The ability to complete and submit an evaluation online is an essential element of any web design.

Feedback: Feedback from the teacher is a vital part of the learning process during which misconceptions are corrected. Feedback seems to be more effective when it is both immediate and in sufficient detail for the student to initiate corrective action (Waldrop et al., 1986). Moreover, feedback should be given frequently during instruction for small steps rather than large chunks of learning.

HYPOTHESIS DEVELOPMENT

From the literature review, we found few studies related to the effect of using online mathematic problems- posing on students' mathematics achievement. Rosli, et. al (2014) conducted a meta-analysis study on "The Effects of Problem Posing on Student Mathematical Learning" and concluded that problem-posing activities provide considerable benefits for mathematics achievement, problem-solving skills, levels of problems posed, and attitudes toward mathematics. Roble , Lomibao, and Luna (2016) investigated the effect of utilizing pre-within-post problem-posing activities in enhancing students' achievement and mathematical flexibility in Differential Calculus. The participants of this study consisted of 36 second-year university students of Escola Naval. The finding revealed that the use of pre-within-post problem-posing activities helped students improve their achievement and flexibility scores in Differential Calculus. Suarsana, et al (2019) studied "The Effect of Online Problem Posing on Students' Problem-Solving Ability in Mathematics," and found that among three methods of teaching, namely online problem-posing, problem-posing, and conventional study, students who attended online problem-posing had higher achievements. Moreover, Nedaeia, Radmehr and Drake (2022) explored undergraduate engineering students' mathematical problem-posing and suggested that problem-posing tasks could be used more often, alongside problem-solving tasks, as part of the teaching and assessment of mathematics at the university level.

From the mentioned review of related literature, we anticipate that the post-test mean score of the experimental group (using the problem-posing method) should be higher than the pre-test. Therefore, the H1 and H2 are set:

H1: The post-test mean score of the experimental group is higher than that of the pre-test.

H0: $\mu 2 = \mu 1$

Ha: $\mu 2 > \mu 1$

Where:

$\mu 1$ = pre-test mean score of the experimental group

$\mu 2$ = post-test mean score of the experimental group

H2: The post-test mean score of the experimental group is higher than the post-test mean score of the control group.

H0: $\mu 1 = \mu 2$

Ha: $\mu 1 > \mu 2$

Where:

$\mu 1$ = post-test mean score of the experimental group

$\mu 2$ = post-test mean score of the control group

METHOD

Research Design

This is an experimental study with a randomized comparison groups pretest and posttest design.

Population

The population of the research was 229 first-year electrical engineering students of the Rajamangala University of Technology Suvarnabhumi.

Participants

Sixty research participants were randomly selected from the population. Systematic random sampling was used to select research participants whose student numbers ended with odd numbers (1,3,5, 7,9). Then, they were randomly organized into two groups using the draw lot technique. The first group was the experimental group (using problem posing through online class). Another group was a control group (using conventional teaching online). To control the bias effect from the instructors and the content of the study, both groups shared the same instructor and learning content but different learning methods.

Research Procedure

The research procedure was divided into 2 phases:

Phase I: Development of the online lesson plans and achievement test on the subject “Partial derivative”

Phase II: Organizing the online class through “Google Classroom”. The problem-posing online class was organized for the experimental group every Wednesday from 2 to 5 p.m. for five weeks from June to July 2022. The online conventional learning was organized every Thursday during the same period. The pre-test was conducted at the beginning of the program while the post-test was conducted at the end of the program using a mathematics achievement test.

Research Instrument

1. Lesson plan:

The lesson plans were drafted for each group. (Experimental group with problem-posing through online class and the control group with conventional learning through online class). Both groups study the same learning content, using the "partial derivative" curriculum for undergraduate students developed by the electrical engineering faculty, at Rajamangala University of Technology Suvarnabhumi. The partial derivative subject is a part of the Calculus subject which is an essential fundamental knowledge for the student to study in the higher level. The teaching plan is comprised of 4 learning sessions:

- Session 1: Subdivisions of Two Variable Functions
- Session 2: Subdivisions of Multivariate Functions
- Session 3: Sub-Derivatives of Implicit Functions
- Session 4: Applications of Sub-Derivatives

Learning models and Class schedules are presented in Table 1 and Table 2

Table 1 Learning models for each group

Experimental group (Problem-posing online class)	Comparative group (Conventional learning online class)
1. Grouping the students of 5 persons 2. into 6 groups. (30 participants) 3. The teacher provides information, situations, charts, and pictures and 4. encourages the students to use mathematic knowledge to analyze and find relationships between information in a given context, create problems. or questions, and then solve the problems. 5. The teacher asks each group to switch the problems that they have formulated with other groups and then solve them. 6. Three selected groups are asked to present their problems and the gained problems from another group 7. The students upload their assignments to Google Classroom and the teacher gives her feedback. 8. Q &A and discussion.	1. Grouping the students of 5 persons into 6 groups. (30 participants) 2. The teacher gave a lecture about the content of each lesson. 3. The teacher asks each group to do an assignment and upload it to Google Classroom. Then the teacher gives feedback. 4. Q &A and discussion.

