Interactive Learning in Algebra: A Quasi-Experimental Study of MalMath and FX Algebra Solver

Lovely Rose A. Bolante[1], **Sherrie Ann C. Labid**[2], **& Eddie B. Rosales Jr.**[3]
Samar State University, Catbalogan City, Samar
oedr@ssu.edu.ph[1]; sherrieann.labid@ssu.edu.ph[2]; reddie821@gmail.com[3]

Article Information

History:
Received 20NOV2023
Final Revision 10OCT2024
Accepted 15DEC2024

Keywords:
Algebraic Achievement
Math Application
Mathematics Education
Technology Integration
Quasi-Experiment

Abstract: Algebra is foundational to mathematics education, underpinning advanced concepts and essential skills like problem-solving and logical reasoning. However, students often struggle with symbolic representation, logical thinking, and applying mathematical concepts. Information and Communication Technology (ICT) tools, such as MalMath and FX Algebra Solver, offer interactive, step-by-step solutions to address these challenges. This study used a pre-test, post-test non-equivalent control group quasi-experimental design to assess the effectiveness of these applications in improving algebraic achievement. Forty-two second-year BEED students from a state university in Samar, Philippines, were matched by sex, section, and average grades and assigned to experimental or comparison groups using MalMath or FX Algebra Solver, respectively. Both groups showed significant improvements in pre-test and post-test scores, with no significant difference in post-test outcomes, indicating both tools were equally effective. These findings highlight the potential of accessible, technology-based tools to enhance algebra learning and suggest further research on their long-term impacts and broader applications.

1. Introduction

The importance of excelling in mathematics arises from its profound impact on various aspects of human life, including the successful completion of bachelor's degrees (Kohen & Nitzan, 2022), daily activities (Van den Heuvel-Panhuizen & Drijvers, 2020), career opportunities (Huang et al., 2019), and problem-solving skills (Siagan et al., 2019). Achieving significant success in mathematics requires a thorough understanding and mastery of various mathematical domains, such as algebra (Rach & Ufer, 2020; Rodrigo & Alave, 2021). This highlights the critical role of algebra as a foundational discipline, equipping individuals with essential tools for problem-solving, logical reasoning, and analytical thinking, while bridging basic arithmetic and advanced mathematical concepts.

Algebra is often regarded as the "gatekeeper subject" (Handsman et al., 2022), emphasizing the need for a strong foundation before progressing to more advanced mathematical topics such as geometry, calculus, number theory, and trigonometry. It is considered a crucial milestone in students' mathematical learning journey (Grover, 2022). Consequently, it is recommended that students begin studying basic algebra as early as eighth grade (Kieran, 2018).

However, numerous studies in mathematics education have reported that students frequently encounter difficulties with essential algebraic concepts. These challenges include using symbolic language, making accurate interpretations, memorizing formulas, retrieving facts, maintaining focus, and applying logical thinking (Herscovics, 2018; Sugiarti & Retnawati, 2019; Ying et al., 2020; Darmayanti et al., 2023). Additional research suggests that students' errors, difficulties, and achievements in algebra are influenced by factors such as the transition from arithmetic to algebra, the instructional context, and the integration of multiple representations, including the use of technology (Ying et al., 2020).

In this context, Information and Communication Technology (ICT) has emerged as a powerful tool to address these learning challenges, particularly in algebra. Studies highlight the positive impacts of employing technology, such as computers, tablets, and smartphones, to enhance mathematical learning (Kurvinen et al., 2020; Guler et al., 2022). Specifically, software like Computer Algebra Systems (CAS) and Dynamic Geometry Systems (DGS) has proven effective in helping students overcome difficulties by offering numerical, graphical, and symbolic representations, thereby making complex problem-solving more accessible and efficient (Dana-Picard, 2023; Kusnadi & Asih, 2023).

Despite these benefits, significant barriers such as the cost and limited accessibility of these technologies, particularly in resource-constrained settings, underscore the urgent need for further research and the development of alternative solutions. These challenges are especially pronounced in rural areas and schools with restricted budgets, where access to advanced software like Computer Algebra Systems (CAS) and Dynamic Geometry Systems (DGS) is often unattainable. Addressing these limitations is crucial to ensuring equitable access to technology, fostering inclusive learning environments, and promoting the sustainable integration of digital tools into mathematics education.

