Effect of mathematica-integrated instruction on mathematics attitude, motivation, and learning experiences among engineering students in TVET institutions in Western Kenya

Henry Nathan Wati [1]
Martin M.S. Wanjala [2]
Catherine M. Muhonja [3]

[1] hwati@mmust.ac.ke

[1,2,3] Masinde Muliro University of Science and Technology, Kenya

https://doi.org/10.51867/ajernet.7.3.88

…….…

ABSTRACT

This study examined the effect of Mathematica-integrated instruction on students' mathematics attitude, motivation, and related learning outcomes in TVET institutions. The study employed a Solomon Four-Group quasi-experimental design involving 239 students distributed across two experimental groups and two control groups. Quantitative data were analysed using descriptive statistics, ANOVA, MANOVA, MANCOVA, and hierarchical multiple regression, while qualitative data were analysed thematically.The findings showed that students exposed to Mathematica-integrated instruction reported significantly more positive mathematics attitudes than those receiving Conventional Mathematics Instruction (CMI), with experimental-group means of 67.79 and 67.02, compared with 55.07 and 54.76 for the control groups. Similarly, motivation scores were higher among the Mathematica groups (67.59 and 66.63) than the CMI groups (56.08 and 55.23). The multivariate analysis showed a significant instructional-group effect on the combined attitude and motivation outcomes, Wilks' $\Lambda = .195$, $F(6, 468) = 98.520$, $p < .001$, partial $\eta^2 = .558$. Instructional method and gender were also examined as predictors, with the hierarchical regression model explaining 61.3% ($R^2 = .613$) of the variance in mathematics achievement; instructional group made the largest contribution, while gender was not a significant predictor. Qualitative findings identified four themes: initial adaptability, dynamic spatial visualization, learner autonomy and self-efficacy, and technical hurdles.The study concludes that Mathematica-integrated instruction can enhance students' mathematics attitude and motivation and provide a more interactive and learner-centred mathematics learning experience. Its effective implementation, however, requires adequate lecturer preparation, structured instructional support, and reliable technological infrastructure.

Keywords: Learning Experiences, Kenya, Mathematica Software, Mathematics Attitude, Motivation, TVET

…….…

I. INTRODUCTION

Technical and Vocational Education and Training (TVET) institutions play an important role in preparing skilled personnel for industrial and technological development. Mathematics is a core component of engineering education because it supports computation, problem-solving, modelling, and the application of technical concepts. However, many engineering students experience difficulties in mathematics, which may be associated not only with academic challenges but also with negative attitudes, low motivation, and limited engagement with mathematical tasks (Oviawe et al., 2017). Students' attitudes and motivation are important dimensions of mathematics learning. Negative perceptions of mathematics can reduce students' willingness to participate and persist when faced with difficult tasks, while positive attitudes and motivation can encourage engagement and sustained effort. Research has shown that engineering student' experiences, perceptions of mathematics, and learning environments can influence their engagement with the subject (Wen & Dubé, 2022). Consequently, mathematics instruction needs to provide learning experiences that encourage active participation, exploration, and meaningful application of mathematical concepts.

Conventional mathematics instruction often emphasizes teacher explanations, worked examples, procedural demonstrations, and repetitive exercises. Although such approaches can support procedural learning, they may provide limited opportunities for visualization, experimentation, and exploration of mathematical relationships. Technology-enhanced mathematics learning offers opportunities to address some of these limitations by providing interactive representations, visualization, computational feedback, and opportunities for students to explore mathematical concepts (Renkl, 2017). Mathematica is a computational mathematics environment that supports symbolic and numerical computation, graphing, visualization, simulation, and interactive exploration. These capabilities can enable students to examine mathematical relationships dynamically and connect abstract concepts with visual and practical representations. Such technology-supported experiences may influence students' attitudes toward mathematics, motivation to engage with mathematical tasks, and perceptions of the learning process (Shyshko & Zetova, 2025).

Despite increasing interest in technology-enhanced mathematics education, limited empirical evidence exists on the use of specialized computational mathematics software to influence affective outcomes among engineering students in Kenyan TVET institutions. In particular, there is limited evidence on how Mathematica-integrated instruction influences students' mathematics attitudes, motivation, and experiences of learning mathematics. Addressing this gap is important because technology integration should be evaluated not only in terms of academic performance but also in terms of students' engagement and affective responses to learning. This study therefore examined the effect of Mathematica-integrated instruction on mathematics attitude and motivation among engineering students in TVET institutions in Western Kenya and explored students' experiences and perceptions of using Mathematica in mathematics learning. The study provides a complementary perspective on technology-supported mathematics instruction by focusing on affective and experiential outcomes.

1.1 Statement of the Problem

Mathematics is essential in technical and engineering education, yet many TVET students experience difficulties in understanding and engaging with mathematics when it is taught mainly through conventional, teacher-centred approaches (Vimbelo & Bayaga, 2024). These difficulties may contribute to negative attitudes, low motivation, and limited confidence in mathematics (Wen & Dubé, 2022). Although technology-supported instruction, including computational software such as *Mathematica*, offers opportunities for visualization, interaction, and exploration, there is limited empirical evidence on its effectiveness among engineering students in Kenyan TVET institutions. In particular, insufficient evidence exists on whether *Mathematica*-integrated instruction improves students' mathematics attitude and motivation, whether instructional method and gender predict these outcomes, and how students experience such technology-supported learning. This study therefore examined the effect of *Mathematica*-integrated instruction compared with Conventional Mathematics Instruction among TVET students.