Table 2 Online Class Schedule

Class Schedule	Experimental group (Wednesday class)	Control group (Thursday class)
Week 1	-Introduction of the course; objectives, structure, learning method (online problem-posing) and evaluation. -Pretest	-Introduction of the course; objectives, structure, learning method (online lecture) and evaluation. -Pretest
Week 2	Session 1: Introduction to partial derivatives	Session 1: Introduction to partial derivatives
Week 3	Session 2: First-Order Partial Derivatives	Session 2: First-Order Partial Derivatives
Week 4	Session 3: Second-Order Partial Derivatives	Session 3: Second-Order Partial Derivatives
Week 5	Session 4: Chain Rule and gradient - Posttest	Session 4: Chain Rule and gradient - Posttest

2. The Achievement Test.

The mathematics achievement test was developed based on the content of the teaching plan on the subject "Partial derivative" for the undergraduate students of the electrical engineering faculty, Rajamangala University of Technology Suvarnabhumi, to measure the students' learning achievement.

The achievement test consists of 15 multiple-choice questions, each one contained four optional answers, and only one is correct. This test measures the student's knowledge before attending the online mathematics class (pre-test). It was also used in the post-test where the positions of multiple choices were switched to ensure that the students could not remember their previous answers.

Instruments Test

1. Lesson plan

Three experts were asked to verify the lesson plan in mathematic problem-posing techniques and online learning regarding accuracy, utilization, appropriateness, and possibility. (Joint Committee on Standard for Education Evaluation, 2010) The revision was made based on their comments.

2. Achievement test

The achievement test was verified for its content validity judged by the index of congruence (IOC), reliability as determined by Cronbach's Alpha, Discrimination (R), and item difficulty (P). The results of the items analysis yielded the following values:

- IOC values of the questions were ranging between .80-1.00 which were above the cut off criterion at .67 (Turner & Carlson, 2003).
- Cronbach's Alpha value of overall 15 questions was at 0.85 which passed the cut-off standard at .70 (Eisinga et al., 2012).
- Item-discrimination (R) of each question was between 0.60-0.85, representing the high discriminant quality of the items in separating intelligent students from poor students (Ronna & Laurie, 2003).
- Item difficulty (P) of each question was between 0.40 -0.35, which indicated the level of difficulty at a medium to a pretty difficult level (Ronna & Laurie, 2003).

Data Collection

Data collections were organized at the beginning and at the end of the program to compare the mathematics achievement of the students in the experimental group and the control group before and after attending classes.

Data Analysis and Statistics

The data from the achievement test were compiled and analyzed by the computer program using two types of statistics, descriptive statistics such as mean and standard deviation to indicate the mean values of the student's learning achievement before and after classes. At the same time, the independent and paired t-tests were used to determine the differences in the mean score of students' achievement before and after attending classes.

FINDINGS

This part presents the result of the analysis according to the research hypothesis as follows:

H1: The post-test mean score of the experimental group is higher than the pretest.

H0: $\mu2 = \mu1$

Ha: $\mu2 > \mu1$

Where:

$\mu1$ = pre-test mean score of the experimental group

$\mu2$ = post-test mean score of the experimental group

Table 3 Comparison of pre-test and post-test mean scores of the experimental group. (N = 30)

Groups		Mean	t-value	Sig (p-value)	Df
Experimental	Pre-test	4.9333	-16.349	.000	29
	Post-test	14.2000			

** Significant at .01 level

The analysis result indicates the t-value at -16.349 and the p-value at .000, which is lower than the significant level at .01. Therefore, we reject H0 and accept Ha. This result indicates a significant difference in the mean values of the experimental group before and after learning mathematics lessons via an online problem-posing method. The post-test mean score is higher than the pre-test mean score.

H2: The post-test mean score of the experimental group is higher than the post-test mean score of the control group.

H0: $\mu 1 = \mu 2$

Ha: $\mu 1 > \mu 2$

Where:

$\mu 1$ = post-test mean score of the experimental group

$\mu 2$ = post-test mean score of the control group

Table 4 Comparison of the post-test mean score between the experimental group and the control group. (N=30)

Groups	Mean	t-value	Sig (p-value)	Df
Experimental	14.20	6.705	.000**	58
Control	12.13			

** Significant at .01 level

The analysis result indicates the t-value at 6.705 and the p-value at .000, which is lower than the significant level at .01. Therefore, we reject H0 and accept Ha. This result indicates a significant difference in the mean score between the experimental and the control group whereas, the post-test mean score of the experimental group is higher than the control group.

