



## An Analysis of Indicators of Students' Motivation to Use Technology in Learning Mathematics: A Case Study of NodeBook™

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### ABSTRACT

This study analyzes factors that affect students' motivation for using technology in learning mathematics at universities. A 12-item questionnaire was developed to measure students' perceptions of four key variables: students' enjoyment (SE), students' perception of success (SPS), significance and need of NodeBook™ (SN), and mathematics course organization using NodeBook (MCO). Based on a quantitative methodology, responses from 86 male and 73 female students enrolled in various mathematics courses in the United Arab Emirates were collected and recorded using a 5-point Likert scale. Factor and regression analyses were used to analyze the collected data. Results indicated that students' enjoyment of the course during learning and their perception of success were the most significant indicators of their motivation to use NodeBook technology while learning mathematics. The study will help students, educators, and administrators understand students' preferences when choosing the right technology that enhances their learning of mathematics.

### KEYWORDS

Students' motivation; learning mathematics; NodeBook technology; innovative visualization; educational technology.

## INTRODUCTION

Mathematics is a significant and essential foundation interwoven with a lot of sciences, like physics, technology, engineering, and architecture, as well as the health, social, and business sciences (Barnett et al., 2019; Dennerly & Krzywicki, 2012; Hoppensteadt & Peskin, 2013; Irving & Mullineux, 2013). Despite the crucial role that mathematics plays and the growing need for it, the success rates of students in college mathematics courses are not encouraging. Nite et al. (2014) reported that the dropout rates in mathematics-intensive Science, Technology, Engineering, and Mathematics (STEM) majors was found to be significantly impacted by students' failure in college-level mathematics courses. Van Dyken et al. (2015) reported that the dropout rates of STEM programs are higher amongst students who take remedial mathematics courses. Kopparla (2019) highlighted that the first mathematics grade of students has the strongest correlation with their retention in STEM programs, i.e., students who earned a C or higher in their first mathematics course in college had better chances to continue their studies, regardless of the first mathematics course they took.

Student motivation is one of the most important determinants of success in mathematics courses. Hammoudi (2019) emphasized that teaching and assisting motivated students is not a complicated task, regardless of whether their motivation is intrinsic or extrinsic. It was found by Tran and Nguyen (2021) that both intrinsic and extrinsic motivation (introjected regulation as well as identified regulation) have a favorable impact on students' mathematics performance. More recently, Boadu and Boateng (2024) highlighted that integrating technology and collaborative learning into mathematics education significantly enhances student achievement and engagement. This supports the growing body of research suggesting that technology-driven interventions would increase students' motivation to learn mathematics.

Furthermore, studies indicate that using applications as well as digital tools can have a positive effect on students' learning experiences of mathematics. Shurygin et al. (2023) examined the effects of using MalMath and the conventional method of teaching mathematics on students' conceptual and procedural knowledge, problem-solving skills, and learning motivation. Findings indicated that motivation of students to learn mathematics is enhanced through the use of MalMath. Similarly, Valdez and Maderal (2021) found that using online assessments affected positively the motivation of students to learn mathematics. Furthermore, Tashtoush et al. (2023) explored the role of ICT-based education in fostering academic enthusiasm, concluding that digital learning environments contribute to increased motivation and engagement among students.

The meta-analysis of Li et al. (2021) indicated that there is a negative relationship between the motivation of students to learn mathematics and their mathematics anxiety. Daher (2022) examined how the setting of robotics affected students' motivation. Compared to students in traditional classes, the robotics-based learning students described their experience with terms of interest, mastery, and self-efficacy. Otoo et al. (2018) demonstrated a strong correlation between motivation and confidence, demonstrating how much students' confidence

increased their interest in learning mathematics. The usefulness of mathematics is one factor that influences the interest of students. According to several research studies, there are gaps in students' mathematical achievements (Abo Hamza et al. 2024; Kopparla, 2019; Nite et al., 2014; Van Dyken et al., 2015). However, not enough studies were made to examine the impact of using technology on students' motivation when learning mathematics.