1.2 Research Objectives

i. To determine the difference in students' mathematics attitude when taught using Mathematica-integrated instruction compared with Conventional Mathematics Instruction.
ii. To investigate the difference in students' motivation toward mathematics when taught using Mathematica-integrated instruction compared with Conventional Mathematics Instruction.
iii. To examine whether instructional method and gender predict students' mathematics attitude and motivation.
iv. To explore students' experiences and perceptions of learning mathematics using Mathematica-integrated instruction.

II. LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Constructivist Learning Theory

Constructivist Learning Theory views learning as an active process in which learners construct knowledge through interaction with their environment and prior experiences (Vygotsky, 1978). In mathematics education, this perspective supports learning environments in which students explore mathematical relationships, manipulate representations, test ideas, and develop understanding through active participation. Mathematica can support such learning by allowing students to visualize mathematical concepts, modify variables, generate graphs, and investigate mathematical relationships dynamically. These affordances may create more interactive learning experiences and encourage students to participate actively in mathematics learning. Recent research on technology-enhanced mathematics education emphasizes the importance of student engagement and the pedagogical conditions under which technology supports meaningful learning (Cooney, 2025).

2.1.2 Social Cognitive Theory

Social Cognitive Theory explains learning through reciprocal interactions among personal factors, behaviour, and the learning environment (Bandura, 1986, 1997). The theory recognizes motivation and engagement as important components of learning behaviour. In this study, Mathematica represents an environmental factor that can influence students' interaction with mathematical tasks through visualization, feedback, and opportunities for exploration. These experiences may influence students' willingness to participate and persist in mathematics learning. Research involving engineering students demonstrates that motivational and cognitive factors are important in understanding students' engagement with university mathematics (Eichler & Gradwohl, 2021).

2.1.3 Technology Acceptance Model

The Technology Acceptance Model (TAM) proposes that perceived usefulness and perceived ease of use influence individuals' acceptance and use of technology (Davis, 1989). In the present study, students who perceive

Mathematica as useful and manageable may be more willing to interact with it during mathematics lessons. Such perceptions may contribute to more positive learning experiences and greater engagement with mathematical tasks. This perspective is particularly relevant because technology-enhanced mathematics resources do not automatically produce positive engagement; students' interaction with the technology and the pedagogical context in which it is used are important.

2.2 Empirical Review

2.2.1 Difference in Mathematics Attitude by Instructional Method

The students' attitudes toward mathematics shape how they understand, approach, and participate in mathematics learning activities. Among engineering students, mathematics anxiety, confidence, perseverance, learning goals, prior knowledge and experience, and perceptions of mathematics constitute important dimensions of attitude (Paudel et al., 2025). Technology-aided mathematics pedagogy may provide opportunities to improve students' experiences of mathematics through demonstration, visualization, interaction, and real-time feedback.

Technology-assisted mathematics learning resources can diversify learning environments; however, their effectiveness depends substantially on the quality of their content and the manner in which they are pedagogically integrated (Wastira et al., 2025). Thus, the availability of technology alone may not necessarily produce positive attitudes unless it is appropriately incorporated into mathematics instruction. However, much of the existing research on mathematics attitudes has been conducted outside Africa, with limited evidence concerning engineering students in Kenyan TVET institutions and their use of computational mathematics software. The present study therefore examined whether Mathematica-integrated instruction produces differences in students' attitudes toward mathematics compared with Conventional Mathematics Instruction.

2.2.2 Difference in Mathematics Motivation by Instructional Method

Student motivation affects effort, persistence, participation, and readiness to engage with difficult mathematics tasks. The demandingness of mathematics subjects might led to engineering students feel they don't perform well, and hence, motivational aspects are crucial when teaching mathematics, (Eichler & Gradwohl, 2021). The motivation of the students can possibly boost up by technology-enhanced learning environments that allow interaction, exploration, the instant reward, and a different presentation of the math contents.

Research findings related to mathematics learning within the scope of technology-supported environment indicate that engagement with technology is determined by the properties of the technology, learning environments, and how well the resource is incorporated in the instructional practice (Simsek & Clark-Wilson, 2025). However, current evidence about whether the use of computational systems like Mathematica is effective to create a remarkable difference to the engineering students' motivation towards Mathematics in the TVET institutions is lack. This study was conducted to fills this void in this respect by comparing motivation between students that exposed to the instruction of Mathematics assisted by Mathematica and Conventional Mathematics Instruction.

2.2.3 Predictive Effect of Instructional Method and Gender on Attitude and Motivation

Gender may influence students' experiences and perceptions of mathematics, including aspects of mathematics attitude and motivational beliefs. Previous research involving students in STEM-related fields has reported gender-related differences in mathematics attitudes, motivational values, and perceptions of mathematics (Wang & Degol, 2017). However, such differences should not automatically be interpreted as evidence of differences in mathematical ability because students' learning experiences, prior preparation, classroom environment, and beliefs may also contribute to observed variations.

Technology-enhanced instruction may provide alternative ways of representing and interacting with mathematical concepts and may therefore create more inclusive learning opportunities (Lee & Branch, 2018). Consequently, examining instructional method alongside gender can provide a clearer understanding of whether differences in students' mathematics attitudes and motivation are associated primarily with the instructional approach or vary according to gender. Despite this, limited evidence is available on the predictive contribution of instructional method and gender to mathematics attitude and motivation among engineering students in Kenyan TVET institutions. The present study therefore examined whether instructional method and gender significantly predict students' mathematics attitude and motivation.

