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Bagatrix on mathematics achievement of college students

Jonathan Q. Monsanto[1], Dionilo M. Llanas[2]
[1]Faculty of Teacher Education, College of Teacher Education Arts and Sciences, Visayas State University-Villaba Campus, Villaba, Philippines
[2]Faculty of Basic Teacher Education, College of Teacher Education, Palompom Institute of Technology, Palompon, Philippines

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ABSTRACT

Integration of technology in mathematics education is one of the innovative ways of instructional delivery in various mathematics subjects. This study investigated the use of Bagatrix, a dynamic geometry software offering step-by-step explanations, interactive graphs, and practice problems with instant feedback. The academic achievement of 80 freshmen Bachelor of Secondary Education (BSED) major in science and mathematics at Visayas State University-Villaba Campus during the school year 2023-2024 using Bagatrix was compared to the traditional lecture-discussion method in Mathematics in the modern world (MMW). Grounded in constructivist learning theory, this study aimed to determine if Bagatrix could enhance student academic achievement. Quantitative research utilizing true experimental design with pretest and posttest was employed, partnered with its statistical treatment which includes the mean, standard deviation, and t-test for independent samples. Data analysis revealed no statistically significant difference between the two teaching methods. However, both groups exhibited significant improvement from pretest to posttest, with students exposed to Bagatrix demonstrating a greater magnitude of improvement. This study highlights the potential of technology-enhanced learning environments in mathematics education, while emphasizing the need for further research to investigate the factors contributing to the observed learning gains.

Corresponding Author:

Jonathan Q. Monsanto
Faculty of Department of Teacher Education, College of Teacher Education Arts and Sciences
Visayas State University-Villaba Campus
Cagnocot, Villaba, Leyte, Philippines
Email: jonathan.monsanto@vsu.edu.ph

1. INTRODUCTION

Technology integration in the teaching-learning process, especially in mathematics education, has been increasing around the world. In the Philippines, these technologies, such as mathematical software, have not been fully recognized by some Filipino mathematics teachers despite their effectiveness and usefulness. There are many mathematical tools used globally, such as Geogebra, MatLab, Geometer's Sketchpad, and Mathway that have already proven their capacity to enhance student academic achievement and learning [1]–[4]. Introducing this mathematical software to Filipino mathematics teachers can offer them an alternative way of delivering mathematics lessons.

Incorporating technology in the classroom can promote a positive and meaningful learning experience [5]. This technology-driven instruction is aligned with the educational goals of the United Nations' Sustainable Development Goal 4 (SDG 4) to provide inclusive and high-quality education for all, emphasizing lifelong opportunities [6]. This goal acknowledges that education is a fundamental human right and crucial to

sustainable development. Aligned with this, integrating tools like Bagatrix can enhance the quality of education, particularly in mathematics education. It is a versatile tool that can be instrumental in achieving the targets outlined in SDG 4. It can help make education more inclusive by providing personalized and self-paced learning experiences. Students from diverse backgrounds and abilities can access the tool which tailors' content to individual needs and ensures that no one is left behind in their pursuit of quality education.

As the educational landscape evolves, the Commission on Higher Education (CHED) introduced the CMO No. 20 series 2013 [7] to guide the New General Education Curriculum (NGEC) within the K to 12 curriculum frameworks. General education is an important part of the curriculum that all undergraduate students must complete regardless of their majors. It aims to meet the requirements of the 21st century by fostering graduates who possess a deep understanding of humanistic principles, a strong sense of self-identity as individuals and Filipinos, awareness of their role in the global community, and a commitment to environmental responsibility.

Mathematics in the modern world (MMW) is a crucial general education course for first-year college students. It explores mathematics' practical, intellectual, and aesthetic aspects and its application in everyday life. The course introduces mathematics as a study of patterns and reasoning methods, emphasizing its beauty and logical language in science. Students learn how mathematics can be used in personal finance, social decision-making, geometric designs, data transmission codes, security, and resource allocation. Through practical exercises, students apply mathematical concepts and enhance their understanding and skills across various dimensions of mathematical knowledge [8].

Students' academic achievement in MMW has been explored and studied. Competencies and difficulties significantly impact students' achievement [9], [10] and researchers recommend that mathematics teachers in MMW classes from various colleges and universities should utilize the proposed instructional module to enhance its reliability and usability to further enhanced students' academic achievement [11]. The necessity to developed a worktext in MMW due to insufficient teaching and learning resources in universities is also emphasized [12]. This is very relevant to this study as, to produce new instructional materials on the potential use of Bagatirx within the MMW course. Additionally, it has been found that the MMW course needs more development [13]. One of the developments that the researchers implemented was Bagatrix integration since student nowadays are more attentive to technology rather than traditional teaching methods.