Since NodeBook is a new technology for organizing and learning mathematics courses, both outside the classroom and online, research into the factors that motivate students to use this technology to learn mathematics is very important. Therefore, this study aims to answer the following research question: What are the predictive factors that influence students' motivation of using NodeBook in learning mathematics?

Following this introduction, several sections are organized to describe the NodeBook technology, relevance of the research, literature review, research methodology, regression analysis and mathematical modeling, as well as discussion of the results and suggested future work. Finally, the conclusion summarizes the paper's findings and outlines its limitations.

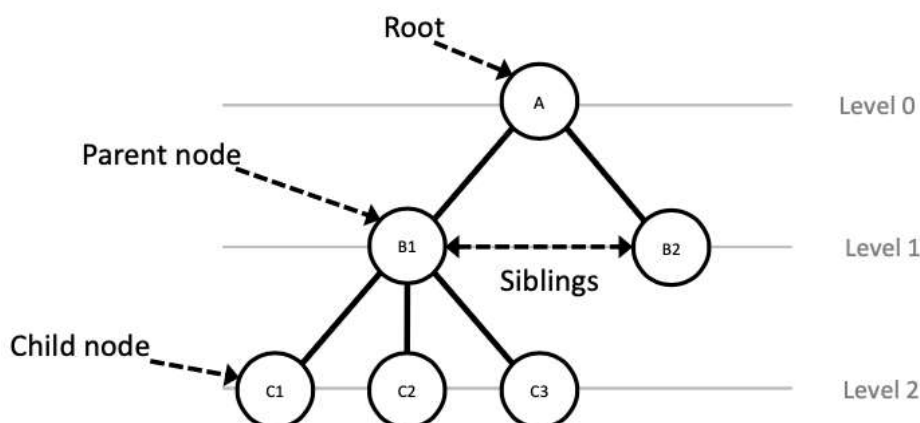
### NodeBook Technology

NodeBook is a new patented technology for creating and presenting tree-structured data. While it can be used as a concept map, note organizer, or e-book reader, this paper focuses specifically on its application in creating and presenting online courses.

A tree data structure is defined recursively as a collection of interconnected nodes, starting from a single root node. Each node is an object consisting of data (in any form) and a list of references to its children nodes. Figure 1 provides a graphical example of a three-level tree, beginning with the root node, followed by parent nodes in Level 1, and their respective child nodes in Level 2.

**Figure 1.**

*Graphical Presentation of NodeBook Levels*

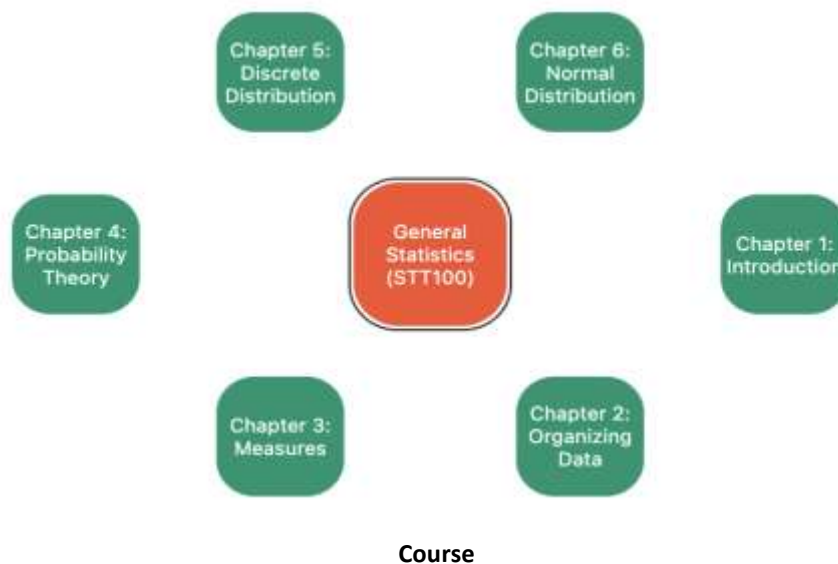


NodeBook enables the creation and navigation of tree-structured information using a 3D or 2D Zooming User Interface (ZUI) (Deif, 2024). A ZUI is a type of Graphical User Interface (GUI) that uses zooming and panning to browse information. This information is added as elements