2.2.4 Students' Experiences and Perceptions of Mathematica-Integrated Mathematics Instruction

Learning experiences also represent how students conceptualise activities they participate in learning; use learning objects; interaction between people, and students exploring and solving problems in mathematics. In technology enhanced mathematics environments, students can be provided with technology to help explore mathematical representations, receive appropriate support while learning (Damşa & Ludvigsen, 2016). A significant literature review on technology enhanced mathematics showed limited exploration on how students interact with the technology itself for learning in higher education mathematics and highlights the necessity of knowledge of the pedagogical affordances of the technology (Sofroniou, 2025).

Students' experiences; perceptions; confidence; previously known knowledge regarding mathematics; determine the interaction with the subject for engineering students (Giannoulas & Stampoltzis, 2021). Mathematica might offer a unique learning experience allowing students interact with the system to visualise ideas, manipulate expressions, and interactively seek solutions. However, there is little qualitative evidence on how engineering students at Kenyan TVET institution learn Mathematics with support of Mathematica. The study therefore intends to support the quantitative analyses with student self-report of experiences and beliefs.

2.2.5 Mathematica-Integrated Instruction in Mathematics Education

An important distinction can be made between generic educational technology and Mathematica. Mathematica provides an integrated environment for symbolic and numerical computation, graphing, visualization, modelling, and mathematical exploration. These capabilities have potential relevance to engineering mathematics because they enable students to connect mathematical procedures with graphical, numerical, and technical representations. Alhejoj (2020), using mathematics instruction integrating Mathematica, reported significantly higher mathematics achievement and self-efficacy among students taught using Mathematica compared with those receiving Conventional Mathematics Instruction. This finding provides empirical support for the potential of Mathematica as an instructional tool.

However, the previous study primarily addressed academic achievement and mathematics self-efficacy, whereas the present study focuses on mathematics attitude, motivation, predictive effects of instructional method and gender, and students' experiences and perceptions. Examining these dimensions is important because improved academic achievement alone does not explain how or why students respond to technology-enhanced mathematics instruction. The present study therefore extends the empirical evidence by examining both affective outcomes and students' lived experiences of Mathematica-integrated mathematics instruction.

III. METHODOLOGY

3.1 Research Design

The study adopted a pragmatist philosophical approach and employed a convergent parallel mixed-methods design. The quantitative component used a Solomon Four-Group quasi-experimental design to examine the effect of Mathematica-integrated instruction on students' mathematics attitude and motivation while controlling for possible pre-test sensitization (Khazaei et al., 2025). The qualitative component explored students' experiences and perceptions of learning mathematics using Mathematica. The mixed-methods approach enabled the study to combine quantitative evidence of differences between instructional groups with qualitative accounts of students' learning experiences. The Solomon Four-Group design comprised two experimental groups exposed to Mathematica-integrated instruction and two control groups exposed to Conventional Mathematics Instruction (CMI). The design was structured as shown in Table 1.

Table 1
Solomon Four-Group Experimental Design

Group	Pre-test	Intervention	Post-test
Experimental 1 (E_1)	O_1	X (Mathematica)	O_2
Control 1 (C_1)	O_3	CMI	O_4
Experimental 2 (E_2)	—	X (Mathematica)	O_5
Control 2 (C_2)	—	CMI	O_6

NB: X = Mathematica-integrated instruction; CMI = Conventional Mathematics Instruction; O = observation/measurement.

3.2 Study Context, Population, and Sampling

The study was conducted in public Technical and Vocational Education and Training (TVET) institutions offering accredited Diploma in Engineering programmes in Kakamega, Bungoma, Busia, and Vihiga Counties in Western Kenya. The programmes included Electrical, Civil, Mechanical, and Building Construction Engineering. The target population comprised students undertaking calculus-based Engineering Mathematics. A multi-stage sampling procedure was used. First, disproportionate stratified sampling was used to select 13 TVET institutions comprising four National Polytechnics and nine Technical Training Institutes/Technical Colleges. Institutions were selected based on the availability of functional computer laboratories, active Diploma in Engineering programmes, and institutional willingness to participate. Intact first- and second-year classes undertaking Engineering Mathematics were subsequently included in the study.

A total of 239 students participated in the study. The participants were distributed across the four Solomon Four-Group conditions as follows: Experimental Group 1 (E_1), n = 58; Experimental Group 2 (E_2), n = 60; Control Group 1 (C_1), n = 59; and Control Group 2 (C_2), n = 62. The use of intact classes preserved normal instructional arrangements within the participating institutions.

3.3 Intervention and Field Procedures

The experimental groups received Mathematica-integrated mathematics instruction, while the control groups received Conventional Mathematics Instruction. The intervention was implemented over a period of 10–12 weeks and covered selected differentiation and integration concepts within the Engineering Mathematics curriculum. Before implementation, lecturers involved in the experimental condition received standardized training on the use of Mathematica for mathematics instruction. The training focused on dynamic visualization, symbolic computation, graphical representation, simulation, and interactive exploration of mathematical concepts.

In the experimental groups, Mathematica was integrated into classroom activities to enable students to visualize mathematical relationships, manipulate variables and expressions, examine graphical representations, and explore solutions interactively. The control groups covered the same curriculum content through conventional face-to-face instruction involving teacher explanations, board-based demonstrations, worked examples, and textbook exercises. Thus, the principal difference between the groups was the instructional approach used to support mathematics learning.