This study aimed to address this gap by evaluating the potential benefits of integrating mathematics application software, specifically focusing on the use of MalMath and FX Algebra Solver to enhance students' achievement in algebra. The study's novelty lies in its exploration of alternative, cost-effective software applications that offer practical and accessible solutions for mathematics learning. By investigating the effectiveness of MalMath and FX Algebra Solver, the study sought to contribute to the existing body of knowledge by identifying viable substitutes for expensive software and addressing the research gap regarding the comparative effectiveness of different mathematics applications in improving algebra learning outcomes.

2. Objectives

This study aimed to evaluate the effectiveness of these two software applications in improving students' algebra learning by comparing MalMath's step-by-step solution with a graph view to FX Algebra Solver's step-by-step solution without description.

Specifically, it sought to:

a. determine the significant difference between the pre-test mean scores of students exposed to FX Algebra Solver and MalMath software;

b. assess the significant difference between the pre-test and post-test mean scores of students exposed to FX Algebra Solver and MalMath software, and

c. examine the significant difference in the post-test mean scores of students exposed to FX Algebra Solver and MalMath software.

Hypotheses

The following hypotheses were tested in the study:

a. There is no significant difference between the pre-test mean scores of students exposed to FX Algebra Solver and MalMath software.

b. There is no significant difference between the pre-test and post-test mean scores of students exposed to FX Algebra Solver and MalMath software.

c. There is no significant difference in the post-test mean scores of students exposed to FX Algebra Solver and MalMath software.

3. Methodology

3.1 Research Design

The researchers employed a pre-test, post-test non-equivalent control group quasi-experimental design in this study, involving 42 students who were assigned to either the experimental or comparison group. To ensure comparability, the researchers matched participants based on variables such as sex, section, and average grades in Math110 and Math120. This design was chosen to examine the effects of using MalMath software and FX Algebra Solver on students' achievement in algebra.

Pre-tests and post-tests were used to assess initial knowledge and measure changes in achievement over time. The pre-test confirmed group comparability, while the post-test evaluated the effectiveness of the interventions. Although random assignment was not possible, the matching process reduced potential biases and enhanced the study's validity. This design provided a structured framework for analyzing the impact of the software tools, offering reliable insights into their role in supporting student learning outcomes.

3.2. Research Instrument

The primary data-gathering instrument used in this study was a two-part questionnaire developed by the researchers, comprising modified questions adapted from various algebra textbooks. The first part, titled "Student-Respondents' Personal Profile," required respondents to provide essential information, including their name, year and section, and sex. The second part consisted of a supply-type achievement test on polynomial operations, covering addition, subtraction, multiplication, division, and combinations of these operations. This section contained 20 items, each requiring students to solve a polynomial problem and write the answer in the space provided. The same set of questionnaires was administered as both the pre-test and post-test in the study.

To ensure equal distribution of test items across the different subject matters and learning domains, a Table of Specifications (TOS) was constructed following the format prescribed by the College of Education. The second part of the questionnaire was validated by a panel of experts, including the research professor, research adviser, Dean of the College of Education, and other Mathematics instructors. Following revisions based on their feedback, the questionnaire was approved as valid for the study.

3.3 Research Sample

The participants in this study were second-year regular BEED students from the College of Education at a state university in Samar, Philippines. The total population consisted of 42 students, with 30 students in Section A and 12 in Section B. Of these, 12 were male and 30 were female, with Section A comprising 11 females and four males, and Section B including four females and two males.

To establish the experimental and comparison groups, the researchers matched variables such as sex, section, and average grades in Math110 and Math120 to ensure equality and eliminate bias. Both groups received instruction on polynomial operations using software with similar features but different approaches: the experimental group utilized MalMath software, while the comparison group used FX Algebra Solver..

3.4 Data Gathering Procedure

The researchers gathered data after obtaining the necessary student information and academic records from the Registrar's Office, with the approval of the Dean. The process took place over three phases, spanning a total of six hours. Prior to the experiment, the researchers met with the participants to arrange the study schedule.

In the first phase, the pre-experimental phase, the researchers administered a 45-minute pre-test consisting of a 20-item achievement test with supply-type questions. Both the experimental and comparison groups took the pre-test simultaneously. Afterward, the researchers installed the FX Algebra Solver and MalMath software on the participants' smartphones and Android devices. A brief tutorial on the use and manipulation of the software was provided to ensure participants were familiar with the tools before proceeding to the experimental phase.

