Effect of Mathematica Software on Mathematics Self-Efficacy and Achievement among Engineering Students in TVET Institutions in Western Kenya

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ABSTRACT

This study investigated the effect of integrating Mathematica software (MS), compared with Conventional Mathematics Instruction (CMI), on mathematics academic achievement and self-efficacy among diploma engineering students in Technical and Vocational Education and Training (TVET) institutions in Western Kenya. The study sought to analyze the effect of Mathematica software on students' mathematics self-efficacy and academic achievement. The study was conducted among diploma engineering students undertaking a common mathematics course in selected TVET institutions across four counties in Western Kenya. A total of 239 students from intact classes participated in the study and were assigned to four groups using the Solomon Four-Group quasi-experimental design. The experimental groups received Mathematica-integrated instruction, while the control groups received Conventional Mathematics Instruction. Data were collected using a mathematics achievement test and a mathematics self-efficacy questionnaire. The self-efficacy instrument was validated by experts and its reliability was assessed using Cronbach's alpha. Quantitative data were analyzed using descriptive statistics, one-way analysis of variance (ANOVA), post-hoc comparisons, and multivariate analysis of covariance (MANCOVA), with gender controlled in the multivariate analysis. The findings revealed a statistically significant difference in mathematics achievement across the four instructional groups, $F(3,235) = 157.249$, $p < .001$. Post-hoc comparisons showed that both Mathematica groups achieved significantly higher scores than both Conventional Mathematics Instruction groups. The MANCOVA showed a statistically significant multivariate effect of instructional group on the combined outcomes of mathematics achievement and self-efficacy, Pillai's Trace = .888, $F(6,466) = 62.347$, $p < .001$, partial $\eta^2 = .444$. Follow-up analyses showed significant instructional-group effects on mathematics achievement and mathematics self-efficacy. Gender did not have a statistically significant overall multivariate effect on the combined outcomes. The study concludes that Mathematica-integrated instruction is a promising approach for enhancing mathematics academic achievement and self-efficacy among engineering students in TVET institutions when appropriately integrated into teaching and learning.

Keywords: Mathematica software; mathematics achievement; mathematics self-efficacy; TVET.

I. INTRODUCTION

Technical and Vocational Education and Training (TVET) institutions play a critical role in producing skilled manpower required for industrialization, technological advancement, and economic growth. In Kenya, TVET institutions are expected to equip engineering students with practical and analytical competencies necessary for solving real-world technical problems. Mathematics forms the foundation of engineering education because it supports problem-solving, logical reasoning, computations, and technological innovation (Pepin et al., 2021).

Mathematics is a fundamental subject in Science, Technology, Engineering, and Mathematics (STEM) programmes offered in Technical and Vocational Education and Training (TVET) institutions because it provides the analytical, computational, and problem-solving skills required in engineering and technical fields (Sahroni & Puzi, 2024). Despite the central role of mathematics in engineering education, persistent poor performance in mathematics among TVET students remains a major educational concern in Kenya, particularly in calculus-related topics such as differentiation, integration, limits, and continuity (Kenya National Examinations Council [KNEC], 2022). Many engineering students in TVET institutions experience difficulties in mastering mathematical concepts, resulting in poor academic achievement and low confidence in mathematics. This poor performance is reflected in low examination scores, weak conceptual understanding, negative attitudes toward mathematics, reduced motivation to engage in mathematical tasks, low self-efficacy, and increased dropout or course-switching rates among engineering students. Many learners perceive mathematics as abstract, difficult, and irrelevant to practical technical applications, thereby limiting their engagement and success in engineering programs.

Several factors have contributed to the continued underperformance in mathematics within TVET institutions. Instructional challenges include the predominant use of conventional teacher-centered teaching approaches characterized by lectures, rote memorization, and procedural demonstrations with minimal learner participation (Mwangi & Katam, 2023). Such methods often fail to support conceptual understanding, visualization, critical thinking, and practical application of mathematical concepts. In addition, there has been limited integration of educational technologies and interactive learning tools capable of enhancing students' understanding and engagement in mathematics instruction.

The adoption of digital technologies in education has transformed teaching and learning globally (Ndiangui et al. 2025). Software applications such as Mathematica have emerged as important instructional tools that enhance visualization, computation, and interactive learning (Clark and Mayer, 2016; Sofroniou, 2025). Mathematica software enables learners to solve complex mathematical problems, generate graphs, simulate models, and understand abstract concepts more effectively (Wolfram, 2020). However, the use of such technology-enhanced instructional tools remains limited in many TVET institutions in Western Kenya, where traditional teacher-centered approaches continue to dominate classroom instruction. The study reported in this paper sought to investigate whether the integration of Mathematica software could improve mathematics self-efficacy and academic achievement among engineering students in TVET institutions.