3.4 Data Collection Instruments

Quantitative data were collected using structured instruments measuring students' mathematics attitude and motivation. The mathematics attitude instrument assessed students' perceptions and feelings toward mathematics, while the motivation instrument assessed students' willingness to participate, effort, persistence, and engagement in mathematics learning. Qualitative data were collected using a semi-structured guide focusing on students' experiences and perceptions of Mathematica-integrated mathematics instruction. The qualitative component examined students' views of the usefulness of Mathematica, opportunities for visualization and exploration, engagement with mathematical tasks, perceived challenges, and the ways in which the software influenced their learning experiences.

3.5 Validity and Reliability

The data collection instruments were reviewed by experts in mathematics education and educational research to establish content validity and ensure that the items adequately represented the study variables. The quantitative instruments were pilot-tested before the main study. Internal consistency reliability was assessed using Cronbach's alpha, with coefficients interpreted in relation to accepted standards for research instruments. For the qualitative component, credibility was enhanced through the use of a structured interview guide and systematic coding of participants' responses. The qualitative data were retained in their original form during transcription and analysis to preserve participants' meanings and perspectives.

3.6 Data Analysis

Quantitative data were coded and analyzed using SPSS Version 32. Descriptive statistics were used to summarize students' mathematics attitude and motivation scores. Preliminary diagnostic tests, including tests of normality and homogeneity of variance, were conducted before inferential analysis. One-way analysis of variance (ANOVA) was used where appropriate to examine differences in individual outcome measures across the instructional groups. Multivariate analysis of variance (MANOVA) was used to examine the combined effect of instructional method on mathematics attitude and motivation. Hierarchical multiple linear regression was used to examine the predictive contribution of instructional method and gender to students' mathematics attitude and motivation. The analysis considered the incremental explanatory contribution of the predictors and reported the change in explained variance (ΔR^2). Qualitative data were transcribed, coded, categorized, and analyzed thematically. An inductive approach was used to identify recurring patterns and themes relating to students' experiences and perceptions of Mathematica-integrated mathematics learning. The qualitative findings were used to complement and provide contextual explanation for the quantitative findings.

IV. FINDINGS & DISCUSSION

4.1 Findings

4.1.1 Difference in Mathematics Attitude by Instructional Method

The first objective sought to determine the difference in students' mathematics academic achievement when taught using *Mathematica* software compared to those taught using Conventional Mathematics Instruction (CMI). The null hypothesis (H_{01}) stated that there was no statistically significant difference in post-test mathematics achievement among students exposed to the four instructional groups (E_1, E_2, C_1 and C_2). A One-Way ANOVA was conducted to determine whether students' post-test mathematics achievement differed significantly across the four instructional groups. Levene's test indicated unequal variances, $F(3, 235) = 8.348$, $p < .001$. Given the relatively balanced group sizes, the ANOVA was nevertheless examined alongside the pairwise comparisons (Abidoye et al., 2021), as shown in Table 2.

Table 2
One-Way ANOVA of Post-Test Mathematics Achievement

Source	Sum of Squares	df	Mean Square	F	p
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			

The results in Table 2 show a statistically significant difference in post-test mathematics achievement among the four groups, $F(3, 235) = 157.249$, $p < .001$. Therefore, H_{01} was rejected. This indicates that students' mathematics achievement differed according to the instructional group. The Scheffé pairwise comparisons showed that both *Mathematica* groups significantly outperformed the CMI groups. E_1 scored 13.206 points higher than C_1 and 16.800 points higher than C_2, while E_2 scored 12.851 points higher than C_1 and 16.445 points higher than C_2; all differences were statistically significant at $p < .001$. However, E_1 and E_2 did not differ significantly ($MD = 0.355$, $p = .988$). These findings indicate that students taught using *Mathematica* achieved substantially higher mathematics post-test scores than students taught using CMI. The absence of a significant difference between E_1 and E_2 further suggests that the presence of a pre-test did not materially alter achievement within the *Mathematica* condition.

4.1.2 Difference in Mathematics Motivation by Instructional Method

The second objective sought to investigate the difference in students' attitude and motivation towards mathematics when taught using *Mathematica* software compared with CMI. The null hypothesis (H_{02}) stated that there was no statistically significant difference in students' attitude and motivation towards mathematics between students taught using *Mathematica* and those taught using CMI.

Table 3
Descriptive Statistics for Motivation and Attitude

Variable	Group	Mean	SD	n
Motivation	E_1	67.59	2.914	58
	E_2	66.63	2.991	60
	C_1	56.08	3.789	59
	C_2	55.23	2.956	62
Attitude	E_1	67.79	3.355	58
	E_2	67.02	3.757	60
	C_1	55.07	4.605	59
	C_2	54.76	3.135	62

Table 3 show that students in the *Mathematica* groups recorded higher motivation and attitude scores than those in the CMI groups. Motivation means were 67.59 and 66.63 for E_1 and E_2, respectively, compared with 56.08 and 55.23 for C_1 and C_2. Similarly, attitude means were 67.79 and 67.02 for E_1 and E_2, compared with 55.07 and 54.76 for C_1 and C_2.. A One-Way MANOVA was conducted to examine the combined effect of instructional group on motivation and attitude.

Table 4
Multivariate Test of the Effect of Instructional Group

Statistic	Value	F	p	Partial η²
Pillai's Trace	0.808	53.14	< .001	0.404
Wilks' Lambda	0.195	98.52	< .001	0.558
Hotelling's Trace	4.103	159.328	< .001	0.672
Roy's Largest Root	4.098	321.036	< .001	0.804

Wilks' Lambda in Table 4 indicated a statistically significant multivariate effect of instructional group on motivation and attitude, $\Lambda = .195$, $F(6, 468) = 98.520$, $p < .001$, partial $\eta^2 = .558$. Thus, H_{02} was rejected. The instructional groups differed significantly in their combined motivation and attitude scores.

