The Effects of Fourier Series Game-Based Learning Activities on Industrial Education and Technology Students' Mathematical Self-Efficacy

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Abstract
Self-efficacy is vital for the development of oneself since it is the belief that one could conduct the required actions to achieve the tasks given to them. At a particular University in Bangkok, Thailand, the students from the faculty of industrial education and technology attained the lowest score in almost every learning module among others, especially the module of Fourier Series, due to the lack of mathematical self-efficacy, which is important for the careers that involve scientific and innovative subject. Game-based learning is proven to be an effective pedagogy for improving self-efficacy since it provides the engagement, motivation, competition, and progression needed to foster self-efficacy. This study aims to improve students' mathematical self-efficacy through game-based learning pedagogy. The classes are on-site with online interactive broadcasting where the students could choose to participate in either manner. The participants were 33 out of 115 students who were willing to commit to the study chosen by volunteered sampling from our learning section. The data was collected through the mathematical self-efficacy questionnaire and semi-structured interview and analyzed using the Wilcoxon Signed-Ranked test and content analysis. The results indicated that the students' mathematical self-efficacy was not improved due to students lacking the needed self-discipline toward learning. From the obtained result, we recommend the implementation of well-constructed classes that promote the students' self-discipline for more precise observations of mathematical self-efficacy development.

Keywords: Mathematical Self-Efficacy, Game-Based Learning, Fourier Series, Self-Discipline, Higher Education

Introduction

1. Theoretical Background

Mathematics is considered to be of great importance, if not the most important, to prepare and enhance one's mind for the enduring process of logical and reasonable thinking. This aspect of thinking is also required in modern education for students need to achieve it to be competent in their career and able to live in society (Thipkhong, 2003). This expectation is also supposed to be met in higher education that is closer to the careers involving scientific and innovative subjects e.g., calculus. The authors had the opportunity to teach and observe MTH 102 (Calculus II) class during the academic year 2020 a university in Bangkok, Thailand. The subject is divided into modules where the students would take an exam at the end of every module (5 week / module), this manner of learning took place just after the outbreak of COVID-19 thus, it is rather new for the students who used to take traditional lessons as midterm phase and final phase. We had found that the students from the faculty of industrial education and technology attained the lowest score in almost every learning module among others, especially in the module of Fourier Series that is considered to be a necessary tool for learning mathematics. Moreover, the data obtained from in-class conversations, observations and interviews indicated worrisome attitudes toward their learning, some of the data is described as follows.

> "I am just too obtuse at mathematics."
>
> "I just study to pass the exam, and I think I am lacking the basics of calculus which I don't really care."
>
> "Online learning and calculus just made me feel unmotivated to learn."

It was shown that students did not believe much in themselves to perform well in class, in fact, they already gave up. These behaviors and expressions were as clear as day during the class, and they spelled the sign of low self-efficacy in mathematics that could stagnate their career in the future.

Self-efficacy is defined as the belief that one could accomplish the task given to them with an effort to overcome some obstacles (Bandura, 1999; Trihatun S. & Jailani Thipanya, 2020; Cheng M., et al., 2015). This is not to be confused with outcome expectancy which focuses on the outcome that is resulted from a certain behavior (Iam-suphasith, 2007) as shown in figure 1.

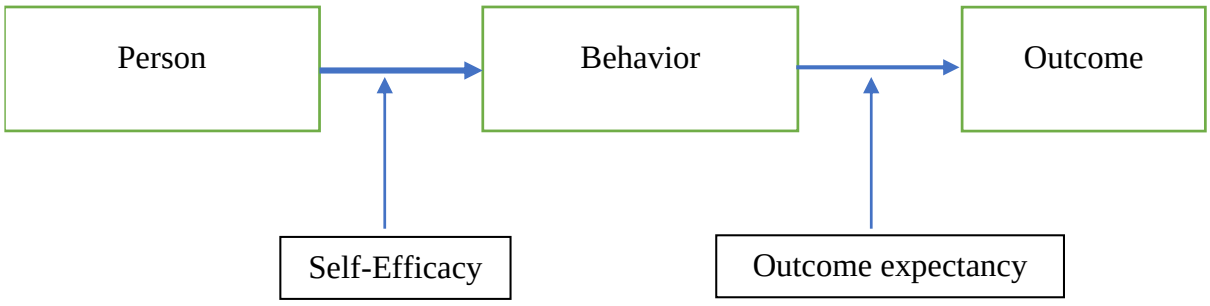

Figure 1: Influence of self-efficacy over behavior

Ayotola & Adedeji (2009) ascertain the positive impact of self-efficacy toward learning mathematics, and that means we could continue to explore self-efficacy in specific context i.e., mathematical self-efficacy which we defined as the belief that one could accomplish the mathematical task given to them with an effort to overcome some obstacles.