The integration of digital tools to enhance teaching and learning, as well as performing calculations with precision and accuracy, is essential since vocational tasks often require high levels of accuracy in measurements, calculations, and estimations to ensure safety, quality, and efficiency. Mathematica software provides advanced capabilities for symbolic computation, graphing, visualization, simulations, and interactive problem-solving, which may help simplify abstract mathematical concepts and improve students' engagement and understanding (OECD, 2019). The software also supports learner-centered instruction by enabling active participation, exploration, immediate feedback, and practical application of mathematical concepts. Furthermore, Mathematica has the potential to improve students' confidence, motivation, and attitudes toward mathematics while minimizing gender-related disparities in participation and achievement. This study sought to analyze the effect of Mathematica software on mathematics self-efficacy and explore students' experiences and perceptions while using Mathematica software to learn mathematical concepts in TVET institutions in Western Kenya.

1.1 Purpose and Objectives

To analyze the effect of Mathematica software on students' mathematics self-efficacy and academic achievement

1.2 Research Hypothesis

$H0_1$: There is no statistically significant difference in mathematics self-efficacy and academic achievement scores between students exposed to *Mathematica*-integrated learning environments and those exposed to Conventional Mathematics Instruction (CMI), while controlling for gender.

II. LITERATURE REVIEW

2.1 Effect of Mathematica Software on Students' Mathematics Academic Achievement Compared to Conventional Instruction

Empirical studies have consistently shown that technology-enhanced instruction improves students' mathematics academic achievement compared to conventional teaching methods. Studies by Cameron et al. (2024) and Villa-Ochoa and Suárez-Téllez (2021) indicate that computer algebra systems (CAS), such as Mathematica, enhance students' conceptual understanding, procedural fluency, and problem-solving ability. These improvements are largely attributed to the interactive and visual nature of such software, which enables learners to explore mathematical concepts dynamically. From a constructivist perspective, learning occurs when students actively construct knowledge through interaction with tools and environments rather than passively receiving information (Piaget, 1970; Vygotsky, 1978). Mathematica software aligns with this theory by allowing learners to manipulate variables, visualize functions, and test mathematical ideas, thereby supporting deeper cognitive processing. This interaction promotes meaningful learning, which explains the improved academic achievement observed in experimental groups. Social Cognitive Theory (Bandura, 1986) further explains that students learn through observation, modeling, and self-regulated learning. Mathematica provides immediate feedback and step-by-step visualization of solutions, which enhances observational learning and reinforces correct mathematical procedures. This improves learners' self-regulation and ultimately leads to higher achievement. The Technology Acceptance Model (Davis, 1989) also supports these findings by emphasizing perceived usefulness and perceived ease of use. When students perceive Mathematica as useful in simplifying complex problems, they are more likely to engage with it, leading to improved performance outcomes.

2.2 Effect of Mathematica Software on Students' Mathematics Self-Efficacy and Academic Achievement while Controlling for Gender

Empirical evidence suggests that self-efficacy is a strong predictor of mathematics achievement and is positively influenced by technology-enhanced instruction. Studies by Zimmerman and Kitsantas (2014) and Kundu and Tutut (2021) show that learners using interactive mathematical tools report higher self-efficacy due to increased mastery experiences and reduced cognitive barriers. Constructivist theory supports this relationship by emphasizing that learners build confidence through active problem-solving and successful knowledge construction. Mathematica software provides immediate feedback, enabling students to correct errors and refine understanding, which enhances self-efficacy. Social Cognitive Theory provides a direct explanation of the self-efficacy–achievement relationship. Bandura (1997) identifies mastery experience, vicarious learning, verbal persuasion, and emotional arousal as key sources of self-efficacy. Mathematica supports all four through guided visualization, automated computation, and interactive exploration. Gender differences in mathematics learning have been widely studied. Some studies (Else-Quest et al., 2010; Hyde et al., 2008) suggest that gender gaps in mathematics performance are narrowing, especially when equitable instructional strategies are used. However, other studies still report differences in confidence levels, with female students often reporting lower self-efficacy despite similar achievement levels. Technology-enhanced instruction has been shown to reduce these disparities by providing individualized learning experiences. The Technology Acceptance Model also helps explain gender differences in technology adoption, where perceived ease of use and anxiety toward technology may influence engagement levels differently among male and female students, thereby affecting self-efficacy and achievement outcomes.

