

The Effects of Inquiry-Based Learning on Students' Mathematics Achievement and Math Anxiety

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Abstract

This study was a classroom action research. The research objectives aimed to enhance students' mathematics achievement by using inquiry-based learning and to investigate the effect of inquiry-based learning on levels of students' math anxiety . The sample consisted of 31 Grade 12 students who enrolled in the first semester of the academic year 2019 at a secondary school in Bangkok Metropolis, Thailand. The research instruments consisted of eight lesson plans covering 12 learning periods on the topic of Limits and Continuity of Functions, pre-test, post-test, and math anxiety questionnaire. The results of this research indicated that the effectiveness concerning students' achievement after being instructed had an Effectiveness Index (E.I.) of 0.7689 which means that the students' learning achievement had been developed by 76.89% based on prior knowledge. In addition, the post-test scores were statistically significantly higher than pre-test scores at the .05 level. As for students' opinions towards the instruction that affected their math anxiety level in learning mathematics, it was found that the students' opinions on teaching that affect the level of anxiety in mathematics learning were: "very high" (6.45%), "high" (25.81%), "low" (48.39%), and "very low" (19.35%).

Keywords: Inquiry-based learning, Math anxiety, Action research

Introduction

In Thailand, the mathematics curriculum for high school students is intended to provide mathematical skills for better understanding the contents aligned with the expectations of university-level courses and to promote learning for the future career. The global context is increasingly becoming more complex, knowledge-based, and intrinsically intertwined with information, communications, and technology for 21st Century skills which play important roles in Thailand's education. The 21st Century education is about giving students the skills they need to succeed in this new world and helping them to gain the confidence to practice those skills, such as communication, collaboration, critical thinking, and problem-solving. Mathematics learning should be about developing conceptual understanding in order to prepare students for the 21st Century (Wathall, 2017).

According to the National Council of Teachers of Mathematics, inquiry is one of the most important contexts in which students learn mathematical concepts and knowledge: by exploring, conjecturing, reasoning logically, and evaluating whether something makes sense or not (NCTM, 1991). Learning begins with students' curiosity by using spiral path of inquiry such as asking questions, investigating solutions, creating, discussing their discoveries and experiences, reflecting on their new knowledge, and asking more questions to lead to more investigation (Bruce & Bishop, 2002; Bruce & Davidson, 1996). The process of inquiry-based learning requires more than simply answering questions or getting the right answer. It involves open-ended investigations into a question or a problem and shifts the students from a position of wondering to a position of enacted understanding and further questioning. The teachers challenge students to ask further questions, connecting those questions and points to the main points of the content which will keep students thinking about the initial problems. During the inquiry-based learning process, students are engaged to sort out information and decide what is important then communicate in pairs or groups to discuss ideas through cooperative interaction. Students are not in competition with each other, but they help to reach a correct answer without having everyone doing the same process (Scardamalia, 2002).

The researcher is a pre-service teacher who has been assigned to teach mathematics for Grade 12 students. In the initial action research assignment, the researcher focused on observing and interviewing experienced teachers to identify an area of concern arose from students' problems in learning mathematics. After consulting with the host supervisor of practicum school, the researcher decided to conduct an action research on teaching calculus in the topic of Limits and Continuity of Functions. From teacher interviews and teaching experience observations in the practicum school, the researcher found that Grade 12 students had low learning achievement in this calculus topic which contains abstract concepts that are difficult for them to understand. Moreover, students had misconceptions in basic concepts of limits and continuity of functions and lacked confidence to solve a problem due to the anxiety in studying calculus of high school course. From various studies, traditional way of teaching maths by figuring equations and plugging in

numbers focuses only on computation, in contrast to an inquiry-based learning, teachers use questions, problems, and scenarios to help students learn through individual thought and investigation.

For this action research, the researcher was interested in the integrated teaching strategies using inquiry-based learning which are keys to improve 21st Century skills in learning mathematics. The concept of inquiry-based learning in mathematics learning is a student-centered method that focuses on real-world mathematics, asking questions, and genuinely investigating those questions. The teacher acts as a facilitator to help students reach conclusions which they must explain the reasonable rules or formula for their conclusions and then construct the new knowledge from the previous knowledge (Guido, 2017; Kim, 2017; Lightfoot, 2018). These kinds of essential questions should make students move Bloom's Taxonomy from lower-order thinking skills (knowledge, comprehension, application) into higher-order thinking skills (analysis, synthesis, evaluation) (Watanabe-Crockett, 2017). Also, the teachers should integrate mathematical skills and processes when asking questions, such as questions to help students predict and plan for problem-solving, make connections, clarify reasonable solutions, or share mathematical representation (Government of Ontario, 2011).