Particularly, in Visayas State University-Villaba Campus, the MMW performance of students for the three years 2020, 2021, and 2022 were declining where the average was 2.38, 2.53, and 2.18, respectively. These declining scores prompted the researchers to find a way to solve this by using a different approach in teaching (i.e., Bagatrix) rather than the lecture-discussion method. Bagatrix is a beautiful software that really suit the MMW course whereas most of the topics can be handled by this software. Despite the features that Bagatrix can offer, studies show that it is rarely used by mathematics educators [14] compared to other mathematical software and tools. This study was to provide empirical evidence whether Bagatrix can play a role even if it is rarely used by mathematics teachers.

In fact, here in the Philippines only few mathematics teachers have explored the beauty of this software. One study was conducted in senior high school (SHS) by Galleto and Pongan [15], particularly for the general mathematics subject. It was also applied to college and advanced algebra by Apostol [16]. However, there is no existing study where Bagatrix has been integrated into the MMW course to improve students' academic achievement. These limited research literature on this, has sparked the researcher's eagerness to explore this within the MMW course.

Moreover, this research gap underscores the novelty of the present study, which aimed to evaluate the effectiveness of Bagatrix as a technological intervention in teaching the MMW course compared to the lecture-discussion method. Specifically, the study seeks to address the following research questions: i) what are the pretest and posttest mean scores of students exposed to the Bagatrix software and those exposed to the traditional lecture-discussion method? iii) what are the mean gain scores of students in both groups? and iii) is there a significant difference between the Bagatrix and lecture-discussion methods? By addressing these questions, the study aimed to provide empirical evidence on the potential of Bagatrix to enhance students' academic achievement in MMW, thereby contributing a fresh perspective to mathematics education research in the Philippines and offering a viable alternative to traditional instruction.

2. METHOD

2.1. Research design

This study employed quantitative research design specifically, a true experimental design utilizing the use of pretest and posttest methods. True experimental design is a type of experimental design that relies on statistical analysis to prove or disprove a hypothesis, making it the most accurate form of research and it needs three factors to be satisfied: There is a control group which will not be subject to changes and an

experimental group which will experience the changed variables, a variable that can be manipulated by the researcher and random distribution [17]. This design was chosen to enable a clearer assessment of Bagatrix compared to the lecture-discussion method.

2.2. Research participants

This study was conducted at Visayas State University-Villaba Campus, located in the province of Leyte, Philippines, during the school year 2023-2024. The participants of this study were the freshmen BSED majoring in Science and Mathematics at Visayas State University-Villaba Campus who enrolled that 1st semester. Systematic random sampling based on their SHS General Weighted Average (GWA) was used to create the two groups composed of 40 students each. The number of participants was limited to 80 students since there are only 25 BSED Mathematics students and 55 BSED Science students who were officially enrolled in the researcher's MMW class in that school year 2023-2024. The experimental group received instruction using Bagatrix software where students worked individually on computers, with teacher guidance and supervision, to explore concepts in MMW. They worked through examples, input data, observed solutions generated by the software and practiced problem-solving manually, comparing their results with Bagatrix's output. The control group received instruction via a traditional lecture-discussion method, supplemented with printed handouts. Both groups spent one hour on core concepts, 15 minutes on independent practice, and 15 minutes on assessment.

2.3. Research instrument

To gather the data, the research instrument was a 40-item teacher-made test. The content of the teacher-made test was validated and pilot tested to ensure its reliability to measure the academic achievement of the students enrolled in the MMW course and follow the process of standardization [18].

2.4. Data collection

Data collection begins by seeking permission from the office of the chancellor of Visayas State University-Villaba Campus; subsequently, the letter was forwarded to the dean's office and department office for the arrangement of the classes. Signing of the participants' consent was followed, and the study's nature, scope, and purpose were explained to the participants by ensuring that all data collected from them would be treated confidentially with hidden identities. The pretest was administered to measure their prior knowledge before the implementation of the Bagatrix. Exposure to the two teaching methods was implemented before the posttest. To better understand the flow, Figure 1 summarizes the series of steps taken in this study.