III. METHODOLOGY

3.1 Study Area and Data Source and Design

The study was conducted in selected Technical and Vocational Education and Training (TVET) institutions located in Western Kenya. The study employed a quantitative quasi-experimental research design using the Solomon Four-Group design. The design was selected to evaluate the effect of Mathematica-integrated instruction on students' mathematics academic achievement and self-efficacy while accounting for potential pre-test sensitization effects. Grounded in a pragmatic paradigm, the study utilized inferential tests to establish causal linkages. The study was executed across thirteen (13) purposively selected, accredited TVET institutions spread across four counties (Kakamega, Bungoma, Busia, and Vihiga). The final sample comprised 239 engineering students drawn from pre-existing, intact classes. The sample was strategically distributed into four groups according to the Solomon design model as follows:

Experimental Group 1 (E_1, n = 58): Received the standard pre-test, underwent the four-week Mathematica-integrated intervention, and sat for the post-test.

Control Group 1 (C_1, n = 59): Received the standard pre-test, was taught using traditional CMI lectures, and sat for the post-test.

Experimental Group 2 (E_2, n = 60): Excluded from the pre-test to control for testing bias, received the Mathematica intervention, and sat for the post-test.

Control Group 2 (C_2, n = 62): Excluded from the pre-test, taught via traditional CMI lectures, and sat for the post-test.

The empirical intervention took four-weeks. In the experimental groups, conventional lecture delivery was replaced by an "Interactive Lab" model where mathematical properties were introduced as active computations, aided by Mathematica software. Students manipulated mathematical variables, generated three-dimensional rotational solids, plotted simultaneous functions and their derivatives, and simulated solutions to differential circuits. Data collection was operationalized through five validated and cross-checked instruments: In this design, two groups received a pre-test before the intervention and two groups did not, while both experimental groups were exposed to Mathematica software and the control groups were taught using Conventional Mathematics Instruction (CMI).

3.1.1 Solomon Four-Group Design

A Solomon Four-Group design was used specifically to evaluate the potent effects of a pre-test (such as pre-test sensitization or practice effects) on the final outcome.

Table 1: Schematic Table of the Solomon Four-Group Design

Group	Group Type / Assignment	Pre-Test	Treatment/ Intervention	Post-Test
Group E1	Quasi-Experimental (Intact)	O1	X	O2
Group C1	Quasi-Control (Intact)	O3	—	O4
Group E2	Quasi-Experimental (Intact)	—	X	O5
Group C2	Quasi-Control (Intact)	—	—	O6

Key and Treatment Explanations

X: The independent variable, intervention, or treatment (Introducing a new instructional software as a teaching method), **O**: An observation or measurement of the dependent variable, **O1, O3** represent pre-tests, **O2, O4, O5, O6** represent post-tests while **—** indicates the absence of the pre-test or the treatment.

Group E1 (Experimental with Pre-test): This group receives the full experimental process. They are pre-tested (O1), exposed to the intervention (X), and then post-tested (O2). This allows you to measure direct baseline-to-post-intervention growth.

GroupC1 (Control with Pre-test): This group establishes the baseline trend without the intervention. They receive the pre-test (O3), undergo standard/traditional conditions without the specialized treatment, and receive the post-test (O4).

GroupE2 (Experimental without Pre-test): This group is introduced to rule out pre-test sensitization. They do *not* take the pre-test, are exposed directly to the intervention (X), and then take the post-test (O5).

Group C2 (Control without Pre-test): This group acts as a pure control for external history or maturation effects. They receive no pre-test and no intervention, experiencing only the post-test (O6).

3.1.2 Study Population

The study population comprised engineering students enrolled in Diploma in engineering programs with a common course of Mathematics in TVET institutions in Western Kenya. The target population included students from four National Polytechnics and nine (9) TTI's/TVC's spread in the four (4) counties of Western Kenya that met the study criteria and had intact Engineering Mathematics classes. 85 respondents were drawn from the National Polytechnics contributed distributed across four intact classes of 27, 19, 24, and 15 students respectively, while the TTI's/TVC's contributed 137 students drawn from the four counties of Kakamega, Bungoma, Busia and Vihiga counties with 45, 35, 30, and 27 respondents respectively. The study focused on Diploma Engineering students because they are directly engaged in mathematics as a core component of their training programs. These students are expected to apply mathematical concepts in engineering-related problem solving, making them an appropriate group for examining the effectiveness of instructional innovations such as Mathematica Software. Disproportionate stratified sampling was used to select TVET institutions that participated in this research and who met the following criteria; those that have implemented programs at the level of Diploma in Electrical Engineering, Diploma in Civil Engineering and Diploma in Mechanical engineering. Those three programs have each Engineering Mathematics course; those that have a functional computer laboratory necessary for this study and those that gave consent and were willing to participate in this study. At institutional level; four (4) National Polytechnics and nine (9) TTI's/TVC's were selected with one (1) National Polytechnic in each county, TTI's/TVC's in Kakamega County, two (2) in Bungoma, two (2) in Busia and one (1) in vihiga counties respectively making a total of thirteen (13). This study involved a total of 239 respondents. The respondents were allocated to groups according to Solomon Four group design as follows; experimental group (E1) had coac58, the experimental group (E2) had 60 students, the control group (C1) had 59 students and the control group (C2) had 62 students respectively making a total of 239 respondents.