Bandura (1986; 1988) stated the importance of self-efficacy, for those who have high self-efficacy believe that they can accomplish their goals whether it results in success or failure, they would not yield and keep improving themselves since they perceive their failure as merely the lack of effort. Thus, it could not be denied that, if their mathematical self-efficacy is left to be deteriorated, it would certainly obstruct their learning process without them realizing it.

To improve self-efficacy, we may increase it corresponding to its sources (Bandura, 1994; Usher & Pajares 2009; Cheng et al., 2015; Haciomeroglu, 2019) as shown below.

1. Mastery experience is the successful experience received after accomplishing the given task that improves their skills and masteries.
2. Vicarious experience is the experience received from observing similar peers accomplishing the same given goals.
3. Social persuasion is the persuasion from the surrounding peers, insisting that they could accomplish the given goals.
4. Emotional and physiological state is the outer influences that affect their mental state which would impact their self -belief in capability.

Game-based learning is defined as the pedagogy that focuses on using game as the medium of formative assessment without further complicating the subject to engage and motivate the students to learn, do and discuss during the class. (Franco-Mariscal, 2014; Khae-Manee, 2000; Moon-Kam, S. & Moon-Kam, 2002). The advantages of game-based learning have shown the positive impacts toward self-efficacy since the students would be looking forward to the classes implemented with games and were tricked to improve themselves as the desire to win stemmed from the feedbacks received, peer observations, social persuasions and competitive environment takes over (Chuayprakong, 2022; Wang & Zheng, 2022). During MTH101 (Calculus I) class in academic year 2021, we had implemented several pedagogies e.g., flipped classroom, self-regulation and game-based learning to engage the students more in learning. The game-based learning was well-received and they tended to be more confident and motivated during the class.

From the aforementioned, this paper aims to improve the industrial education and technology students' mathematical self-efficacy through the use of game-based learning pedagogy.

2. Implementation and Results

The study was conducted at a university in Bangkok, Thailand with 33 out of 1533 industrial education and technology students chosen as the sample using volunteer sampling. As we chose to use game-based learning to improve the students' mathematical self-efficacy, the game that is suitable for educational context in Thailand is Vonder Go. It is the game that could harness the motivation and engagement from students by plunging them through the game progression that requires co-operation, self-improvement and competition. The students must band together to fight waves of enemy using the right answer to each question as their attack. It also provides leaderboard and virtual currency as reward for those who participate in the game. The mentioned elements would prove quite useful for teaching and formative

assessment (Insa-ad, 2022; Kru-Diary, 2021; Leart-thirunsap, 2022). The game interface used in the class is shown in the figure below.