to a workspace called a 'canvas,' which is larger than the device's viewing window. Users can pan the viewing window to see different elements or scale (zoom in/out) a viewed area to see more or less detail.

**Figure 2.a.**

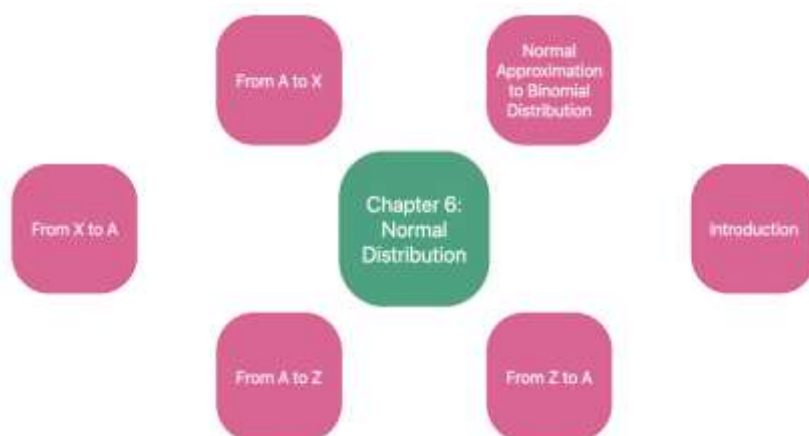
*The ZUI Presents Levels 0 and 1 of a Statistics*



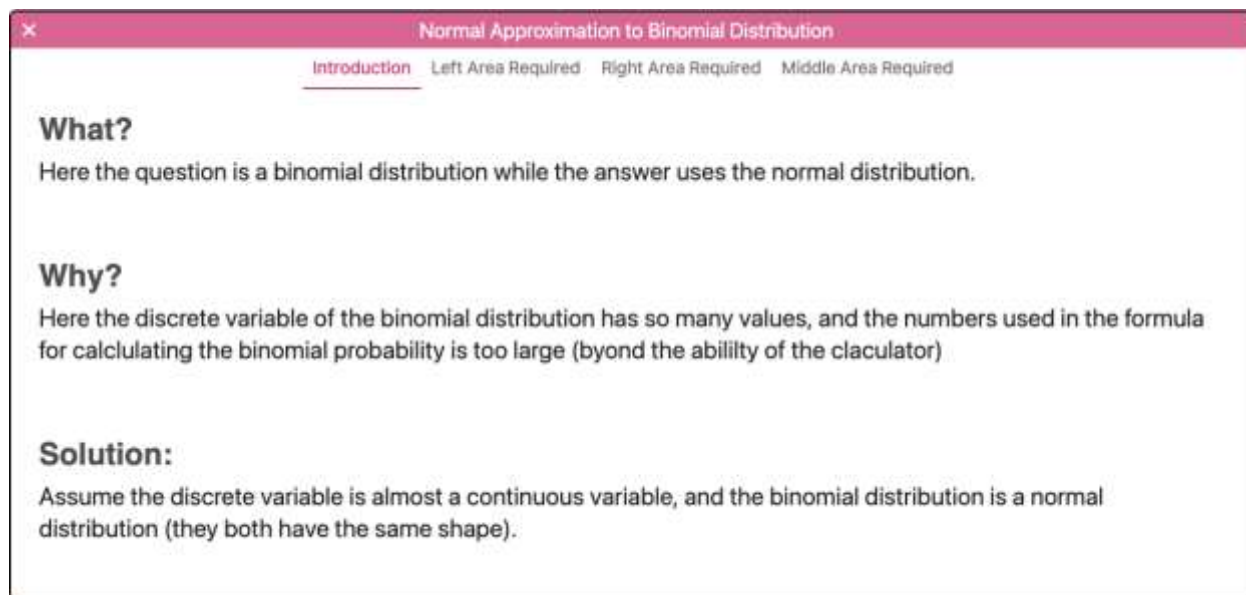
In NodeBook, the ZUI displays two or three levels simultaneously. Figure 2.a provides an example of how the technology is used to build a statistics course. The central root node contains the course name, while parent nodes represent the different chapters. The sections of any chapter are stored in the next level and are only visible when the user zooms into that specific chapter, as shown in Figure 2.b.