DISCUSSION

From the analysis result, we found a significant difference in the mean score between the pre-test and post-test of the experimental group where the mean score of the post-test was higher than that of the pretest. The finding implies that the problem-posing method can be used to enhance students' mathematics achievement. The finding is congruent with the findings of previous studies. Rosli, et. al (2014) conducted a meta-analysis study on "The Effects of problem-posing on Student Mathematical Learning" and concluded that problem-posing activities provide considerable benefits for mathematics achievement. Roble, Lomibao and Luna (2016) investigated the effect of utilizing pre-within-post problem-posing activities in enhancing students' achievement and mathematical flexibility in Differential Calculus and found that the use of pre-within-post problem-posing activities helped students improve their achievement score and flexibility in Differential Calculus.

The comparison of the post-test mean score between the experimental group and the control group revealed a significant difference in the mean score between the two groups where the post-test mean score of the experimental group was higher than that of the control group. The result of this experiment implies that using online problem-posing in teaching mathematics was more effective than the conventional teaching method. The result may be because the students in the experimental group using online problem posing were encouraged to actively participate and engage in learning activities. The students in the control group learned from lecturing and online materials which was less interesting. This result is consistent with the study of Suarsana et al. (2019) who concluded that online problem-posing had a greater effect on students' problem-solving ability than problem-posing or conventional learning. Furthermore, the findings of this study are in line with the findings of Bevan and Capraro (2021). They found that problem-posing activities can positively impact students' mathematical understanding while allowing for freedom of expression, which leads to better mathematics achievement. Therefore, it is recommended that online problem posing be frequently and broadly used in schools and colleges.

Despite the benefits of the problem-posing technique, mathematics teachers do not widely use the posing of problems (English & Kirshner, 2015; National Council of Teachers of Mathematics [NCTM], 2000). Moreover, the study of Thaikam and Ugsonkid (2021) revealed that Thai teachers usually avoid setting up the questions for the students by themselves and rarely use the problem-posing technique in their teaching because they have obtained very few experiences regarding the problem posing in mathematics from their high school to college education. Thus, schools and universities should foster problem-posing techniques in their mathematics classroom so that the students who may become future mathematics teachers can deliver such knowledge and skills to their students. However, Gopal et al. (2021) found that the critical elements of online learning, such as the quality of instructors, course design, prompt feedback, and expectations of the students, influence students' performance through the students' satisfaction. Therefore, besides using problem-posing in a mathematics online classroom, teachers should improve the critical online learning elements to enhance the effectiveness of using problem-posing in mathematics online classes.

IMPLICATIONS TO EDUCATION PLANNING

Planning to use the problem-posing method in education can be organized using case studies, group discussions, and project simulation to allow students to create problems and solve problems systematically. Teachers and educational institutions can support student learning by providing resources and tools to research and solve problems, such as digital libraries. Software can help with data analysis online learning platform and provide evaluation and reflection on students' learning processes, thinking, and problem-solving. Student reflection on learning can create an open learning environment that encourages expressing opinions and asking questions. Students would feel involved and confident in creating problems and solving problems. In addition, teachers can apply technology for the students to create problems and solve problems, such as using online platforms for group work and simulation software, etc. The problem-posing method allows the students to reflect on what they have learned and how that knowledge applied to other situations.

CONCLUSION AND RECOMMENDATIONS

This research is experimental with a randomized comparison groups pretest- and post-test design, which aims to examine the use of online problem-posing in enhancing students' mathematics achievement. The participants were sixty electrical engineering students of the Rajamangala University of Technology Suvarnabhumi. The research instruments included a lesson plan and a mathematics achievement test. The result indicated a significant difference in the mean values of the experimental group before and after learning mathematics lessons via an online problem-posing method. The post-test mean score was higher than the pre-test mean score. Moreover, a statistically significant difference was found between the experimental and the control group post-test mean scores. In comparison, the students in the experimental group gained higher mathematics achievement than the comparative group. This result implies that online problem-posing is more effective in teaching mathematics than the conventional online class.

Therefore, it is recommended that schools and universities inculcate online problem-posing approach rather than the traditional learning model in their mathematics classroom. However, the instructors should pay attention to other elements such as the quality of instructors, course design, prompt feedback, students' expectations, and students' satisfaction to ensure the quality and effectiveness of the online class.

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