International Journal of Multidisciplinary Approach and Studies
ISSN NO:: 2348 – 537X

# Students' Self-Efficacy in Mathematics with Mathematical Modelling Integrated with Dynamic GeoGebra Application

**Joseph C. Pasco**

*Casisang National High School, Malaybalay City, Bukidnon, Philippines*

## ABSTRACT

*The study utilized quasi-experimental control pretest-posttest group design to investigate the effects of integrating GeoGebra in mathematical modelling in teaching mathematics on student's self-efficacy. The design involved two intact groups from Casisang National High School during the school year 2019-2020. Results revealed that mathematical modelling integrated with dynamic GeoGebra software can boost and enhance student's self-efficacy in mathematics. Moreover, mathematical modelling integrated with dynamic GeoGebra application was effective in improving students' self-efficacy in mathematics. It was recommended that mathematics teachers should utilized mathematical modelling integrated with dynamic GeoGebra application in the teaching and learning process to increase student's self-efficacy in mathematics. Likewise, educators could be trained on the use of available mathematical open software in mathematics to increase efficiency in classroom instructions. Lastly, similar studies may be conducted to a wider scope using different population in different learning institutions to promote better generalizability of the method.*

**KEYWORDS:** *self-efficacy, mathematical modelling, GeoGebra*

## INTRODUCTION

Mathematical modelling and its role in mathematics education have been receiving increasing attention across the globe. Still, few studies have been conducted using modeling since teachers who want to integrate modeling into their teaching does not have sufficient resources. Sources including good examples of modeling tasks are needed by the teachers to use such strategy (Erbas, Kertil, Çetinkaya, Çakiroglu, Alacaci, & Bas, 2014). Mathematical modelling as an approach (i.e., modelling as a means for teaching mathematics) seems more developed for pedagogical purposes. However, whatever approach is preferred and used, integrating modelling into mathematics education is essential for improving students' problem-solving and analytical thinking abilities; hence multiple reasonable solutions exist that students may present in modelling tasks.

According to Ramirez(2019), teachers have difficulty in classroom management and in teaching the content. Hence, teacher should explore innovative approaches as they progress in their practice which in the end would benefit the students greatly (Ramirez, 2018).Recognizing that teaching mathematical modelling is an ambitious and challenging endeavor, teachers can navigate these challenges with planning and support. Teachers can work to understand how mathematics can be used to address a real-world problem. Teachers can also prepare themselves for modelling by planning and anticipating students' mathematical questions. In class, teachers can expect to pause their lessons to facilitate discussions regarding students' mathematical questions or ideas.

Similarly, it is important to consider that in the teaching and learning process, teacher should gain an understanding of the realities of the students and used the information as starting point to find a good strategy for instruction (Ramirez, 2018). Mathematical modelling is an ambitious but important to teaching (Fulton, 2017). Mathematical modelling presents many choices in planning and teaching.Teachers need to facilitate the initial step of mathematical interpretation of a real-world problem given its open nature. Students use multiple and varied mathematical strategies while investigating their modelling tasks. Thus, teachers need to be prepared for productive mathematical strategies and potential questions students generate in the middle of the task.

Zhang &Su (2017) pointed out that integrating mathematical modelling into mathematics education is a more apparent requirement of a new curriculum standard and a consensus view of mathematics education reform. Hence, mathematical modelling shows the relationship between learning mathematics and applying mathematics to solve practical problems. Chamberlin (2019) states that mathematical modelling is considered a process or act, in which problem solvers seek to generate an understanding of mathematical information through mathematizing in an iterative process.

Furthermore, the idea is a presentation of a miniature scientific research process so that students find it fresh, which promotes the strengthening of students' mathematical awareness and mathematics literacy. More importantly, it also encourages the students' mathematical quality. Whether in colleges, middle schools, or primary schools, the value of mathematical modelling will positively impact students' learning, so we should carry out the idea of mathematical modelling and grasp the connotation of mathematical modelling in mathematics teaching to start a perfect math learning process.