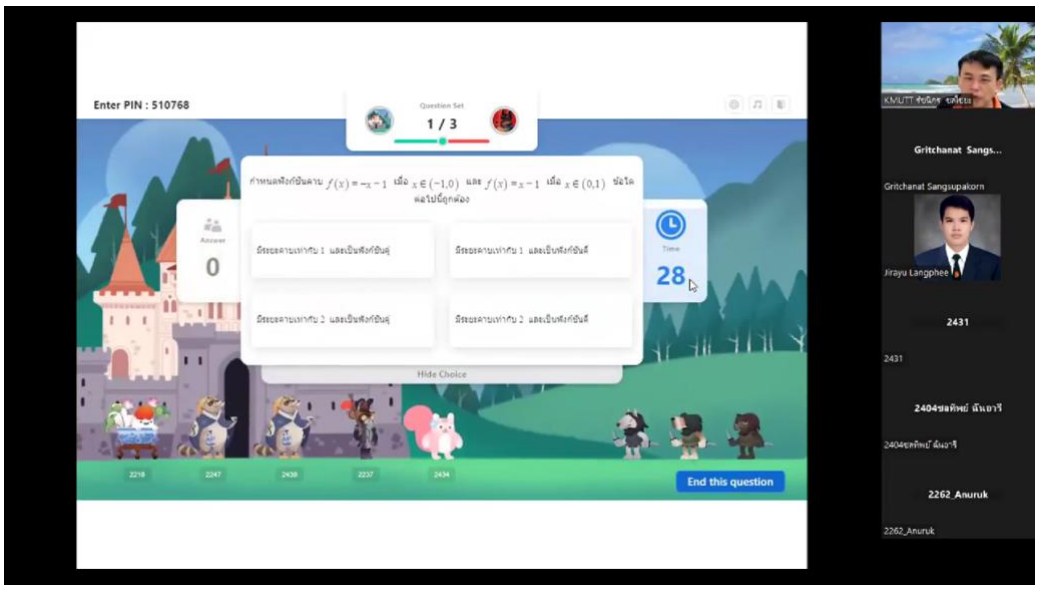

Figure 2: Vonder Go user interface

The game-based learning pedagogy was implemented during MTH102 (Calculus II) class under the topic of Fourier Series for 5 periods in the academic year 2021 where the classes are on-site with online interactive broadcasting and the students were required to attend the classes in either manner they preferred. The teaching process would start with necessary content revision, interactive class teaching followed by formative assessment using Vonder Go. Five students with the most score would be rewarded with virtual ticket that could be used to draw a price from the price pool. The volunteered students must complete mathematical self-efficacy questionnaire that consisted of 24 questions and covers the entire four aspects of the source of self-efficacy (Usher & Pajares, 2009) before and after their participation where the obtained data would be analyzed using dependent t-test with 0.05 significance level. The topics of the module are as follows.

1. Periodic Function
2. Fourier Series, Even Function and Odd Function
3. Fourier Series of Even Function and Odd Function
4. Convergence of Fourier Series
5. Half-Range Extension

After the implementation, only 16 out of 33 students were willing to complete our course. Thus, Wilcoxon Signed-Ranked Test with 0.05 significance level was chosen to analyze the data instead of the dependent t-test. The data analysis result is shown in Table 1 below.

Table 1: The results of statistical test on the students' mathematical self-efficacy

	The difference of pre-test and post-test (general)
Z	-0.817
Sig. (2-tailed)	0.414

As the sig. (2-tailed) is equal to 0.414 > 0.05, we would conclude that the mathematical self-efficacy of the students had not significantly changed in general.

Moreover, the Wilcoxon Signed-Ranked Test results of the students' mathematical self-efficacy according to the sources of self-efficacy are shown in Table 2 below.

Table 2: The results of statistical test on the students' mathematical self-efficacy according to its sources

Source of self-efficacy	Z	Sig. (2-tailed)
Mastery experience	-1.251	0.211
Vicarious experience	-0.410	0.682
Social persuasions	-2.108	0.035
Emotional and physiological state	-0.628	0.530

The results indicated that only the result in the part of social persuasions had improved since its sig. (1-tailed) is 0.0175 < 0.05. The reason might be that the students had the chance to be persuaded by their peers during the classes. These had shown that game-based learning pedagogy did not improve the students' mathematical self-efficacy which is not aligned with Wang & Zheng (2021) and Chuayprakong (2022). This occurrence requires more details for further investigation. Thus, the authors decided to acquire more qualitative data from the students through 7 semi-structured interview questions. Since most of the students chose to learn in online class, and many also decided to quit our course midway, the questions would also involve those aspects. The participants were 5 of the students chosen by convenience sampling; 2 students with higher self-efficacy (H.S.), 1 student with lower self-efficacy (L.S.), 1 student with unchanged self-efficacy (U.S.) and 1 student who chose to leave the course midway (N.P.). The qualitative results and excerpts from the interview are shown below.

Question 1. "How do Vonder Go and the rewarding system promote your learning?" revealed that the students felt more engaged, motivated and interested in our lessons which was resulted from the use of Vonder Go. Though a student (L.S.) had shown the lack of self-efficacy and uncertainty, stating that "Teaching in this way really helped me through the content. It was challenging and motivating, but when I answered the questions wrong, it made me feel a little anxious", we would say that the majority of participants still held positive thought toward our teaching.

Question 2. "Are there any differences between the traditional class and our class? How?" indicated that all the students stated many positive aspects of our lessons i.e., the lessons provided content revision during formative assessment, more engagement and class participation. A student (U.S.) stated that "There were vast differences between your lessons and traditional classes, one of those is it felt more engaging and motivating."

Question 3. "What do you think is the reason that make your classmates choose to learn in online class more than on-site class?" showed that all the students agreed that public transportation, too early class schedule, and lack of self-discipline were the reasons behind why their classmates would only participate in online classes. A student (N.P.) said that "During COVID-9, everything was online so I wouldn't want to change that since it was more convenient." Another student (L.S.) stated that "The classes were too early and hard, I couldn't keep them up with my sleep schedule so not participating might be the right choice."