2.5. Data analysis

The data collected were analyzed using the mean, standard deviation, and t-test for independent samples, while the qualitative description of the computed mean transmuted percentage score (MTPS) based on 50% passing of the MMW course was determined using the Visayas State University transmutation table taken from the Visayas State University Code of 2016. It was interpreted as in Table 1.

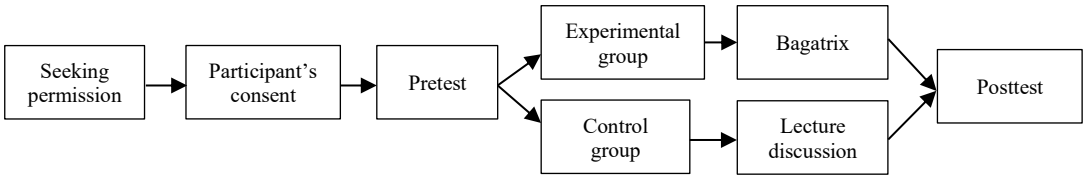

Figure 1. Flowchart of steps in the study

Table 1. Visayas State University transmutation table

MTPS	Adjectival rating
100-99	Excellent
98-96	Highly outstanding
95-93	Outstanding
92-90	Very good
89-87	Good
86-84	Very satisfactory
83-81	Satisfactory
80-78	Fair
77-75	Passing
74 and below	Failed

3. RESULTS AND DISCUSSION

This part is dedicated in presenting, analyzing, and interpreting the data collected from the pretest and posttest scores of the Bagatrix group (experimental) and lecture-discussion group (control). The goal is to ascertain whether there is a significant difference between the Bagatrix and lecture-discussion method regarding the academic achievement of freshman BSED students majoring in mathematics and science at Visayas State University-Villaba Campus, particularly in MMW.

3.1. Results

3.1.1 Pretest and posttest mean scores

The computed pretest and posttest mean between Bagatrix and lecture-discussion method is being presented in Table 2. Table 2 presents the computed results together with its equivalent interpretation. Specifically, it answers on the first objective of the study.

Table 2. Pretest and posttest mean scores of the Bagatrix and lecture-discussion group

Group		N	Mean	MTPS	SD	Interpretation
Lecture-discussion (control)	Pretest	40	13.63	67.03	2.771	Failed
	Posttest	40	23.30	79.13	5.431	Fair
Bagatrix (experimental)	Pretest	40	13.48	66.84	3.896	Failed
	Posttest	40	24.65	80.81	5.736	Fair

3.1.2. Mean gain scores

This part presents the mean gain scores of the two groups exposed to the different teaching methods employed. Table 3 present its computed value and its equivalent interpretation. Additionally, it addresses the second objective of this experimental study.

Table 3. Mean gain scores of the Bagatrix and lecture-discussion group

Group	Mean		Mean gain	Interpretation
	Posttest	Pretest		
Lecture-discussion (control)	23.30	13.63	9.68	Fair
Bagatrix (experimental)	24.65	13.48	11.18	Fair

3.1.3. Significant difference between mean gain scores

Table 4 presents the computed results for the significant difference between the Bagatrix and lecture-discussion methods based on the computed mean gain. The researcher found out that the gain scores between the two groups are normally distributed using the Shapiro-Wilk Test which indicates that the data (gain) are normally distributed. Thus, a t-test for independent samples was used to determine the significant difference between the two groups concerning their mean gain.

Table 4. Significant difference between the mean gain scores of the Bagatrix and lecture discussion group

Group	Gain scores		t-test for independent sample			
	Mean	SD	Statistics	p	df	Interpretation
Lecture discussion (control)	9.68	4.665	-1.42	0.16	78	Not significant
Bagatrix (experimental)	11.18	4.782				

Note: *p≤0.05 is considered significant.

3.2. Discussion

Table 2 presents the pretest and posttest mean scores of the Bagatrix (experimental) and lecture discussion method (control) groups. The pretest mean score of the experimental group was 13.48 with a standard deviation of 3.896, while the control group was 13.63 with a standard deviation of 2.771. It revealed that the lecture-discussion group had a slightly higher mean score than the Bagatrix group. However, they were both interpreted as pretest fails, which indicates that the level of achievement before the study is equal, and that is a good indicator as a starting point before the study's implementation, where the student's knowledge and skills are equal. This result was consistent with the study of Lantajo and Tipolo [19], which found that the pretest mean score of the control group was slightly higher than the experimental group, but they were both interpreted as average. However, failed interpretation of the pretest results between the groups

is expected to happen since the students are not familiar with the new concept being introduced to them. This observation was supported by Zhussupbayev *et al.* [20] who reported that low or failed pretest results established equivalence between the groups before the study, which indicates an equal level of knowledge and the results is a good indicator as a baseline for measuring the learning gain after the given intervention.