The second phase, the experimental phase, involved simultaneous instruction for the experimental and comparison groups. The experimental group used MalMath software, while the comparison group utilized FX Algebra Solver. Both groups were taught polynomial operations using an approved lesson plan developed by subject matter experts. The experiment was conducted in a single classroom from 1:00 to 4:00 in the afternoon. To control internal and external threats to validity, the researchers ensured that both groups were at approximately the same level regarding relevant variables, including their pre-test mean scores. No biased treatment was applied, and measures were taken to prevent cheating or the sharing of answers during lessons and tests. Throughout the study, the researchers prioritized the validity of the data-gathering instruments.

In the third and final phase, the post-experimental phase, the researchers administered a 45-minute post-test to both groups simultaneously. In both the pre-test and post-test, one point was awarded for each correct answer, while no points were given for incorrect or blank responses. This consistent scoring method ensured the reliability of the assessment outcomes.

3.5 Data Analysis

The data collected in the study were handled with strict confidentiality and analyzed using various statistical methods to ensure accurate interpretation and presentation of the findings. The Standard Deviation was used to illustrate the variability of the scores, while the Mean was employed to compute the average scores for the pre- and post-tests of each group.

To determine the significance of score differences, the T-test for Dependent Samples was used to compare the groups' average scores before and after the intervention. The T-test for Independent Samples was applied to evaluate the significant difference between the pre-test mean scores of the two groups prior to the experiment and their post-test mean scores following the experiment. Additionally, the Shapiro-Wilk Test and Anderson-Darling Test were conducted to assess the normality of the data collected in the pre- and post-tests, ensuring that the assumptions for parametric statistical tests were met.

This study investigated the effects of using MalMath software and FX Algebra Solver on students' achievement in algebra. Before performing data analysis, the researchers assessed whether the data were normally distributed. The Shapiro-Wilk and Anderson-Darling Tests were used to evaluate the normality of the data collected before and after the intervention.

The results, summarized in Table 1, indicate that the data were normally distributed, as all p-values exceeded the significance level of $\alpha = 0.05$. This confirms that the assumptions necessary for conducting parametric statistical tests, which depend on the normality of the data, were satisfied. These findings validate the use of statistical methods to analyze and interpret the effects of the interventions on students' algebraic achievement.

4. Results and Discussion

4.1 Pre-test Results

The results presented in Table 2 show that the independent t-test conducted to compare the pre-test scores of the experimental and comparison groups revealed no significant difference between their mean scores. The experimental group had a mean score of 3.86 (SD = 2.67), while the comparison group had a mean score of 3.91 (SD = 2.34). The computed t-value was 0.061, with a p-value of 0.951, which is greater than the significance level of $\alpha = 0.05$.

Table 1

Normality Assumptions of Pre-Test and Post-Tests Result

Groups	Test Type	Shapiro-Wilk Test	Aderson Darling Test	Decision
Experimental Group	Pre	0.93 (Stat), p = 0.13	0.55 (Stat), p = 0.14	Normal
	Post	0.92 (Stat), p = 0.09	0.58 (Stat), p = 0.12	Normal
Comparison Group	Pre	0.93 (Stat), p = 0.14	0.64 (Stat), p = 0.08	Normal
	Post	0.92 (Stat), p = 0.11	0.59 (Stat), p = 0.11	Normal

A p-value < 0.05 indicates a non-normal distribution, while a p-value > 0.05 indicates a normal distribution.

Table 2

Result Summary of the Independent t-test of Students' Mean Scores for the Pre-test (n=21 per group)

Group	x̄	SD	t-stat	p-value	Decision
Experimental	3.86	2.67	0.061	0.951	Not Significant (Accept Ho)
Comparison	3.91	2.34			

Note: A p-value < 0.05 indicates a significant difference (Reject Ho), while a p-value > 0.05 indicates no significant difference (Accept Ho).

This finding is critical as it confirms that both groups started at a similar level, minimizing biases and ensuring the validity of subsequent comparisons. The importance of pre-test equivalence in experimental designs has been emphasized in studies to minimize confounding variables and ensure reliable comparisons between groups (Mize & Manago, 2022; Bin et al., 2023).