In light of technological advancement, the use of Computer Technology has become increasingly popular in schools over the past several decades. There is little doubt that technology has become a ubiquitous tool for teaching and learning (Li & Ma, 2010). It was revealed that CT has larger effects on particular needs students' mathematics achievement than general education students. The positive effect of CT was greater when combined with a constructivist approach to teaching than with a traditional approach to teaching. Besides, successful integration of technology can have a transformative effect on schools and the education system as a whole (Umugiraneza, Bansilal, & North, 2018).

Information technology influences every field of society profoundly, especially in the educational area. With the impact of information technology, using information technology to serve mathematics teaching in secondary school is an essential research topic. The study of Feng (2011) suggested that it is urgent to integrate information technology into mathematics teaching since it positively impacts students' learning interest, comprehension, and thinking ability. The application of modern information technology has led to educational level development, which has formed the core of modern educational technology, such as multimedia, network, and artificial intelligence. Using multimedia software in mathematics teaching could increase the intuitive, experimental, interesting, and reduce the difficulty of learning. The integration of information technology and mathematics curriculum can make full use of modern information technology's advantages and make computer technology as a teaching aid (Wan, Li, & Hu, 2016).

According to Blum (2015), many studies show that digital technologies can be used as powerful tools for modelling activities, not only in the intra-mathematical phases. Vorhölter, Greefrath, Borromeo Ferri, Leiß, and Schukajlow (2019) suggest extending the modeling cycle by adding a third world: the technological world. Hence computers can be used for experiments, investigations, simulations, visualizations, or calculations. Concomitant to this, the Common Core State Standards Initiative stated that graphing utilities, spreadsheets, computer algebra systems, and dynamic geometry software are powerful tools that can model purely mathematics phenomena (e.g., the behavior of polynomials) as well as physical phenomena (CCSSI, 2010). It can help support the Philippines K-12 Basic Education Program's aim to provide every Filipino child with the education he needs to compete in a global context. Technology is essential in teaching and learning mathematics; it influences the mathematics taught and enhances student's learning (NCTM, 2000). It provides a process and uses information for development, participates, and take advantage of and be creative in the new technological environment (Bakhtiari and Shajar, 2006).

Ruggiero & Mong (2015) suggested the importance of incorporating technology into the lesson plans to enhance the students' learning, which is a big help with cross-curricular teaching and differentiated learning. It dramatically helps the teachers with strongly student-centered practices exhibit a more pronounced need to create learning opportunities with technology as a base for enhancing 21st-century skills in students. Hence, students made a significant improvement in their math skills (Kermani & Aldemir, 2015).

On the other hand, an essential element of human behavior that can be harnessed to optimize students' learning experience in mathematics is their self-efficacy (Relojo-Howell, 2017). Self-efficacy in mathematics indicates students' self-belief in their ability to overcome difficulties or obstacles in solving math problems. Such a belief has been shown to be necessary to motivation because the confidence that one will solve a problem is a precursor to investing the time and effort needed to tackle it (New Zealand Ministry of Education, 2009). According to Geraghty (2013), high self-efficacy views difficult tasks as challenges to be mastered, develop a strong connection and deeper interest tasks, set more challenging goals, are more committed to their work, sustain their efforts in the face of setback or failure, recover quickly from setbacks and disappointments, and attribute setbacks to insufficient effort or knowledge (both of which can be acquired). While low self-efficacy views difficult tasks as threats to be avoided, believe that more intricate tasks are beyond their capabilities, perseverate on failures and adverse outcomes, and quickly lose confidence in their abilities.

Students' self-efficacy in mathematics is anchored on Bandura's (1997) social cognitive theory. According to this theory, mathematics self-efficacy is defined as an individual's beliefs or perceptions with respect to his or her abilities in mathematics. In other words, an individual's mathematics self-efficacy is his or her confidence about completing a variety of tasks, from understanding concepts to solving problems in mathematics. Self-efficacy, in general, has been linked with motivation. It has been well established that students with higher self-efficacy levels tend to be more motivated to learn than their peers and are more likely to persist when presented with challenges (Zeldin, Britner & Pajares, 2008). Bandura also suggested that self-efficacy should be measured close to the time that the task would take place. This proximity helps students to make more accurate judgments about their abilities than otherwise. With these guidelines for measuring self-efficacy in mind, it is crucial to understand how researchers typically measure mathematics self-efficacy.