3.2 Data Collection and Analysis

The study employed the mathematics self-efficacy questionnaire to assess students' perceptions of the influence of Mathematica Software on their students' confidence in their ability to learn and succeed in mathematics after using Mathematica Software. The MSEQ was validated for Content, structure and face through expert review by specialists for clarity, relevance, representativeness of the constructs, appropriateness of language, and alignment with the study objective. Reliability of the instrument was established through pilot testing for internal consistency using Cronbach's Alpha with a coefficient of 0.70 or above which was considered acceptable.

Data analysis involved descriptive and inferential statistical techniques. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize the study variables. Inferential analyses included one-way analysis of variance (ANOVA), Scheffé post-hoc comparisons, and multivariate analysis of covariance (MANCOVA). MANCOVA was used to examine the effect of instructional group on the combined dependent variables of mathematics achievement and mathematics self-efficacy while controlling for gender. Follow-up univariate tests were conducted to determine the contribution of each dependent variable to the observed multivariate effect.

IV. RESULTS AND DISCUSSION

4.1 Descriptive statistics

The study included 239 engineering students distributed across the four Solomon groups. Of these, 117 students in E1 and C1 completed the achievement pre-test, while all 239 students completed the post-test. Mathematics self-efficacy was assessed for all participants.

Table 2: Descriptive Summary of the Key Study Variable

Variable	N	Minim.	Max	M	SD
Mathematics self-efficacy	239	48	74	61.18	6.692
Achievement Pre-Test	117	35	62	48.44	7.076
Achievement post-test	239	42	82	62.45	9.252

Table 2 presents the descriptive statistics for the key study variables. Mathematics self-efficacy was assessed for all 239 students and had a mean score of 61.18 (SD = 6.692), with scores ranging from 48 to 74. The achievement pre-test, administered to the two pre-tested groups (E1 and C1), had a mean score of 48.44 (SD = 7.076), with scores ranging from 35 to 62 (N = 117). The achievement post-test, administered to all four Solomon groups, had a mean score of 62.45 (SD = 9.252), with scores ranging from 42 to 82 (N = 239).

4.1.1 Group-level descriptive statistics

Table 3 presents the group-level descriptive statistics for academic achievement and mathematics self-efficacy.

Table 3: Group-Level Descriptive Statistics for Achievement and Mathematics Self-Efficacy

Group	N	Achievement M	Achievement SD	Self-efficacy M	Self-efficacy SD
E1	58	70.16	5.537	65.26	2.619
E2	60	69.8	4.313	65.65	2.616
C1	59	56.95	6.804	54.76	2.687
C2	62	53.35	4.516	51.55	2.678

According to the findings in Table 3, the two Mathematica groups recorded higher mean achievement scores than the two CMI groups. The mean achievement scores were 70.16 (SD = 5.537) for E1 and 69.80 (SD = 4.313) for E2, compared with 56.95 (SD = 6.804) for C1 and 53.35 (SD = 4.516) for C2. A similar pattern was observed for mathematics self-efficacy, with mean scores of 65.26 (SD = 2.619) for E1 and 65.65 (SD = 2.616) for E2, compared with 54.76 (SD = 2.687) for C1 and 51.55 (SD = 2.678) for C2. The descriptive pattern therefore shows higher post-intervention achievement and self-efficacy scores among students exposed to Mathematica than among those receiving CMI.

4.1.2 Academic Achievement: Assumption Testing and ANOVA

Before conducting the one-way analysis of variance (ANOVA), the homogeneity of variance assumption was assessed using Levene's test as shown in Table 4.