Lastly, a student (H.S.NO. 2) said that "It was more convenient that way, and no one was going to force you to learn if you would not."

Question 4. "If you have to choose between learning in online class and on-site class, what will you choose?" indicated that the majority of the students would choose to participate in on-site class while only one student would choose to learn in online manner. They indicated that on-site class might provide them with more detailed content and more opportunities to ask questions. A student (N.P.) stated that "Online learning would be better. You could do anything, and no one is going to complain, and since I would rather learn by myself, having classmates during on-site class would only distract me." While most students seemed to choose on-site class, it contradicted with the result in Question 3 and what we encountered during the lessons, as a scarce number of them appeared then.

Question 5. "What are the pros and cons of learning in the manner of module?" revealed that the students reasonably pointed out the pros and cons of module lessons e.g., the content for each exam is reduced, or having to take exam more frequently resulted in them being more stressed. They agreed that it also reduced their motivation to learn since the module learning provides excessive opportunities for them to pass. A student (U.S.) said that "If we failed to pass a module, we would be provided with a chance to retake the exam. This might affect our motivation to learn in the class. And from taking the exam three times per semester, it made me feel more stressed."

Question 6. "Do you think that learning in the manner of module which requires you to take part in the exam more often makes you feel stressed? How?" indicated that most of the students were willing to take part in the module lesson since it reduced the amount of content they needed to review for each exam, making them feel more relieved. A student (U.S.) stated that "Both module and traditional learning produce the same amount of stress for me."

Question 7. "Do you think that online learning affects your stress in your daily life or when you study mathematics? How?" showed that 3 out of 5 students thought that they were more stressed when participating in online learning since there were communication barriers, and sitting in front of the desk all day would negatively affect their health, but 2 out of 5 students disagreed and pointed out that there were no negative impacts from online learning. A student (N.P.) stated that "Online learning does not provide much interaction to develop the relationship between teachers and students. This may hinder the students from asking questions confidently."

The qualitative data indicated game-based learning had positive impact toward the students' mathematical self-efficacy although the quantitative data had provided us with sufficient evidence that there was no improvement in mathematical self-efficacy. The results in both manners might seemed to be contradictory, but in fact they were not. The game-based pedagogy as we mentioned, has positive impact to students' mathematical self-efficacy, but it was not enough to improve it in this case. At first, we thought the cause of this occurrence might be from stress from module lesson and online learning, but from the qualitative data obtained and our observation, we arrived at another conclusion.

The question 3 and question 4 provided us the needed information. Online learning might not be the reason behind their undeveloped self-efficacy, but what come alongside it i.e., self-discipline. This is in line with Gorbunovs et al. (2016) and Hwang et al. (2021) stating that online learning requires a reasonable amount of discipline under social rules. This would

explain why half of the participants leaved our study half -way through. As open-minded as we are, we let them take responsibility in their learning without any negative treatments which most of them choose online learning, and in the end, they chose convenience over discipline in their learning. Most of the students would choose to watch the recorded class video instead of participating in person. There might be the cases that some students would choose on-site class, but in reality, they would not as shown in Figure… This spelled the lack of self-discipline that is an important bridge toward developing mathematical self-efficacy through both online and on-site learning since before they would start believing in their capabilities of doing something, they should be able to do it consistently without excuse first (Jung, 2013; Jung et al., 2017; Wahyuni, 2017; Yang et al., 2019).

Figure 3: On - Site Class Learning

Thus, in this study, game-based learning pedagogy has positive impacts toward students' mathematical self-efficacy, but it is not enough for developing it since the students lack self-discipline that is the key point and first step in higher education which they need to be responsible for their learning. Unless self-discipline is implemented, it may prove difficult to improve their mathematical self-efficacy and other domain-related aspects.

Conclusions

Game-based learning pedagogy has positive impacts toward the students' mathematical self-efficacy, but the quantitative results indicated that we failed to improve it. The qualitative data suggested that the lack of self-discipline that is the main bridge toward self-efficacy might be the possible reason that hindered the development of mathematical self-efficacy since students are required to be responsible for their learning and be consistent in improving themselves before they start believing that they could achieve their goal.

Further research might be augmented with the elements of self-discipline that would be of great help in developing mathematical self-efficacy. Since the classes were online and it had been shown that the students might neglect learning in this manner, and simply watch the recorded class video instead of participating, more engagement and class interaction should be implemented for the entire class.

Further research direction should involve more diverse groups of the students i.e., ethnic, gender, and major. The duration of the implementation could also be lengthened to entire semester since it might help to provide more insight to the development of mathematical self-efficacy.

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