Meanwhile, the posttest mean score of the experimental group (Bagatrix) and control group (lecture-discussion) was 24.65, with a standard deviation of 5.736, and 23.30, with a standard deviation of 5.431, respectively. The posttest mean score of the Bagatrix group was higher than that of the lecture-discussion group. However, they were both interpreted as fair. It means that the level of achievement between the two groups was equal during the posttest. This result was consistent again with Lantajo and Tipolo [19], where the experimental group's mean was slightly higher than the control group during the post-test, but were both interpreted as average. Similarly, a study by Apostol [16] found that the experimental group had a slightly higher posttest mean than the control group, but it was insignificant. It means that the performance of the two groups during the posttest was statistically interpreted as equal with the Bagatrix group showing a slightly higher posttest mean. The results by other researchers being mentioned support the interpretation of the result of this study of the posttest and pretest scores of two groups. A fair interpretation of the posttest mean results between the groups may be attributed to several reasons observed by the researcher, namely the length of the study, computer literacy, and difficulties in calculating mathematical concepts.

According to the study by Eyi-Uko [21], computer literacy can improve students' ability to analyze and present related information. Ullah *et al.* [22] also found that computer literacy can positively affect the academic performance of students. However, some students in the study needed to be more proficient in manipulating the computer, leading to a less significant increase in academic achievement. The length of the study also influenced the results as it was only conducted over a period of 7 weeks. However, study by Kavanagh *et al.* [23] suggested better results are achieved with 8 to 12 weeks of studies. Additionally, students' difficulties in understanding mathematical concepts, where students struggle with math due to underlying cognitive difficulties, can affect their academic performance and lead to a lower level of achievement after the intervention [24], [25].

Moreover, based on the results in Table 2, the experimental and control groups performed equally during the pretest and posttest, as shown in their adjectival ratings, which are both failed and fair, respectively. It further implies that both Bagatrix and the lecture-discussion group achieved an equal level of achievement in MMW before and after the experiment. Furthermore, the two methods contributed equally to increasing the achievement from pretest to posttest with the Bagatrix group leading with a higher posttest mean.

Table 3 presents the mean gain scores between the groups. The mean gain score of the Bagatrix group was 11.18, while the lecture-discussion group was 9.68. Based on that result, the study revealed that the mean gain score of the Bagatrix group was slightly higher than the lecture-discussion group. However, they are both interpreted as fair. It means that they are both equal and comparable. The result was consistent again with the study of Lantajo and Tipolo [19], which revealed that the mean gain score of the Bagatrix group was slightly higher than that of the lecture-discussion group, but they were equally interpreted as average level. However, in the context of this study they are both interpreted as fair.

A fair interpretation of the results between the groups may be attributed to Lima *et al.* [26] who found that students faced difficulties in solving mathematical concepts that could impact their academic performance. Additionally, one factor that could have influenced the results was the duration of the implementation [23]. Similarly, Ahmad *et al.* [27] demonstrated that spaced repetition leads to superior learning outcomes compared to massed practice, suggesting that a short Bagatrix intervention may be similar to massed practice, providing initial exposure but not enough time for true mastery. Moreover, it implies that the two methods equally contributed to the increase in the student's academic achievement based on the mean gain result of the two groups

Table 4 compares the mean scores of the two groups using the t-test for independent samples. The computed p-value was 0.16, greater than the 0.05 significance level; it indicates no significant difference between the Bagatrix and lecture-discussion groups concerning their mean gain. This result was consistently shown in the study of Apostol [16], who used the Bagatrix and lecture-discussion method in comparing the student's academic performance in learning Algebra. She found out that there was no significant difference between the two groups. Moreover, we cannot conclude that Bagatrix was more effective than lecture-discussion, or vice versa. This increase in academic achievement cannot be attributed to either of the two teaching methods employed since they are statistically comparable but is more likely due to some maturation process or historical event common to both groups [28].