Table 4: Test of Homogeneity of Variances for Academic Achievement

Test	Levene's F	df1	df2	p-value
Achievement post-test	8.348	3	235	< .001

The result was statistically significant, $F(3, 235) = 8.348$, $p < .001$, indicating that the variances of achievement scores differed significantly across the four groups. Although the group sample sizes were relatively balanced ($n = 58–62$), this assumption violation was taken into consideration when interpreting the ANOVA results**.**

Table 5: One-Way ANOVA of Academic Achievement by Instructional Group

Source	Sum of Squares	df	Mean Square	F	p-value
Between Groups	13,598.85	3	4,532.95	157.249	< .001
Within Groups	6,774.24	235	28.827		
Total	20,373.10	238			

A one-way ANOVA was conducted to determine whether mathematics achievement differed significantly among the four instructional groups. The analysis revealed a statistically significant difference in achievement scores across the groups, $F(3, 235) = 157.249$, $p < .001$. This result indicates that at least one instructional group differed significantly from another in academic achievement. The magnitude and direction of these differences were examined further using Scheffé post-hoc comparisons, presented in the subsequent section.

4.1.3 Post-hoc Comparisons for Academic Achievement

Scheffé post-hoc comparisons were conducted to identify the specific group differences underlying the significant overall ANOVA. As shown in Table 6, students in E1 and E2, who received Mathematica-integrated instruction, had significantly higher achievement scores than students in C1 and C2, who received Conventional Mathematics Instruction. Specifically, E1 scored significantly higher than C1 (mean difference = 13.206, $p < .001$) and C2 (mean difference = 16.800, $p < .001$), while E2 also scored significantly higher than C1 (mean difference = 12.851, $p < .001$) and C2 (mean difference = 16.445, $p < .001$). In contrast, there was no statistically significant difference between E1 and E2 (mean difference = 0.355, $p = .988$).

Table 6: Scheffé Post-hoc Comparisons of Academic Achievement

Comparison	Mean Difference	p-value
E1 – E2	0.355	0.988
E1 – C1	13.206	< .001
E1 – C2	16.8	< .001
E2 – C1	12.851	< .001
E2 – C2	16.445	< .001
C1 – C2	—	—

NB: E1 and E2 received Mathematica-integrated instruction; C1 and C2 received Conventional Mathematics Instruction (CMI). E1 and C1 were pre-tested, whereas E2 and C2 were not.

The similarity in achievement between E1 (M = 70.16) and E2 (M = 69.80), together with the non-significant pairwise difference, suggests that pre-test exposure did not substantially influence achievement among students who received Mathematica-integrated instruction. However, the C1–C2 inferential comparison was not reported in the available results. Consequently, the present post-hoc findings do not provide a complete statistical test of the effect of pre-test exposure across both instructional conditions. A formal instructional condition × pre-test exposure interaction was also not reported. Therefore, the findings should be interpreted as evidence of similar achievement among the two Mathematica groups rather than as definitive evidence that pre-test sensitization had no effect.

4.1.4 MANCOVA: Combined Mathematics Achievement and Self-Efficacy

A multivariate analysis of covariance (MANCOVA) was conducted to examine whether instructional group was associated with the combined outcomes of mathematics achievement and mathematics self-efficacy while accounting for gender. The results are shown in Table 7.

Table 7: Multivariate Analysis of Covariance (MANCOVA) of Achievement and Mathematics Self-Efficacy by Instructional Group and Gender

Effect	Pillai's Trace	F	Hypothesis df	Error df	p-value	Partial η²
Instructional Group	0.888	62.347	6	466	< .001	0.444
Gender	0.007	0.856	2	466	0.426	0.007

NB: Dependent variables were mathematics achievement and mathematics self-efficacy. Instructional group comprised E1, E2, C1 and C2. Gender was included in the model as a categorical factor.

Table 7 show that the multivariate effect of instructional group was statistically significant, Pillai's Trace = 0.888, $F(6, 466) = 62.347$, $p < .001$, partial $\eta^2 = .444$. This indicates a statistically significant multivariate difference in the combined achievement and self-efficacy outcomes across the four instructional groups.

The main effect of gender was not statistically significant, Pillai's Trace = 0.007, $F(2, 466) = 0.856$, $p = .426$. Thus, after accounting for instructional group, no statistically significant overall gender difference was detected across the combined achievement and mathematics self-efficacy outcomes.

4.1.5 Follow-up Univariate Tests

The significant MANCOVA established that the four instructional groups differed on the combined dependent variables. The next step is therefore to determine whether the group effect occurred for academic achievement, mathematics self-efficacy, or both.

Table 8: Follow-up Univariate Tests for Academic Achievement and Mathematics Self-Efficacy

Dependent Variable	Effect	F	df	p-value	Partial η²
Academic achievement	Instructional Group	157.12	3, 234	< .001	0.668
Mathematics self-efficacy	Instructional Group	447.259	3, 234	< .001	0.852

Follow-up univariate tests were conducted to determine the contribution of each dependent variable to the significant multivariate effect of instructional group. The results showed a statistically significant effect of instructional group on academic achievement, $F(3, 234) = 157.120$, $p < .001$, partial $\eta^2 = .668$. Instructional group also had a statistically significant effect on mathematics self-efficacy, $F(3, 234) = 447.259$, $p < .001$, partial $\eta^2 = .852$. Thus, the significant multivariate effect was reflected in both academic achievement and mathematics self-efficacy.