Research Objectives

1. To enhance students' mathematics achievement by using inquiry-based learning.
2. To investigate the effect of inquiry-based learning on levels of students' math anxiety.

Research Scopes

1. The research population used in the classroom action research consisted of 352 Grade 12 students studying during the first semester of the academic year 2019 at Mahaprutaram Girls' School under the Royal Patronage of Her Majesty the Queen, Thailand.
2. The variables were (1) independent variable: learning management based on inquiry-based learning method, and (2) dependent variables: student's mathematics achievement and level of students math anxiety.
3. The duration of this experiment covered 12 learning periods in the first semester of the academic year 2019.

Definition of Terms

1. Inquiry-based learning (IBL) is a pedagogical approach that engages learners activities in a knowledge-building process through the generation of answerable questions. Instead of presenting information to the student, the teacher allows students to explore materials by their own. Using inquiry-based learning, the student learns by doing; curiosity and exploration often lead to better comprehension and understanding of materials. There are several different

inquiry-based learning models. In this study, the researcher applied five steps focused on answering the questions for engaging, exploring, explaining, evaluating, and extending knowledge in teaching.

2. Math anxiety is an intense emotional feeling of tension that students have about their ability to understand and do mathematics. Students who suffer from math anxiety feel that they are incapable of doing activities and classes that involve math. Level of math anxiety refers to the range of adding up the number that students have checked off in the math anxiety questionnaire (five-scale rating) as a self-test after using inquiry-based learning approach to determine the level of anxiety as follows:

- 10 – 19 means 'Very low math anxiety';
- 20 – 29 means 'Low math anxiety';
- 30 – 39 means 'High math anxiety';
- 40 – 50 means 'Very high math anxiety'.

3. Mathematics achievement is the proficiency of performance in any or all mathematics skills in topic limits and continuity of functions. It measures the performance on the mathematical achievement test developed by the researcher.

Methodology

Population and Sample

The research population comprised ten Grade 12 classes (352 students) studying mathematics courses during the first semester of the academic year 2019 at Mahaprutaram Girls' School under the Royal Patronage of Her Majesty the Queen, in Bangkok Metropolis, Thailand.

The research sample consisted of 31 Grade 12 students in a contact classroom. According to the population of Grade 12, there was only one class studying additional mathematics. Therefore, this contact classroom consisting of 31 students was purposively selected to be the research sample of this study.

Research Instruments

1. The total number of 8 lesson plans covering 12 learning periods on the calculus topic of Limits and Continuity of Functions in Grade 12 were developed by the researcher for the instruction using the integrated inquiry-based learning model. The lesson plans were subjected to a validation process for the Index of Item-Objective Congruence (IOC) by three experts. The IOCs were found to range from 0.67 - 1.00.

2. An achievement test consisting of 15 items was developed by the researcher covering the learning objectives under the topic. The test included 2 items of answer from graphs, 10 multiple-choice items and 3 items of essay test focused on the contents of Limits and Continuity of Functions. The total score of this test was 20 points. The

items had been verified by three experts. The IOCs of the items, as evaluated by the experts, ranged from 0.67 - 1.00 which means they were acceptably congruent with the objectives.

3. A questionnaire on student's math anxiety consisting of 10 statements of a negative feeling about doing mathematics activities adapted from Freedman (2017). These statements measured the level of math anxiety of students in learning mathematics. A questionnaire was presented to the thesis advisor for any suggestions for improvement. After receiving recommendations, the IOCs were used to evaluate the items of the questionnaire based on the score range from -1 to +1. The questionnaire was checked by three experts, the items that had scored lower than 0.5 were revised.

4. The GSP instruction media was designed for illustrating the concept and solving problems of limits and continuity of functions. The researcher also used these media to answer questions in a textbook and activity sheet visually based on the lesson plans.

Data collection

1. The researcher introduced students to the learning processes based on the inquiry-based learning.
2. The researcher tested students by using the mathematics achievement test before the instruction.
3. The researcher taught students according to the inquiry-based learning lesson plans.
4. The researcher tested students by using the mathematics achievement test and asked students to respond to the questionnaire on student's math anxiety at the end of the instruction.

Data Analysis

The statistics used to analyze the data in this study were as follows:

1. The lesson plans, pre-test, and post-test (achievement test) designed for this study were subjected to a validation process for Index of Item – Objective Congruence (IOC).
2. The basic statistics used in the analysis were the mean and standard deviation.
3. Pre-test and post-test scores were calculated by using (1) E.I. (Kidrakan, 2002) to compare the difference between the summation of post-test score of all students with the achievement score after using IBL (post) and the sum of pretest score of all students before using IBL (pre) to the difference between the summation of the total score of all students (total) and the sum of pre-test score of all students before using IBL (pre) and (2) t-test Dependent.
4. The questionnaire on student's math anxiety was of five scales from 1 to 5: 1 = Strongly disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly agree. Students' responses in each of the 10 statements were summed up and then compared to the five scales to determine the level of their anxiety.