Not significant results in the study may be attributed to the conclusion of the study by Rosyada and Retnawati [29] whom demonstrated that learners are not all-knowing (omniscient), with students facing challenges with calculations, limited information, or knowledge gaps that may resort to heuristics such as anchoring. Anchoring involves relying on a familiar example or data point as a reference for comparison,

potentially leading to biased decision-making. It might be one of the factors that affect the result of the study wherein the participants face challenges in calculations during the implementation of the selected topics in MMW. This could lead to anchoring. This phenomenon was evident based on the assessment result in every lesson during the implementation phase, wherein some of the participants got a failing score, and most of the scores were very dispersed from the average.

Another factor was the length of the study's implementation, which lasted for only 7 weeks. The study showed that spaced repetition led to better learning outcomes than massed practice [27]. Similarly, a short Bagatrix intervention might be analogous to massed practice-providing initial exposure but not enough time for true mastery. In the future studies, extended practice with the Bagatrix method, spaced over time, could have a stronger effect on academic achievement. Furthermore, Dunn and Kennedy [30] found that technology-enhanced learning (TEL) is not associated with students' academic performance.

Moreover, no significant result led to the acceptance of the study's hypothesis, which implies that the Bagatrix and lecture-discussion methods were comparable in increasing the students' academic achievement. It means that both are equally effective in increasing students' academic achievement in MMW. However, the Bagatrix group had a favorable increase from pretest to posttest which suggests an alternative way of handling the MMW course with technology integration especially on the topics of statistics.

In the future, further studies might consider increasing the sample size, extending the duration of the experimental treatment, and including more topics in mathematics to enhance the study's outcomes. Organizing a one to two-day seminar on the Bagatrix software before its implementation can ensure a better understanding and utilization of the software. Additionally, considering additional moderator variables, such as a computer literacy test, can explore their potential impact on academic achievement in mathematics.

4. CONCLUSION

Based on the results of this study, it can be concluded that the mean scores of the Bagatrix and lecture-discussion groups on the pretest and posttest were classified as failed and fair, respectively. This result suggests that the students' achievement levels were similar before and after the intervention, with a slightly higher mean gain score in the Bagatrix group compared to the lecture-discussion group. However, both groups were considered to have achieved a fair level. Additionally, no significant difference was found between the groups, which indicates that both methods were equally effective in improving students' academic achievement in MMW, with Bagatrix leading the posttest performance. It further implies that Bagatrix can also be used as an alternative way of handling MMW courses, particularly in statistics topics and its allied mathematics subjects, giving an opportunity to the mathematics educators' community to integrate technology-driven instruction.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Jonathan Q. Monsanto	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Dionilo M. Llanas			✓	✓	✓			✓				✓		

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing financial interests or personal relationships that have appeared to influence this manuscript.

INFORMED CONSENT

The researchers obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The study has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review committee of the College of Graduate Studies Palompon Institute Technology. However, as of this study conducted there is no ethical clearance given to the researcher, only the notice to proceed after the paper review which includes ethical review.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, [JQM]. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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BIOGRAPHIES OF AUTHORS

Jonathan Q. Monsanto is an instructor at the College of Teacher Education, Arts, and Sciences of Visayas State University in Villaba, Leyte, Philippines, where he teaches Mathematics, Professional and General Education subjects. He obtained his bachelor's degree in secondary education majoring in Mathematics from Visayas State University-Villaba Campus in 2017 and completed his Master of Arts in Education majoring in Mathematics from Palompon Institute of Technology year 2024. He is a former Senior High School Teacher at the Department of Education, Division of Leyte from 2019 to 2023, where he taught mathematics and practical research subjects. He has presented a paper nationally on mathematics education at Mathematical Society of the Philippines-Region 10 during the Annual Convention at Bukidnon State Universitity Malaybalay, Bukidnon, Philippines. He can be contacted at email: jonathan.monsanto@vsu.edu.ph.

Dionilo M. Llanas is an assistant professor at the College of Teacher Education of the Palompon Institute of Technology where he teaches Mathematics and General Education subjects. He obtained his Bachelor of Science in Industrial Education major in Mathematics in 1998, Master of Arts in Developmental Education in 2005 and Doctor of Philosophy in Educational Management in 2020 in same school where he is currently affiliated. He is handling mathematics subjects in both graduate and undergraduate courses. He had published paper related to fund allocation and budget utilization rate in relation to SUC leveling performance. He can be contacted at email: dionilo.llanas123@gmail.com or dionilo.llanas@pit.edu.ph.