**Figure 2.b.**

*The ZUI Presents Levels 1 and 2 of a Statistics Course*



When a user clicks on a node, its contents appear. This content may be a summary of a chapter, a section, or a full explanation of a topic or subtopic. A node can also include multiple tabs for further classification. Each tab functions as a page with unlimited length. Figure 3 shows an example of a node with multiple tabs.

**Figure 3.***Example of a Node Content with Four Tabs*

NodeBook is a new technology that has been used by instructors in Abu Dhabi University in the last couple of years to present course materials for Algebra, Statistics, Discrete Mathematics, and Probability courses.

**Significance of Research**

This research makes a substantial contribution to the literature by analyzing the factors that determine university students' motivation to learn mathematics via NodeBook technology. The findings are anticipated to provide significant benefits to students, mathematics educators, university administrators, and society.

It is emphasized by Hammoudi (2020) that the appropriate measurement of students' motivation in mathematics courses helps in minimizing failure and withdrawal rates at the university level. Using NodeBook technology, students can utilize the created models to promote their success in mathematics, which will ultimately enable them to complete their courses and graduate from the colleges they chose. It is suggested by Tarver (2015) that mathematics educators can have a greater influence on students' lives by ensuring that students are learning to support the growth of STEM majors. Schools, colleges and institutions may use the suggested models to increase students' motivation to learn mathematics with NodeBook technology before they enroll in programs that need mathematics courses. This research is expected to enhance students' retention in STEM programs by identifying students who are likely to succeed in their mathematics courses and who are motivated as they use NodeBook technology.

**THEORETICAL FRAMEWORK AND LITERATURE REVIEW**

The purpose of this study is to examine the relationship between a variety of students' perceptions of NodeBook technology and their motivation to learn mathematics. Based on

previous research, our model proposes that student motivation is affected by four factors: students' enjoyment (SE), their perception of success (SPS), the significance and need of the technology (SN), and mathematics courses organization using the NodeBook (MCO). To provide a theoretical foundation, the following review of literature synthesizes existing research on student motivation to learn mathematics, with a focus on the use of technology and its impact.

A growing body of research has demonstrated the positive impact of using technology on student motivation when learning mathematics. The meta-analysis conducted by Higgins et al. (2019) illustrates that results from 24 papers (4,522 subjects) show that technology has a large overall impact on students' accomplishment, motivation, and attitudes. However, outcomes vary depending on the particular intervention aspect that was evaluate. This is supported by studies on a variety of digital tools. For example, Serin (2020) examined how technology-based instruction might help students become more motivated by explaining if the use of technology in the classroom may enhance students' learning of geometry. Furthermore, it was found by Liburd and Jen (2021) that students who use a technological approach perform well in mathematics. The self-determination theory advocates that intrinsic motivation (enjoyment and interest) compels the responses of students to the course contents (Deci & Ryan, 1985; Ryan & Deci, 2000).

More specific applications of technology have also shown promising results. The research study conducted by Fadda et al. (2022) found that video games can be effective teaching aids that increase student motivation, and Daher (2022) observed that students in a robotics environment showed increased interest, mastery, and self-efficacy. Similarly, Ben Abu and Kribushi (2022) demonstrated that a digital writing board had a favorable impact on significant motivational factors among engineering students.