Research Findings

The researcher presented the research results according to the research objectives as follows:

1. For the first objective, the researcher aimed to enhance students' mathematics achievement by using inquiry-based learning. Quantitative methods were employed to determine this objective which composed of scores from pre-

test and post-test and applying the Effectiveness Index with an acceptance criterion of 0.50 (Kidrakan, 2002) as shown in Table 1. Also, the pre-test mean score and the post-test mean score were compared with the use of dependent t-test the result of which is shown in Table 2.

Table 1: Effectiveness Index (E.I.) of Students' Mathematics Achievement (N = 31, Total score = 20)

List	Sum of Students' Mathematics Achievement		Effectiveness Index
Pre-test score	250		$E.I. = \frac{534.5 - 250}{620 - 250}$
Post-test score	534.5		
Total score	620		= 0.7689

Table 1 presents the results of the value of the Effectiveness Index of students' mathematics achievement. The sum of 31 students' mathematics achievements in pre-test is 250, that of the post-test is 534.5, and the total score is 620. The value of the Effectiveness Index is 0.7689 which indicates how students could improve from pre-test to post-test then compared to the differences of pre-test score and total score. It means that the students can be developed by 76.89% from the beginning of lesson to the end of lesson using inquiry-based learning approach.

Table 2: Result of Pre-test Scores and Post-test Scores for Students' Achievement

Limits and continuity of functions test	<i>M</i>	<i>SD</i>	<i>t</i>	<i>Sig.</i>
Pre-test	8.06	2.29	38.90*	.00*
Post-test	17.24	1.87		

Remark: * $p < .05$

From Table 2, the mean of students' mathematics achievement after using inquiry-based learning instruction is higher than their mean of achievement before instruction. On the other hand, the standard deviation of post-test scores is lower than that of pre-test scores. Comparing the pre-test and post-test scores, it is found that the post-test mean score is significantly higher than the pre-test mean score at the .05 level.

2. For the second objective, the researcher aimed to investigate level of students' math anxiety affected from inquiry-based learning. The students were asked to rate 10 statements using five scales: (5) Strongly Agree, (4) Agree, (3) Neutral (2) Disagree, (1) Strongly Disagree. The anxiety frequencies for each statement are shown in Table 3 and the analysis results of the students' level of math anxiety are shown in Table 4.

Table 3: Number of Students' Responses to Math Anxiety in Doing IBL Activities

Statement	Strongly Agree		Neutral (3)	Strongly Disagree	
	Agree (1)	Agree (2)		Disagree (4)	Disagree (5)
	1. I cringe when I have to go to math class.	0		0	9
2. I feel uneasy about going to the board in a math class.	0	3	11	13*	4
3. I am afraid to ask questions in math class.	2	4	13*	9	3
4. I am always worried about being called on in math class.	2	2	16*	8	3
5. I understand math now, but I worry that it's going to get really difficult soon.	5	12*	10	4	0
6. I tend to zone out in math class.	0	0	10	12*	9
7. I fear math tests more than any other subjects.	0	6	9	11*	5
8. I don't know how to study for math tests.	3	6	11*	8	3
9. It's clear to me in math class, but when I go home it's like I was never there.	4	5	9*	8	5
10. I am afraid I won't be able to keep up with the rest of the class.	0	4	6	13*	8

* Indicate students' highest frequency of agreement for each statement.

Table 4: Analysis Results of Math Anxiety Level of Students

Level of Mathematics Anxiety of Students	Range of Scores	Number of Students	Percentage
Very high anxiety	10 - 19	2	6.45
High anxiety	20 - 29	8	25.81
Low anxiety	30 - 39	15	48.39
Very low anxiety	40 - 49	6	19.35
Total		31	100

Table 4 presents the level of mathematics anxiety of the 31 students, 2 of them or 6.45% are identified with 'Very high anxiety' and 8 students or 25.81% are diagnosed with 'High anxiety'. This resulted to a total percentage of 32.26% or 10 students with anxiety in learning mathematics.

Conclusion and Discussion

This action research aimed to study students' mathematics achievement in the topic of Limits and Continuity of Functions and to investigate students' level of math anxiety in learning mathematics by using inquiry-based learning.