This study combined mathematical modelling strategy and GeoGebra application in the teaching and learning process. It aims to explore the effectiveness of integrating GeoGebra in mathematical modelling as a teaching approach to improve students' self-efficacy in mathematics.

## METHODS

The study utilized quasi-experimental control pretest-posttest group design to investigate the effects of integrating GeoGebra in mathematical modelling in teaching mathematics on student's self-efficacy. The design involved two intact groups: the experimental group and the control group. The experimental group were taught using mathematical modelling with GeoGebra while the control group were taught using the conventional method of teaching with the integration of GeoGebra. The self-efficacy questionnaire was administered as pretest and posttest to both groups to measure their self-efficacy in mathematics.

Moreover, this study was conducted at Casisang National High School, District Four, Division of Malaybalay City, Bukidnon, Philippines for the school year 2019-2020.The study utilized two intact classes which were handled by the researcher. In Grade 8, there were three sections and two of these sections which are heterogeneous were handled by the researcher. The assignment of the experimental and control groups was randomly selected.

Meanwhile, the questionnaire for self-efficacy in mathematics was adapted from May (2009) which measured students' interest and motivations in mathematics learning. The Mathematics Self-Efficacy Test was composed of 14 statements and student's extent of agreement or disagreement for every statement was expressed in a 4-point scale. The four choices of response were: Strongly Agree (SA), Agree (A), Disagree (D), and Strongly Disagree (SD).The self-efficacy in mathematics questionnaire was first presented to experts before it was validated to ensure correctness and appropriateness of the questions as well as the indicators. The said test was validated during the first quarter in other classes and obtained a Cronbach alpha of 0.86 described as highly reliable.

In order to maintain the anonymity of the students -participants, coding method was applied. The code G8SAExp1 denotes Grade 8 student's section A while G8SBC1 denotes Grade 8 student's section B. The code Exp stands for the experimental which mean that the students belong to the experimental group and C for the control group. Likewise, the code M indicates male students while F indicates female students. Thus, the code G8SAMExp1 stands for Grade 8 male students section A of the experimental group.

Furthermore, to describe the level of students' self-efficacy in mathematics, descriptive statistics using mean and standard deviation were used. Additionally, to determine the significant differences of students' self-efficacy in mathematics for both experimental and control groups, analysis of covariance (ANCOVA) was employed. Analysis of Covariance was used to test the main and interaction effects of categorical variables on a continuous dependent variable, controlling for the effects of selected other continuous variables, which co-vary with the independent. It was used in this study to control factors which cannot be randomized but which can be measured on an interval scale.

On the other hand, permissions and informed consent from the concerned authorities were secured before the study was conducted. This is compliance with the Republic Act 10173, or the Data Privacy Act, protects individuals from unauthorized processing of personal information that is (1) private, not publicly available; and (2) identifiable, where the identity of the individual is apparent either through direct attribution or when put together with other available information.

## RESULTS AND DISCUSSION

The next table presents the pretest and posttest mean score of the self-efficacy test of the students in mathematics between those taught with mathematical modelling integrated with GeoGebra and those taught using the conventional method with the aid of GeoGebra.

Table 3: Mean and Standard Deviation of Students' Self-Efficacy in Mathematics

| Groups | N | Pretest | | | Posttest | | |
|---|---|---|---|---|---|---|---|
| | | Mean | SD | Response | Mean | SD | Response |
| Control | 40 | 2.64 | 0.791 | Agree | 2.69 | 0.834 | Agree |
| Experimental | 40 | 2.71 | 0.911 | Agree | 2.97 | 0.891 | Agree |

| Legend: | Mean Interval | Verbal Description |
|---|---|---|
| | 3.25-4.00 | Strongly Agree |
| | 2.50-3.24 | Agree |
| | 1.75-2.49 | Disagree |
| | 1.00-1.74 | Strongly Disagree |

As shown in table 3, pretest mean scores of the two groups differed only by 0.07 which was an indicator that both groups have closer learning interest and motivation towards mathematics. This can be noticed in the results of the standard deviations between the groups. The responses of the experimental group were more dispersed than the control group. It means that the beliefs of the students in the experimental group towards mathematics varies more than the control group. There were seven items that the control group and experimental group agreed upon and two items disagreed on. The two groups agreed that they were confident enough to ask questions, can do well on a mathematics class, somehow can manage to understand mathematics subjects, has the belief that one has the ability to do the math in a mathematics subjects and able to do well in the future mathematics subjects. Also, the control group strongly agreed that they will be able to use mathematics in their future career when needed.