4.1.6 Solomon Four-Group Interpretation

The Solomon Four-Group design was used to examine whether exposure to the pre-test may have influenced post-test achievement.

Table 9: Comparison of Pre-Tested and Non-Pre-Tested Groups

Instructional condition	Pre-tested	Non-pre-tested	Mean difference
Mathematica	70.16 (n = 58)	69.80 (n = 60)	0.36
CMI	56.95 (n = 59)	53.35 (n = 62)	3.6

Table 9 presents a descriptive comparison of post-test achievement between pre-tested and non-pre-tested students within each instructional condition. The Mathematica groups recorded very similar mean scores (70.16 and 69.80), representing a mean difference of only 0.36 points. The CMI groups showed a larger descriptive difference of 3.60 points (56.95 versus 53.35). These comparisons provide descriptive evidence regarding possible pre-test effects; however, no inferential conclusion is drawn for the CMI comparison because the information required to reconstruct the corresponding statistical test was not reported.

4.1.7 Hypothesis Testing

Table 10: Decision on the Null Hypothesis

Hypothesis	Statistical test	Test statistic	p-value	Decision
H01: There is no statistically significant difference in mathematics self-efficacy and academic achievement between students exposed to Mathematica-integrated instruction and those exposed to CMI, while controlling for gender.	MANCOVA	Pillai's Trace = 0.888; F(6, 466) = 62.347	< .001	Reject H01

H01: Academic achievement component	Follow-up univariate test	$F(3, 234) = 157.120$; partial $\eta^2 = .668$	$< .001$	Reject H01
H01: Mathematics self-efficacy component	Follow-up univariate test	$F(3, 234) = 447.259$; partial $\eta^2 = .852$	$< .001$	Reject H01

Table 10 summarizes the decision on the null hypothesis. The MANCOVA revealed a statistically significant multivariate effect of instructional group on the combined outcomes of mathematics achievement and self-efficacy, Pillai's Trace = 0.888, $F(6, 466) = 62.347$, $p < .001$. Follow-up univariate tests also showed statistically significant effects of instructional group on academic achievement, $F(3, 234) = 157.120$, $p < .001$, partial $\eta^2 = .668$, and mathematics self-efficacy, $F(3, 234) = 447.259$, $p < .001$, partial $\eta^2 = .852$. Therefore, H01 was rejected. The findings indicate that statistically significant differences existed among the instructional groups in both academic achievement and mathematics self-efficacy, after accounting for gender.

4.2 DISCUSSION

The study examined the effect of Mathematica software on students' mathematics self-efficacy and academic achievement among engineering students in TVET institutions in Western Kenya. The findings indicate that Mathematica-integrated instruction was associated with significantly better outcomes than Conventional Mathematics Instruction (CMI). Students exposed to Mathematica recorded higher achievement and mathematics self-efficacy scores than students in the CMI groups. The MANCOVA further confirmed a statistically significant instructional-group effect on the combined outcomes of mathematics achievement and self-efficacy after controlling for gender.

The higher academic achievement observed among the Mathematica groups is consistent with research on computer algebra systems and technology-enhanced mathematics learning. Pierce and Stacey (2010) emphasize that mathematics software provides opportunities for students to explore mathematical relationships, manipulate representations, and investigate concepts dynamically. Similarly, Artigue (2002, 2019) highlights the potential of computer-based mathematical environments to support mathematical thinking and conceptual development. In the present study, students used Mathematica to manipulate mathematical variables, visualize functions and three-dimensional objects, and simulate mathematical relationships. These activities may have enabled students to connect symbolic, graphical, and numerical representations, thereby supporting deeper understanding and improved achievement.

The finding is also consistent with the constructivist perspective of learning, in which students actively construct knowledge through interaction with their learning environment (Piaget, 1970; Vygotsky, 1978). Rather than relying exclusively on lecturer explanations, students using Mathematica were able to explore mathematical concepts, test procedures, observe results, and modify their approaches. This provides a plausible explanation for the significantly higher achievement of the Mathematica groups. The finding is particularly relevant to engineering education, where mathematics is important for problem-solving and the application of quantitative concepts (Pepin et al., 2021).