Table 5
Univariate Tests of Motivation and Attitude

Dependent Variable	F	p	Partial η²
Motivation	259.996	< .001	0.768
Attitude	221.443	< .001	0.739

The instructional group had a statistically significant effect on both motivation, $F(3, 235) = 259.996$, $p < .001$, partial $\eta^2 = .768$, and attitude, $F(3, 235) = 221.443$, $p < .001$, partial $\eta^2 = .739$. The findings indicate that students exposed to *Mathematica* demonstrated more positive attitudes and greater motivation towards mathematics than students receiving CMI.

4.1.3 Predictive Effect of Instructional Method and Gender on Attitude and Motivation.

The third objective sought to analyse the effect of *Mathematica* software on students' mathematics self-efficacy and academic achievement while controlling for gender. The null hypothesis (H_{03}) stated that there was no statistically significant effect of instructional method on students' mathematics self-efficacy and academic achievement after controlling for gender.

Table 6
Descriptive Statistics for Achievement and Self-Efficacy

Variable	Group	Mean	SD	n
Achievement	E_1	70.16	5.537	58
	E_2	69.8	4.313	60
	C_1	56.95	6.804	59
	C_2	53.35	4.516	62
Self-efficacy	E_1	65.26	2.619	58
	E_2	65.65	2.616	60
	C_1	54.76	2.687	59
	C_2	51.55	2.678	62

Table 5 show that the *Mathematica* groups recorded higher achievement and self-efficacy scores than the CMI groups. Achievement means were 70.16 and 69.80 for E_1 and E_2, respectively, compared with 56.95 and 53.35 for C_1 and C_2. Similarly, self-efficacy means were 65.26 and 65.65 in the experimental groups compared with 54.76 and 51.55 in the control groups. A MANCOVA was conducted to examine the effect of instructional group on the combined outcomes of mathematics achievement and self-efficacy while controlling for gender.

Table 7
MANCOVA Results

Effect	Pillai's Trace	F	p	Partial η²
Gender	0.007	0.856	0.426	0.007
Group	0.888	62.347	< .001	0.444

The MANCOVA showed a statistically significant multivariate effect of instructional group on the combined dependent variables, with Wilks' Lambda = .114, $F(6, 466) = 152.675$, $p < .001$, partial $\eta^2 = .663$. Gender was not statistically significant, $p = .426$, partial $\eta^2 = .007$.

Table 8
Univariate Effects of Group and Gender

Dependent Variable	Effect	F	p	Partial η^2
Achievement	Group	157.12	< .001	0.668
Achievement	Gender	0.579	0.447	0.002
Self-efficacy	Group	447.259	< .001	0.852
Self-efficacy	Gender	1.134	0.288	0.005

The instructional group had significant effects on both achievement, $F(3, 234) = 157.120$, $p < .001$, partial $\eta^2 = .668$, and self-efficacy, $F(3, 234) = 447.259$, $p < .001$, partial $\eta^2 = .852$ as shown in Table 7. Gender did not significantly affect achievement or self-efficacy. Therefore, *H_{03} was rejected with respect to instructional group but retained with respect to gender.*

4.1.4 Students' Experiences and Perceptions of Mathematica-Integrated Mathematics Instruction

The fourth objective sought to determine the predictive power of instructional methods and gender on students' academic achievement, mathematics self-efficacy, attitude towards mathematics and learning motivation. A hierarchical multiple regressions were conducted with mathematics achievement as the dependent variable. Gender was entered in Block 1, instructional group in Block 2, and motivation, self-efficacy and attitude in Block 3.

Table 9
Descriptive Statistics for Regression Variables

Variable	Mean	SD	N
Achievement	62.45	9.252	239
Gender	1.5	0.501	239
Instructional Group	2.52	1.122	239
Motivation	61.3	6.568	239
Self-efficacy	61.18	6.692	239
Attitude	61.08	7.288	239

The correlation analysis showed that achievement was positively associated with motivation ($r = .695$), self-efficacy ($r = .669$) and attitude ($r = .684$), all $p < .001$. Gender had a weak and non-significant relationship with achievement ($r = -.055$).

Table 10
Correlation Matrix

Variable	Achievement	Gender	Group	Motivation	Self-efficacy	Attitude
Achievement	1					
Gender	−.055	1				
Group	−.769	0.028	1			
Motivation	0.695	0.035	−.813	1		
Self-efficacy	0.669	0.077	−.806	0.901	1	
Attitude	0.684	0.062	−.785	0.877	0.837	1

Table 11
Hierarchical Regression Model Summary

Model	Predictors Entered	Adjusted R^2	ΔR^2	ΔF	p
1	Gender	−.001	0.003	0.709	0.4
2	Gender + Group	0.588	0.589	340.474	< .001
3	Gender + Group + Motivation + Self-efficacy + Attitude	0.605	0.021	4.211	0.006

Gender alone did not significantly predict achievement, $F(1, 237) = .709$, $p = .400$, explaining only 0.3% of the variance. The addition of instructional group in Model 2 significantly increased explained variance by 58.9%, $\Delta R^2 = .589$, $\Delta F(1, 236) = 340.474$, $p < .001$. The addition of motivation, self-efficacy and attitude in Model 3 produced a further significant 2.1% increase in explained variance, $\Delta R^2 = .021$, $\Delta F(3, 233) = 4.211$, $p = .006$. The final model explained 61.3% of the variance in achievement ($R^2 = .613$; adjusted $R^2 = .605$).