Conversely, the experimental group strongly agreed that they can learn well in a mathematics subject. Likewise, the groups disagreed that they were the type of person who are good in mathematics. This implies that groups, the control and the experimental, has somehow low level of confidence in themselves in dealing mathematics that they do not yet mastered. In addition, the experimental group believe that they can get an excellent grade in mathematics subjects contrary to the control group. Furthermore, the control group, believe that they can do all of the assignments in a mathematics subjects and feel confident when taking a mathematics test contrasting to the belief of the experimental group. Both groups disagreed that they can think like a mathematician.

It can be observed that posttest mean score of both groups increased but the self-efficacy of students who were exposed to mathematical modelling integrated with GeoGebra was greater by a margin of 0.28 compared to the students taught using the conventional method with the aid of GeoGebra. The table above shows that the mean score of the control group only increased by 0.05 which means that their beliefs on themselves to achieved their goals and finished the task is smaller than the other group. Furthermore, it also implies that large number of students in the control group realized that they did not perform well in the mathematics test. In addition, students in this group might failed to manage to solve the problems even if they tried hard enough.

Conversely, the mean score of students' in the experimental group was larger than the control group. It means that they somehow succeeded in achieving their goals and accomplished the task set before them. Zhang &Su (2017) &Chamberlin(2019) support this result since mathematical modelling seek to generate an understanding of mathematical information through mathematizing it in an iterative process. Furthermore, the successful integration of GeoGebra in mathematical modelling has a transformative effect on learners conceptual understanding in solving real-world problems (Li & Ma, 2010, Umugiraneza et al, 2018).

Also, it would mean that even if they struggle to accomplish something difficult, they stay focus in their individual progress instead of feeling discouraged. It might as well that they found out that when they were exposed to mathematical modelling integrated with GeoGebra, their ability in dealing mathematical problems grew and felt that their hard works pays off after finding out the test results(Erbas et al., 2014; Fulton, 2017).

It can be observed that the standard deviation of the control group was lower compared to the standard deviations of the experimental group. This shows that there was a lesser variation on the self-efficacy score of the control group. The experimental group has a higher standard deviation indicating that their self-efficacy scores were more varied and scattered. Both groups remain to agree that they can do well in a mathematics test, understand the content in a mathematics subjects, they are the type of persons who can do mathematics and believe that they can do the mathematics in a mathematics subject. The experimental group gained much higher confidence in asking question in a mathematics class, more convinced that they will be able to use mathematics in their future career when needed and were optimistic that they will be able to do well in their future mathematics subjects while the control group somehow remained constant. The results show that the groups still disagreed that they can think like a mathematician. It can be inferred from the results that students from the experimental group became more interested and motivated in dealing mathematical problems in mathematics with the use mathematical modelling integrated with dynamic GeoGebra than those in the control group (Wan et al., 2016; Blum, 2015).

To determine if there is a significant difference in the posttest self-efficacy scores between the students from experimental and control group, analysis of covariance was employed.

Table 4: One-Way ANCOVA Summary of the Students' Mathematics Self-Efficacy

| Source | Df | Adj SS | Adj MS | F-Value | p-Value |
|---|---|---|---|---|---|
| Treatment Within | 1 | 0.704 | 0.704 | 14.610 | 0.000* |
| Error | 77 | 3.712 | 0.048 | | |
| Total | 80 | 661.402 | | | |

*significant at $p<0.05$ alpha level

The data in table 4 shows that there was a significant difference in the posttest scores in the self-efficacy between the students in the experimental group and the students in the control group. The null hypothesis which states that there was no significant difference in the self-efficacy of Grade 8 students when taught with mathematical modelling integrated with GeoGebra and those taught using conventional method of teaching with the aid of GeoGebra was tested at 0.05 level of significance. The result shown in the above table indicated that the treatment within obtained a p-value of 0.000. Since the p-value was lower than the significant level of 0.05, the null hypothesis was *rejected*. Therefore, there was a significant difference in the self-efficacy in mathematics of students when taught using mathematical modelling with the integration of GeoGebra and those taught using conventional methods of teaching with the aid of GeoGebra (Ruggiero & Mong 2015; Kermani & Aldemir, 2015).