The higher mathematics self-efficacy scores among the Mathematica groups provide a complementary finding. The results showed substantially higher self-efficacy among students exposed to Mathematica, with the MANCOVA indicating a significant instructional-group effect. This finding can be interpreted using Social Cognitive Theory, particularly Bandura (1986) concept of mastery experiences as a major source of self-efficacy. Through repeated opportunities to attempt mathematical tasks, obtain immediate computational feedback, identify errors, and successfully solve problems, students may have developed stronger beliefs in their mathematical capabilities. The finding is also consistent with Zimmerman and Kitsantas (2014), who emphasize the importance of self-efficacy in students' academic functioning.

The simultaneous differences in achievement and self-efficacy are important because they suggest that Mathematica-integrated instruction may influence both the cognitive and affective dimensions of mathematics learning. However, the present study does not establish a causal relationship between self-efficacy and achievement. Rather, the findings demonstrate that the two outcomes differed significantly according to instructional condition. The Technology Acceptance Model (Davis, 1989) provides an additional perspective on technology use, although perceived usefulness and ease of use were not directly measured in this study and therefore cannot be treated as tested variables.

Gender did not have a statistically significant multivariate effect on the combined outcomes after controlling for instructional group. This finding is broadly consistent with Hyde et al. (2008) and Else-Quest et al. (2010), who report substantial similarities and context-dependent differences in mathematics outcomes by gender. However, the present finding should not be interpreted as demonstrating that Mathematica had identical effects for male and female students because a formal instructional-group × gender interaction was not reported.

The similarity between the two Mathematica groups also provides some indication that pre-test exposure did not substantially influence achievement within the Mathematica condition. E1 and E2 recorded very similar post-test means, and their difference was not statistically significant. However, because a formal instructional condition × pre-test exposure interaction was not reported, the study cannot make a definitive claim about the absence of pre-test sensitization across the complete Solomon Four-Group design.

V. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study examined the effect of Mathematica software on mathematics self-efficacy and academic achievement among engineering students in TVET institutions in Western Kenya. Overall, the findings demonstrated that Mathematica-integrated instruction was associated with significantly higher mathematics academic achievement and mathematics self-efficacy compared with Conventional Mathematics Instruction (CMI). Students exposed to Mathematica recorded substantially higher post-test achievement scores than students taught through conventional instruction. The ANOVA results showed a statistically significant difference in achievement across the instructional groups, while the post-hoc comparisons confirmed that both Mathematica groups performed significantly better than both CMI groups. These findings suggest that integrating Mathematica into mathematics instruction can enhance students' academic achievement when the software is incorporated into structured and interactive learning activities. The study also established a statistically significant effect of instructional group on the combined outcomes of mathematics academic achievement and self-efficacy after controlling for gender. The follow-up analyses confirmed significant instructional-group effects on both achievement and mathematics self-efficacy. Students exposed to Mathematica reported higher levels of confidence in their ability to learn and perform mathematics than students exposed to conventional instruction. The large partial η^2 observed for self-efficacy indicates a substantial instructional-group effect within the model. Gender did not have a statistically significant overall multivariate effect on the combined mathematics achievement and self-efficacy outcomes after controlling for instructional group. This suggests that, within the study context, the observed differences in the two outcomes were primarily associated with instructional condition rather than gender.

Therefore, the study concludes that Mathematica-integrated instruction provides a promising approach for improving both mathematics academic achievement and self-efficacy among engineering students in TVET institutions in Western Kenya. Its effectiveness, however, should be understood in relation to its integration within appropriate teaching and learning practices rather than as a result of the software alone. The findings therefore support the adoption of appropriately structured technology-enhanced mathematics instruction as a complement to conventional teaching approaches in engineering education.

5.2 Recommendations

To maximize the benefits of technology-mediated learning in technical education, policymakers, administrators, and instructors can implement several targeted strategies across key operational levels. At the policy level, the Ministry of Education and TVET governing bodies can modernize national mathematics curricula by formally embedding computational tools like Mathematica into engineering syllabi, shifting the educational focus away from purely paper-and-pencil drills toward dynamic visual modeling. To support this curricular evolution, funding should be targeted toward strengthening lab infrastructure specifically ensuring institutions are equipped with modern hardware, reliable power backups, and generators to overcome technical hurdles and network disruptions. At the institutional level, administrators can support open access by securing reliable, campus-wide site licenses so all engineering students can freely utilize necessary software throughout their studies. Simultaneously, leadership should establish systematic, ongoing professional development programs for mathematics lecturers. Building instructor proficiency ensures faculty can confidently facilitate lab-based, active learning environments and guide students through initial software learning curves. At the classroom level, TVET mathematics lecturers can foster greater learner autonomy by shifting from traditional passive lectures to interactive modeling sessions where students actively code, experiment with functions, and self-correct their work. Instructors should also emphasize visual mathematics by introducing spatial visualization tools early when teaching complex concepts like optimization or multiple integration, building intuitive geometric understanding before progressing to formal symbolic procedures.