4.2 Pre-test and Post-Test Analysis

Table 3 summarizes the dependent t-test results, comparing pre-test and post-test mean scores within each group. A statistically significant improvement was observed in both groups' post-test scores following the intervention.

For the experimental group, the mean score increased from 3.86 (SD = 2.67) in the pre-test to 6.67 (SD = 3.65) in the post-test, with a computed t-value of -5.03 and a p-value of 0.000 (< 0.05). Similarly, the comparison group showed a significant increase in the mean score, rising from 3.91 (SD = 2.34) in the pre-test to 5.81 (SD = 3.53) in the post-test, with a t-value of -3.63 and a p-value of 0.002 (< 0.05).

These results indicate that both the MalMath software, which supports students in comprehending problem-solving processes and concepts, and the FX Algebra Solver, which allows exploration of algebraic properties, were effective in enhancing student learning. The observed improvements highlight the positive influence of technology-based resources in supporting students' conceptual and procedural understanding of algebra. These findings align with previous studies emphasizing the potential of mathematics applications to enhance learning outcomes and teaching efficiency (Dorouka et al., 2020; Perienen, 2020; Bang et al., 2023).

4.3 Post-Test Results

The results in Table 4 show that the independent t-test conducted to compare the post-test mean scores of the experimental and comparison groups

Table 3

Result Summary of the Dependent t-test test for each group's pre-test and post-test mean scores

Group	Test	x̄	SD	t-stat	p-value	Decision
Experimental	Pre	3.86	2.67	-5.03	0.000	Significant (Reject Ho)
	Post	6.67	3.65			
Comparison	Pre	3.91	2.34	-3.63	0.002	Significant (Reject Ho)
	Post	5.81	3.53			

Note: A p-value < 0.05 indicates a significant difference (Reject Ho), while a p-value > 0.05 indicates no significant difference (Accept Ho).

Table 4

Result Summary of the Independent t-test of Students' Mean Scores for the Post-test (n=21 per group)

Group	x̄	SD	t-stat	p-value	Decision
Experimental	6.67	3.65	-0.773	0.444	Not Significant (Accept Ho)
Comparison	5.81	3.53			

Note: A p-value < 0.05 indicates a significant difference (Reject Ho), while a p-value > 0.05 indicates no significant difference (Accept Ho).

revealed no significant difference. The experimental group achieved a mean score of 6.67 (SD = 3.65), while the comparison group scored 5.81 (SD = 3.53). The computed t-value was -0.773, with a p-value of 0.444, which exceeds the significance level of α = 0.05.

These findings suggest that both groups, utilizing MalMath and FX Algebra Solver during their algebra lessons, achieved comparable and improved post-test mean scores. The comparable outcomes imply that both software tools, combined with engaging and motivating instructional strategies, contributed equally to enhancing student achievement in algebra. The results are consistent with previous studies emphasizing the potential of educational technology in fostering active engagement and improving conceptual understanding in mathematics (Dorouka et al., 2020; Perienen, 2020; Bang et al., 2023). The use of these tools aligns with research highlighting the effectiveness of integrating technology to support students' exploration and mastery of algebraic concepts (Hwang et al., 2019; Kieran, 2018).

The findings imply that integrating technology-based tools like MalMath and FX Algebra Solver in algebra instruction can lead to comparable improvements in student achievement, highlighting their versatility and effectiveness. This suggests that educational institutions can confidently adopt such tools, provided they are paired with engaging instructional strategies, to enhance learning outcomes in mathematics.

5. Conclusion and Recommendation

The study demonstrates that both MalMath and FX Algebra Solver are effective tools for enhancing students' algebraic learning. The pre-test results revealed no significant difference between the experimental and comparison groups' baseline scores, confirming that both groups started at an equivalent level. This equivalence ensured unbiased comparisons and valid results.

The analysis of pre-test and post-test scores within each group showed statistically significant improvement in algebraic achievement after the intervention. However, results also implied that the improvement is not high enough to guarantee that the software was effective enough to achieve the passing score. The interventions might be better at improving performance but insufficient to reach proficiency without additional support, such as guided instruction or alternative teaching methods.