Table 12
ANOVA for the Final Regression Models

Model	F	p
1. Gender	0.709	0.4
2. Gender + Group	171.1	< .001
3. Full Model	73.76	< .001

The final model was statistically significant, $F(5, 233) = 73.760$, $p < .001$, indicating that the predictors jointly explained a significant proportion of variation in mathematics achievement.

Table 13
Regression Coefficients for Academic Achievement

Predictor	B	SE	β	t	p
Gender	−.947	0.766	−.051	−1.235	0.218
Group	−4.631	0.623	−.562	−7.429	< .001
Motivation	0.17	0.158	0.121	1.078	0.282
Self-efficacy	−.030	0.139	−.022	−.216	0.829
Attitude	0.202	0.113	0.159	1.783	0.076

Instructional group was the strongest statistically significant predictor of achievement, $\beta = -.562$, $p < .001$. Gender was not a significant predictor ($p = .218$), while motivation ($p = .282$), self-efficacy ($p = .829$) and attitude ($p = .076$) did not make statistically significant unique contributions after the other predictors were included. Thus, H_{04} was rejected, as the overall regression model significantly predicted mathematics achievement. The negative coefficient for instructional group should be interpreted in relation to the coding used in the analysis. Because the groups were coded $E_1 = 1$, $E_2 = 2$, $C_1 = 3$ and $C_2 = 4$, higher numerical values correspond to movement from the *Mathematica* groups towards the CMI groups. The negative coefficient therefore reflects the lower achievement associated with the higher-coded CMI groups. It should not be interpreted as evidence that an intrinsically "higher" group number causes lower achievement.

4.1.5 Students' Experiences and Perceptions of Mathematica-Integrated Mathematics Instruction

Qualitative findings on students' experiences and perceptions were obtained through focus group discussions. The analysis identified four main themes: initial adaptability, dynamic spatial visualization, learner autonomy and self-efficacy, and technical hurdles.

Table 14
Qualitative Themes from Student Focus Group Discussions

Theme	Main Categories	Summary of Student Experience
1. Initial Adaptability	Syntax difficulty; command errors; learning curve	Students initially experienced difficulty with syntax and commands but became more comfortable after practice.
2.Dynamic Spatial Visualization	Graphing; visual representation; manipulation of mathematical functions	Students reported that graphical and dynamic representations made abstract calculus concepts easier to understand.
3. Learner Autonomy and Self-Efficacy	Independent verification; experimentation; alternative solutions	Students gained confidence from independently checking and exploring mathematical solutions.
4. Managing Technical Hurdles	Computer failures; electricity interruptions; network problems	Technical and infrastructural challenges occasionally disrupted learning and required peer or lecturer assistance.

Theme 1: Initial Adaptability

Students reported that their first encounters with *Mathematica* involved difficulties with syntax and commands. However, these challenges decreased with practice. As one participant explained:

> *"At first I thought it was complicated... strict syntax and command errors... but after a few lessons I became more comfortable."*

This suggests that initial software difficulty was temporary and could be addressed through guided practice.

Theme 2: Dynamic Spatial Visualization

Students consistently identified visualization as an important advantage of *Mathematica*. Graphs and dynamic representations helped them connect mathematical expressions with their geometric meaning. One participant stated:

"Limits became clearer because I could observe behavior near critical points visually."

This finding helps explain the higher achievement observed among the experimental groups, particularly for abstract calculus concepts.

Theme 3: Learner Autonomy and Self-Efficacy

Students also reported greater independence in checking answers and exploring alternative solution methods. This was associated with increased confidence in solving mathematics problems. One participant stated:

"I became more confident checking answers and exploring alternative solution methods."

The qualitative evidence therefore supports the quantitative finding of significantly higher self-efficacy among students taught using *Mathematica*.

Theme 4: Managing Technical Hurdles

Despite the positive experiences, students identified computer, electricity and network interruptions as barriers to effective use of the software. Such challenges sometimes interrupted lessons and required students to rely on peers and lecturers. Thus, the effectiveness of technology-supported mathematics instruction depends not only on the availability of software but also on adequate institutional infrastructure and technical support.

4.2 Discussion

Across the five objectives, the quantitative and qualitative findings provide converging evidence that *Mathematica*-supported mathematics instruction was associated with better student outcomes than Conventional Mathematics Instruction (CMI). This finding is consistent with the broader literature showing that technology-supported mathematics instruction can enhance students' conceptual understanding, engagement and learning outcomes when digital tools are integrated with appropriate pedagogical strategies rather than used merely as computational substitutes (Borba et al., 2016).

First, students exposed to *Mathematica* achieved significantly higher post-test mathematics scores than students in the CMI groups. The differences between the experimental and control groups were substantial, while the two experimental groups did not differ significantly, suggesting that pre-testing did not materially influence achievement within the *Mathematica* condition. This finding is consistent with evidence that dynamic mathematical software can support students' understanding by enabling them to explore mathematical relationships through multiple representations, including symbolic, graphical and numerical forms (Zengin, 2019). The finding also supports the view that digital technologies can improve mathematics learning when they are embedded in purposeful instructional activities that encourage exploration and conceptual reasoning rather than simply automating calculations (Borba et al., 2016).