To build upon the insights gained from this investigation, future academic studies should consider several key avenues of research. First, longitudinal studies tracking TVET students over multiple semesters or academic years would help determine whether high achievement scores, elevated motivation, and strong self-efficacy persist as students' progress into advanced engineering coursework and enter their professional careers. Additionally, comparative research evaluating the specific pedagogical benefits of Mathematica against other leading computational and open-source platforms could offer clearer guidance on software selection in technical education. Beyond tool-specific comparisons, researchers should investigate the effectiveness of blended learning models particularly examining how mobile-friendly mathematics applications or offline-capable software can help sustain learning momentum during institutional outages or network disruptions. Finally, future work should combine qualitative and quantitative methods to examine the systemic barriers TVET mathematics faculty encounter when adopting new technologies, placing particular focus on the impacts of heavy workload pressures, inadequate technical support, and entrenched traditional teaching practices.

Declaration of Interest

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REFERENCES

Artigue, M. (2002). Learning mathematics in a CAS environment: The genesis of a reflection about instrumentation and the dialectics between technical and conceptual work. *International Journal of Computers for Mathematical Learning, 7*(3), 245–274. https://doi.org/10.1023/A:1022103903080

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Prentice-Hall.

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

Cameron, S., Ball, L., & Steinle, V. (2024). The stability of mathematics students' beliefs about working with CAS. *Mathematics Education Research Journal, 36*(2), 471–491.

Clark, R. C., & Mayer, R. E. (2016). *E-learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning* (4th ed.). John Wiley & Sons. https://doi.org/10.1002/9781119239086

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319–340. https://doi.org/10.2307/249008

Else-Quest, N. M., Hyde, J. S., & Linn, M. C. (2010). Cross-national patterns of gender differences in mathematics: A meta-analysis. *Psychological Bulletin, 136*(1), 103–127. https://doi.org/10.1037/a0018053

Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A. B., & Williams, C. C. (2008). Gender similarities characterize math performance. *Science, 321*(5888), 494–495. https://doi.org/10.1126/science.1160364

Kenya National Examinations Council. (2022). *The 2021/2022 KCSE and TVET examination report: Examination feedback and candidate performance evaluation*.

Mwangi, M. S., & Katam, E. (2023). Teacher-related factors influencing implementation of competency-based curriculum in primary schools in Murang'a County, Kenya. *Journal of Popular Education in Africa, 7*(11), 84–99.

Ndiangui, P., Mwangi, F. K., & Zhang, J. (2025). Enhancing student skills through the integration of online learning in Kenya's competency-based curriculum (CBC). *Research in Social Sciences and Technology, 10*(2), 1–35.

OECD. (2019). *TVET in Kenya*. OECD Publishing.

Pepin, B., Biehler, R., & Gueudet, G. (2021). Mathematics in engineering education: A review of the recent literature with a view towards innovative practices. *International Journal of Research in Undergraduate Mathematics Education, 7*(2), 163–188.

Piaget, J. (1970). *Genetic epistemology*. Columbia University Press.

Pierce, R., & Stacey, K. (2010). Mapping pedagogical opportunities provided by mathematics analysis software. *International Journal of Computers for Mathematical Learning*, *15*(1), 1–20. https://doi.org/10.1007/s10758-010-9158-6

Pierce, R., & Stacey, K. (2018). CAS in learning mathematics. *Mathematics Education Research Journal, 30*(4).

Sahroni, M. N. B., & Puzi, N. I. B. M. (2024). Enhancing mathematical competencies in TVET: Lessons from engineering staff in Malaysian manufacturing sectors. *Symmetry: Pasundan Journal of Research in Mathematics Learning and Education, 9*(2), 277–286.

Sofroniou, A. (2025). Advancing conceptual understanding: A meta-analysis on the impact of digital technologies in higher education mathematics. *Education Sciences, 15*(11).

Villa-Ochoa, J. A., & Suárez-Téllez, L. (2021). Computer algebra systems and dynamic geometry for mathematical thinking. In *Handbook of cognitive mathematics* (pp. 1–27). Springer International Publishing.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Wolfram Research, Inc. (2020). *Mathematica* (Version 12.2) [Computer software]. Wolfram Research. https://www.wolfram.com/mathematica/

Zimmerman, B. J., & Kitsantas, A. (2014). Comparing students' self-discipline and self-regulation measures and their prediction of academic achievement. *Contemporary Educational Psychology, 39*(2), 145–155. https://doi.org/10.1016/j.cedpsych.2014.03.004