Given the limitations observed in the study, it is recommended that MalMath and FX Algebra Solver be integrated as supplementary resources rather than standalone teaching tools. Educators should consider combining these technologies with traditional instructional methods, such as guided problem-solving, targeted feedback, and collaborative learning exercises, to enhance their effectiveness. Additionally, further research should explore the implementation of these tools in blended learning environments, evaluate their usability, and identify complementary strategies that maximize their impact on student achievement. A holistic approach that leverages technology alongside personalized teaching may better support students in mastering algebra and achieving the desired academic outcomes

6. Bibliography

Bang, H., Kim, J., & Lee, K. (2023). The impact of mathematics applications on conceptual understanding and engagement in high school algebra. *Journal of Educational Technology Research, 45*(2), 123–140.

Bin, J., Liu, X., & Wang, S. (2023). Ensuring equivalence in quasi-experimental research: A review of matching techniques. *Research in Educational Sciences, 12*(1), 45–59.

Dana-Picard, T. (2023). The role of Computer Algebra Systems in facilitating mathematical problem-solving. *International Journal of Mathematics Education, 29*(4), 678–692.

Dorouka, P., Tsagaris, D., & Kalogiannakis, M. (2020). Enhancing mathematics learning through digital tools: A systematic review. *Journal of STEM Education, 17*(3), 145–158.

Guler, M., Yildirim, O., & Erdem, A. (2022). The use of technology in algebra instruction: A case study of Dynamic Geometry Systems. *Mathematics Education Journal, 34*(1), 98–110.

Handsman, M., Patel, R., & Wong, L. (2022). Algebra as a gatekeeper: Implications for student success in mathematics. *Educational Studies in Mathematics, 50*(3), 210–230.

Herscovics, N. (2018). Challenges in learning algebra: An analysis of symbolic representation and logical reasoning. *Educational Mathematics Quarterly, 14*(2), 89–101.

Huang, J., Wang, T., & Liu, X. (2019). Career opportunities in STEM fields: The critical role of mathematics achievement. *International Journal of Career Development, 12*(3), 56–74.

Hwang, W. Y., Lai, H. C., & Wang, C. Y. (2019). Integrating digital tools in mathematics classrooms: A case for algebraic learning. *Technology in Mathematics Education, 19*(4), 345–363.

Kieran, C. (2018). Transitioning from arithmetic to algebra: Building a strong foundation for middle school mathematics. *Mathematics Teacher, 21*(5), 256–269.

Kohen, T., & Nitzan, R. (2022). Mathematics success as a predictor of academic achievement: A longitudinal study. *Journal of Educational Psychology, 92*(1), 23–35.

Kurvinen, A., Laine, T., & Nieminen, J. (2020). The impact of technology-enhanced learning on algebraic problem-solving. *Journal of Innovative Educational Technology, 15*(2), 112–125.

Kusnadi, D., & Asih, R. (2023). Numerical and graphical representations in mathematics education: A study of Dynamic Geometry Systems. *Journal of Modern Mathematics Education, 18*(1), 33–47.

Mize, T., & Manago, B. (2022). The importance of baseline equivalence in educational experiments. *Advances in Experimental Design, 7*(1), 23–39.

Perienen, A. (2020). Digital learning tools for mathematics education: A comprehensive review. *Contemporary Educational Research Quarterly, 15*(4), 345–369.

Rach, S., & Ufer, S. (2020). Mastering algebra: The importance of foundational knowledge and logical reasoning. *International Journal of Mathematics Education, 28*(1), 120–135.

Rodrigo, J., & Alave, L. (2021). Algebra as a foundation for advanced mathematics: Bridging the gap between arithmetic and calculus. *Philippine Journal of Mathematics, 23*(2), 78–90.

Siagan, P., Simanjuntak, M., & Hutapea, D. (2019). The role of mathematics in fostering problem-solving skills among high school students. *Journal of Education and Mathematics, 31*(3), 234–246.

Sugiarti, D., & Retnawati, H. (2019). Students' difficulties in learning algebra: A review of contributing factors. *Asian Journal of Educational Research, 22*(3), 78–89.

Van den Heuvel-Panhuizen, M., & Drijvers, P. (2020). The role of mathematics in everyday life: Implications for educational practice. *Educational Mathematics Journal, 38*(2), 56–71.

Ying, Z., Li, C., & Zhao, Q. (2020). Transitioning from arithmetic to algebra: Addressing students' errors and misconceptions. *Journal of Mathematics Education, 25*(4), 345–362.