Second, students exposed to *Mathematica* reported significantly higher motivation and more positive attitudes towards mathematics. The qualitative findings suggest that the interactive nature of the learning environment contributed to greater engagement and reduced reliance on rote procedural learning. This interpretation is supported by research indicating that technology-enhanced learning environments can increase student engagement by providing opportunities for interaction, feedback, exploration and learner participation (Barana et al., 2019). Similarly, meta-analytic evidence indicates that the effectiveness of educational technology is influenced by how technology is integrated into teaching and learning activities rather than by the presence of technology alone (Hillmayr et al., 2020).

Third, *Mathematica*-based instruction was associated with significantly higher mathematics self-efficacy as well as higher academic achievement after controlling for gender. Gender did not have a statistically significant effect on either outcome. The finding is important because self-efficacy is closely related to students' willingness to engage with challenging academic tasks, persistence and confidence in their ability to succeed. The qualitative evidence, particularly students' reports of independently checking answers and exploring alternative solution procedures, provides a plausible explanation for the observed increase in self-efficacy. Digital learning environments that provide immediate feedback and opportunities for active problem solving can create conditions that support students' perceived competence and engagement (Schindler et al., 2017).

Fourth, the hierarchical regression model explained 61.3% of the variance in mathematics achievement. Instructional group provided the largest incremental contribution, while gender did not provide significant predictive power. Motivation, self-efficacy and attitude were strongly correlated with achievement but did not make statistically significant independent contributions after instructional group and the other affective variables were included. This pattern suggests that the affective outcomes may be closely intertwined with the instructional environment rather than functioning as completely independent predictors of achievement. The high correlations among motivation, self-efficacy and attitude in the present study further support this interpretation. Previous research similarly indicates that the learning effects of educational technology depend on the interaction between technological tools, instructional design and learner characteristics rather than on technology as an isolated factor (Bower et al., 2015).

Finally, the qualitative findings provide an explanation for these quantitative patterns. Students described *Mathematica* as supporting visualization, conceptual understanding, independent verification and confidence. At the same time, technical limitations such as electricity interruptions, computer failures and network problems constrained the learning experience. This finding is consistent with research showing that the educational benefits of digital technologies depend partly on access to appropriate infrastructure, teacher competence and effective pedagogical integration (UNESCO, 2023). Thus, the positive effects observed in the present study should be understood within the conditions under which the intervention was implemented.

Overall, the findings indicate that *Mathematica* can serve as an effective instructional tool for mathematics in TVET settings when its use is accompanied by appropriate lecturer support, structured practice and adequate technological infrastructure. The results therefore support a shift from viewing mathematical software merely as a computational aid towards using it as a pedagogical resource for visualization, exploration, feedback and independent problem solving. However, the findings should be interpreted as evidence of an association within the present quasi-experimental design rather than as proof that *Mathematica* alone caused all observed improvements.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

The study examined the effect of *Mathematica*-supported instruction on mathematics achievement, motivation, attitude and self-efficacy among TVET students. The findings from the quantitative and qualitative components consistently indicate that students exposed to *Mathematica* achieved better outcomes than those taught through Conventional Mathematics Instruction (CMI). First, students taught using *Mathematica* recorded significantly higher mathematics post-test achievement scores than students taught through CMI. The experimental groups also performed similarly to each other, indicating that the observed difference was not substantially affected by exposure to the pre-test. Second, *Mathematica*-supported instruction was associated with significantly higher levels of learning motivation and more positive attitudes towards mathematics. The findings suggest that the interactive and visual nature of the software provided students with greater opportunities to engage actively with mathematical concepts.

Third, students exposed to *Mathematica* demonstrated significantly higher mathematics self-efficacy and academic achievement after controlling for gender. Gender did not have a statistically significant effect on either outcome. This suggests that the benefits observed in the study were not restricted to one gender. Fourth, the hierarchical regression analysis showed that the instructional group was the strongest predictor of mathematics achievement. The final regression model explained 61.3% of the variance in achievement. Although motivation, self-efficacy and attitude were positively correlated with achievement, they did not make statistically significant independent contributions after instructional group and the other variables were controlled.

Finally, the qualitative findings provided contextual explanations for the quantitative results. Students reported that *Mathematica* improved visualization, conceptual understanding, independent verification and confidence in solving mathematical problems. However, electricity interruptions, computer problems and network limitations sometimes disrupted learning. The effectiveness of technology-supported mathematics instruction therefore depends not only on the availability of software but also on appropriate pedagogical support and reliable institutional infrastructure. Overall, the study concludes that *Mathematica*-supported instruction provides a promising approach to improving mathematics learning among TVET students. Its value lies not simply in performing mathematical computations but in supporting visualization, exploration, feedback and independent problem solving. Nevertheless, the findings should be interpreted within the context of the study's quasi-experimental design and should not be taken to mean that *Mathematica* alone explains all observed differences.

5.2 Recommendations

Based on the findings of the study, the Ministry of Education and TVET institutions should promote the integration of *Mathematica* and similar dynamic mathematical software into mathematics and engineering mathematics curricula. Such integration should be supported by adequate computer laboratories, reliable electricity, internet connectivity and appropriate technical support to minimize disruptions reported by students.

TVET institutions should also provide continuous professional development for mathematics lecturers to strengthen their ability to use *Mathematica* for visualization, exploration, problem solving and learner-centred instruction. Lecturers should use the software alongside conventional mathematical procedures rather than as a replacement for mathematical reasoning, while providing students with introductory training to overcome initial difficulties with syntax and commands. Students should be encouraged to use *Mathematica* for independent exploration, solution verification and interpretation of mathematical representations. Finally, future studies should examine the long-term effects of *Mathematica*-supported instruction across different TVET institutions and mathematical topics to establish the generalizability and sustainability of the observed benefits.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding Declaration

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

Abidoye, A. O., Lamidi, W. A., Alabi, M. O., & Popoola, J. (2021). Testing for equality of means with equal and unequal variances. *Scientia Africana, 20*(2), 51–60.