The result indicates that the students in the experimental group develop a sense of confidence to deal efficiently the unforeseen situation in the mathematical problem given. Also, this implies that students' belief that they can solve problems even if they invest necessary effort in using mathematical modelling integrated with GeoGebra to attain their specific goals. It also entails that, students' in this group remained calmed when facing difficulties in dealing mathematics hence used their coping abilities to enrich learning (Geraghty, 2013).

Similarly, it connotes that the students believe that they can find several solutions when confronted with different problems in math or when they are in trouble, they can usually think of a solution with the help of mathematical modeling integrated with GeoGebra application. Conversely, the students in the control group, after being exposed to conventional method with GeoGebra, have shown an increase of self-efficacy in mathematics but not at the same degree compared to the experimental group. The reason of the increase of self-efficacy in the control group might be their experience in using GeoGebra application which is part of the stages that students followed when they were working with similar sets of problems (Feng, 2011).

Furthermore, the stages of mathematical modelling aided the students in the experimental group in solving the problem. When the students were doing the math part of mathematical modelling, they were taught how to model the problem using drawings and figures in order for them to visualized and create an illustration. Also, in this stage, students need to come up a linear equation that will represent the problem which was the most challenging part for them. After this, students were still unsure and confused if they got the correct answer that is why the next stage which is the GeoGebra integration guided them if their answers were correct or not. Using GeoGebra application excites students and upon verifying that they got the answer correctly, they felt happy and driven since they can see the outcome of their hard work. It might be that in this stage of mathematical modelling, the students become more inspired in answering problems (Geraghty, 2013).

Likewise, the students' in the experimental group succeeded at most in their objectives in learning the mathematics in their lessons and still perform quite well even if things were tough because they tend to be encouraged to proceed in solving challenging mathematical problem since mathematical modelling integrated with GeoGebra was of great help to them. This shows that the use of the mathematical modelling integrated with GeoGebra significantly affects the learning interest, confidence and motivations of the students in learning mathematics. Besides, it assisted students to boost their performance, persist longer and to have fewer adverse emotional reactions when encountering difficulties in dealing real-world problems in mathematics (Zeldin et al., 2008).

The result means that mathematical modelling with GeoGebra application became a motivational construct of the students hence it affected their self-efficacy. This is supported by the study of Zimmerman (2000) who found out that self-efficacy beliefs are sensitive to subtle changes in students' performance context, to interact with self-regulated learning processes, and to mediate students' academic achievement. Furthermore, the study of Saha, Ayub, &Tarmizi(2010) showed that the use of Geogebra enhance the students' performance in learning thus help students and teachers to perform calculation, analyze data, explore mathematical concepts with an increasing understanding and comprehension skills.

## CONCLUSION AND RECOMMENDATION

It can be inferred from the result of the study that mathematical modelling integrated with dynamic GeoGebra software can boost and enhance student's self-efficacy in mathematics. Moreover, mathematical modelling integrated with dynamic GeoGebra application was effective in improving students' self-efficacy in mathematics.

It is recommended that mathematics teachers should utilized mathematical modelling integrated with dynamic GeoGebra application in the teaching and learning process to increase student's self-efficacy in mathematics. Likewise, educators could be trained on the use of available mathematical open software in mathematics to increase efficiency in classroom instructions. Lastly, similar studies may be conducted to a wider scope using different population in different learning institutions to promote better generalizability of the method.