The results showed that the inquiry-based learning had effects on the students' mathematics achievement with an Effectiveness Index score of 0.7689 which was higher than 0.50 as the acceptance criteria (Kidrakan, 2002). As a consequence, it indicated that students developed 76.89% of concept, knowledge and skills from the beginning. Also, the result of compared between the pre-test mean score and post-test mean score showed that the students' post-test mean score was significantly higher than their pre-test mean score at the .05 level. Additionally, the results from the questionnaire responses indicated the student opinions towards the instruction that affects their math anxiety in learning mathematics were at the following levels: 'Very high anxiety (6.45%)', 'High anxiety' (25.81%), 'Low anxiety' (48.39%), and 'Very low anxiety' (19.35%).

Inquiry-based learning approach in teaching and learning mathematics focuses on the process over the solutions. The students investigate the teacher's issues and worked individually or in pairs to share and build upon their ideas to find out a solution. The teacher takes a role as a facilitator to ask the guided questions to help students move forward. The students may ask their questions to seek information such as previous concepts, theories, principles, or rules for correct answers.

The conducting of this action research for planning, instruction, and evaluation of each unit was composed of 3 stages: Look (gather information related to what is most valued), Think (analyze and clarify the situation gathering to provide consequences and potential actions), Act (judge the worth, effectiveness, and appropriate activities to support central value) (Nasrollahi, 2015; Stringer, 2007). The information from each stage was different based on the previous concepts of limits and continuity of functions. Students may not be able to ask the question by themselves for combining the new knowledge with the background knowledge or applying the previous procedural concepts to solve non-routine exercises. This observation of cycle 1 reflected that students had difficulties in posing questions corresponded to the previous research that used inquiry-based learning to the teaching and learning of mathematics. The results of the first cycle of the study reflected that the students had difficulties in posing sensible questions and needed more guidance at this stage.

For this study, the learning management plans for cycle 2 required better planning and providing appropriate questions to encourage students to participate in learning. There were more questions used during inquiry-based learning, for examples: Can you say that again? (Repeat explanation), Can you say a little more about that...? (Elaborate idea), Can you explain why that works? (Reason), etc. Also, students had more opportunities to Look-Think-Act in pairs through using computer software such as the Geometer's Sketchpad during constructing the new concepts and practicing

the exercises. At the end of cycle 3, the students had more confidence and less anxiety in learning mathematics. Moreover, they could develop their achievement in learning limits and continuity of the functions.

Discussions on enhancing students' achievement

According to the results of this study for enhancing students' mathematics achievement by using inquiry-based learning with 5E and the dynamic geometry software that it can improve their achievement level, the results are consistent with the previous research findings (Battista, 2007; Santos & Boyon, 2020). Besides, the findings of Siregar and Siregar (2019) that used the classroom action research in 3 stages of the cycle showed the increase in the value of the average and overall learning outcome for each cycle. The students' average scores in cycle 1, cycle 2, and cycle 3 were 72.5%, 83.33%, and 97.22%, respectively. Therefore, it can be concluded that the use of learning strategies of inquiry on the topic of Set improves students learning mathematics with effectiveness.

Discussions on mathematics anxiety

The investigation of students' anxiety after using inquiry-based learning showed that the students responding to a five-point scale of agreement on the math anxiety survey were: 'Very high anxiety' (6.45%), 'High anxiety' (25.81%), 'Low anxiety' (48.39%), and 'Very low anxiety' (19.35%). Thus, inquiry-based learning is considered as one appropriate method to create low anxiety and very low anxiety in learning mathematics for about 67.74% of students in the sample group (31 students). This result is consistent with Kuar's study (2019) on enhancing motivation and engagement in math classroom using inquiry-based learning. This is because motivation and engagement affect students' positive attitude in learning and a positive attitude is the factor in reducing math anxiety. Moreover, Beilock and Willingham (2014) suggested the remediation of math anxiety by enhancing students' fundamental skills, changing the assessment, acknowledging their works, and challenging them for success.

Recommendations

1. There are five stages of inquiry-based learning which take more time to teach. Therefore, the teachers have to control the time. Each step can be flexible with appropriate activities.
2. The teachers must create an environment where students feel comfortable expressing their mathematical understanding. It is better to use a variety of activities in teaching.
3. The application of inquiry-based learning is possible to develop higher mathematics achievement. Teachers should understand the learning management algorithms by starting to experiment as part of teaching as a primary teaching method.
4. During teaching, teachers should reinforce and create a classroom environment to attract students' interests, such as peer tutoring, some techniques suggested by students in solving some specific topics or group activities.

5. After each period of teaching, teachers should take notes thoroughly for analysis to improve the next lesson plan.

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