Alhejoj, K. (2020). *A multiple case study of college mathematics instructors' technological pedagogical content knowledge (TPACK) and its relationship to the integration of information and communications technology (ICT) in their teaching practices and students' learning*. Illinois Institute of Technology.

Bandura, A. (1986). *Social foundations of thought and action*. Prentice Hall.

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

Barana, A., Boffo, S., Gagliardi, F., Garuti, R., & Marchisio, M. (2019). Empowering engagement in a technology-enhanced learning environment. In *Project and design literacy as cornerstones of smart education: Proceedings of the 4th International Conference on Smart Learning Ecosystems and Regional Development* (pp. 75–77). Springer.

Borba, M. C., Askarian, N., Engelbrecht, J., Gadanidis, G., Llinares, S., & Sánchez, A. (2016). Blended learning, e-learning and mobile learning in mathematics education. *ZDM Mathematics Education, 48*, 589–610.

Bower, M., Dalgarno, B., Kennedy, G. E., Lee, M. J., & Kenney, J. (2015). Design and implementation factors in blended synchronous learning environments: Outcomes from a cross-case analysis. *Computers & Education, 86*, 1–17.

Cooney, C. (2025). *Examining the effect of technology-enhanced formative assessment on student engagement and learning in higher education: An action research study* [Doctoral dissertation, National University of Ireland Maynooth].

Damşa, C. I., & Ludvigsen, S. (2016). Learning through interaction and co-construction of knowledge objects in teacher education. *Learning, Culture and Social Interaction, 11*, 1–18.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*(3), 319–340.

Eichler, A., & Gradwohl, J. (2021). Investigating motivational and cognitive factors which impact the success of engineering students. International Journal of Research in Undergraduate Mathematics Education, 7(3), 417–437. https://doi.org/10.1007/s40753-020-00127-4

Giannoulas, A., & Stampoltzis, A. (2021). Attitudes and perceptions towards mathematics by Greek engineering students at university: An exploratory study. International Electronic Journal of Mathematics Education, 16(2), Article em0639. https://doi.org/10.29333/iejme/10906

Hillmayr, D., Ziernwald, L., Reinhold, F., Hofer, S. I., & Reiss, K. M. (2020). The potential of digital tools to enhance mathematics and science learning in secondary schools: A context-specific meta-analysis. *Computers & Education*, *153*, 103897.

Khazaei, M. R., Moradi, E., Barry, A., Keshavarzi, M. H., Hashemi, A., Ramezani, G., … Farzadnia, F. (2025). Retracted article: Effect of flipped classroom method on the reflection ability in nursing students in the professional ethics course; Solomon four-group design. *BMC Medical Education, 25*, 56.

Lee, S. J., & Branch, R. M. (2018). Students' beliefs about teaching and learning and their perceptions of student-centred learning environments. *Innovations in Education and Teaching International*, *55*(5), 585–593.

Oviawe, J. I., Uwameiye, R., & Uddin, P. S. (2017). Bridging skill gap to meet technical, vocational education and training school-workplace collaboration in the 21st century. *International Journal of Vocational Education and Training Research, 3*(1), 7–14.

Paudel, T., Dahal, N., & Hasan, M. K. (2025). Female undergraduates' perception of mathematics: A mixed-methods study. *Frontiers in Education, 10*, 1555519.

Renkl, A. (2017). Learning from worked examples in mathematics: Students relate procedures to principles. *ZDM, 49*(4), 571–584.

Schindler, L. A., Burkholder, G. J., Morad, O. A., & Marsh, C. (2017). Computer-based technology and student engagement: A meta-analysis. *Computers & Education, 100*, 1–15.

Simsek, A., & Clark-Wilson, A. (2025). Adopting a framework for investigating mathematics teachers' technology-integrated classroom teaching practice: Structuring features of classroom practice. *International Journal of Science and Mathematics Education*, *23*(3), 589–616.

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

Shyshko, N. S., & Zetova, T. R. (2025). Using Wolfram Mathematica software environment to process the results of the laboratory work "Newton's ring." *Journal of V. N. Karazin Kharkiv National University. Series Physics*, (42), 74–78.

UNESCO. (2023). *Global education monitoring report 2023: Technology in education: A tool on whose terms?* UNESCO.

Vimbelo, S., & Bayaga, A. (2024). Transforming mathematics education in TVET colleges through humanising pedagogy: An exploration of teaching approaches, student engagement, and real-life examples. *IETE Journal of Education, 65*(2), 139–154.

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

Wang, M. T., & Degol, J. L. (2017). Gender gap in science, technology, engineering, and mathematics (STEM): Current knowledge, implications for practice, policy, and future directions. *Educational Psychology Review, 29*(1), 119–140.

Wastira, J., Waluyo, E. T. B., & Fajarianto, O. (2025). Integrating technology into teaching to foster student engagement and interaction. *JTP–Jurnal Teknologi Pendidikan, 27*(2), 464–486.

Wen, R., & Dubé, A. K. (2022). A systematic review of secondary students' attitudes towards mathematics and its relations with mathematics achievement. *Journal of Numerical Cognition, 8*(2), 295–325.

Zengin, Y. (2019). Development of mathematical connection skills in a dynamic learning environment. *Education and Information Technologies*, *24*(3), 2175–2194.