## REFERENCES


i. *Bakhtiari, S., &Shajar, H. (2006). Globalization and education: Challenges and opportunities. International Business & Economics Research Journal (IBER), 5(2).*

ii. *Bandura, A. (1997). Self-efficacy: The exercise of control. New York: W.H. Freeman*

iii. *Blum W. (2015) Quality Teaching of Mathematical Modelling: What Do We Know, What Can We Do? In: Cho S. (eds) The Proceedings of the 12th International Congress on Mathematical Education. Springer, Cham https://link.springer.com/chapter/10.1007/978-3-319-12688-3_9*

iv. *Chamberlin, S. A. (2019). The Construct of Affect in Mathematical Modeling. In Affect in Mathematical Modeling (pp. 15-28). Springer, Cham*

v. *Common Core State Standards Initiative (CCSSI). 2010. Common Core State Standards for Mathematics. Washington, DC: National Governors Association Center for Best Practices and the Council of Chief State School Officers. http://www.corestandards.org/wpcontent/uploads/Math_Standards.pd*

vi. *Erbas, A. K., Kertil, M., Çetinkaya, B., Çakiroglu, E., Alacaci, C., & Bas, S. (2014). Mathematical Modeling in Mathematics Education: Basic Concepts and Approaches. Educational Sciences: Theory and Practice, 14(4), 1621-1627.*

vii. *Feng, Y. J. (2011). A research on the integration of information technology with mathematics teaching of probability in senior high school (Order No. 10572380). Available from ProQuest Dissertations & Theses Global. (1873864999). Retrieved from https://search.proquest.com/docview/1873864999?accountid=173015*

viii. *Fulton, E. A. W. (2017). The mathematics in mathematical modeling (Order No. 10682119). Available from ProQuest Dissertations & Theses Global(1985985522). Retrieved from https://search.proquest.com/docview/1985985522?accountid=173015*

ix. *Greefrath, G., &Vorhölter, K. (2016). Teaching and learning mathematical modelling. Springer International Pu.*

x. *Greefrath, G., Siller, H.-S. &Weitendorf, J. (2011). Modelling Considering the Influence of Technology. In: Kaiser, G. et al. (Eds, 2011), Trends in Teaching and Learning of Mathematical Modelling (ICTMA 14). Dordrecht: Springer, 315-329.*

xi. *Kermani, H., & Aldemir, J. (2015). Preparing children for success: integrating science, math, and technology in early childhood classroom. Early Child Development and Care, 185(9), 1504-1527.*

xii. *Li, Q., & Ma, X. (2010). A meta-analysis of the effects of computer technology on school students' mathematics learning. Educational Psychology Review, 22(3), 215-243.*

xiii. May, D. K. (2009). Mathematics self-efficacy and anxiety questionnaire (Doctoral dissertation, University of Georgia).

xiv. *Ministry of Education, New Zealand (2009). PISA (2003): Student learning approaches for tomorrow's world.*

xv. *Ramirez, IA. L. (2018). Biological sciences pre-service teachers' challenges in teaching physics: A grounded theory. International Journal of Multidisciplinary Approach and Studies, 5(3), 136-150.*

xvi. Ramirez, IA. L. (2018). Pre-service teachers: experiences in teaching junior high school. International Journal of Multidisciplinary Approach and Studies, 5(2), 134-153.

xvii. Ramirez, IA. L. (2019). Teaching senior high school: Through the eyes of student intern. International Journal of Multidisciplinary Approach and Studies, 6(3), 42-52.

xviii. Relojo-Howell, Dennis (2017). Help Your Students Believe In Themselves: Self-Efficacy In The Classroom. American Psychological Association Education Directorate

xix. Ruggiero, D., & Mong, C. J. (2015). The teacher technology integration experience: Practice and reflection in the classroom. Journal of Information Technology Education, 14.

xx. Vorhölter K., Greefrath G., Borromeo Ferri R., Leiß D., Schukajlow S. (2019) Mathematical Modelling. In: Jahnke H., Hefendehl-Hebeker L. (eds) Traditions in German-Speaking Mathematics Education Research. ICME-13 Monographs. Springer, Cham. https://doi.org/10.1007/978-3-030-11069-7_4

xxi. Zeldin, A. L., Britner, S. L., &Pajares, F. (2008). A comparative study of the self- efficacy beliefs of successful men and women in mathematics, science, and technology careers. Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 45(9), 1036-1058.