The attitudes of students toward mathematics play a tremendous role in identifying if students will be motivated to learn. The negative experiences of students or stereotyping radically minimize students' engagement. According to the attribution theory, the encouragement of controllable reasons of failure such as effort instead of uncontrollable reasons like ability, nurtures resilience and attitude (Weiner, 1985).

Several intrinsic and extrinsic factors influence Students' motivation, which is a critical determinant of academic success. It was found by Otoo et al. (2018) that there is a strong correlation between motivation and confidence, indicating that students' confidence significantly impacts their interest in learning mathematics. This is further supported by research on the self-efficacy theory (Bandura, 1997), a key component of motivation. For instance, Schöber et al. (2018) highlighted that mathematical self-efficacy has a favorable impact on subsequent mathematical achievement. Other research has explored the relationship between motivation and students' self-concept (Girra et al., 2025; Lee & Kung, 2018), mathematics anxiety (Li et al., 2021), and the adversity quotient (Suryadi & Santoso, 2017).

Several studies have also explored the impact of various instructional factors on student achievement and motivation. It was found by Toropova et al. (2019) that students give better

instructional quality ratings for teachers with stronger self-efficacy beliefs, which suggests an indirect link to student motivation. Furthermore, the role of instructors' quality (Ekmekci & Serrano, 2022), instructors' performance (Tambunan et al., 2021), and instructors' support (Yu & Singh, 2018) have all been identified as significant factors influencing students' academic success.

### **Research Questions and Hypotheses**

Based on the literature, the main goal of this study is to investigate how a variety of factors influence university students' motivation to learn mathematics using NodeBook technology. This study aims to understand how the dependent variable, students' motivation to learn mathematics through NodeBook (SMLM-N), is predicted by four independent variables: students' enjoyment (SE), students' perception of success (SPS), the significance and need of NodeBook (SN), and mathematics course organization (MCO).

The following null hypotheses have been developed for the study:

Ho<sub>1</sub>: No relation between students' enjoyment when learning mathematics through NodeBook and their motivation to learn mathematics ( $b_1 = 0$ ).

Ho<sub>2</sub>: No relation between students' perception of success in mathematics through NodeBook and their motivation to learn mathematics ( $b_2 = 0$ ).

Ho<sub>3</sub>: No relation between the significance and need of NodeBook in learning mathematics and students' motivation to learn mathematics ( $b_3 = 0$ ).

Ho<sub>4</sub>: No relation between organization of mathematics courses through NodeBook and their motivation to learn mathematics ( $b_4 = 0$ ).

### **RESEARCH METHODOLOGY**

A quantitative, correlational research is employed in this study to explore the relationships between various factors and university students' motivation to use technology for learning mathematics. A correlational design is non-experimental and is used to investigate and describe the degree of association between two or more variables without manipulating them (Creswell, 2014). This approach was appropriate for this study as it allowed for the systematic measurement and statistical analysis of the connections between student perceptions (enjoyment, perceived success, significance of the technology, and course organization) and their motivation. The data were collected and analyzed using regression analysis to determine the predictive relationships between these factors and student motivation.

A 12-item survey questionnaire was created to collect the data in this study. The population consisted of all students who are enrolled in mathematics courses at Abu Dhabi University in the UAE. The instructors of mathematics courses, who used NodeBook technology to deliver their courses of mathematics at the university, were approached. Their students were given the right to withdraw at any time as their participation was entirely voluntary. To ensure the strictest confidentiality, all submitted responses were used exclusively for this study. The final sample included a total of 159 students, comprising 73 males and 86 females.

SPSS 26.0 software was used to conduct the quantitative analyses, including both factor and regression analysis. Factor analysis was used to enhance the validity and reliability of the gathered data. Regression analysis was then conducted to identify how the study's dependent variable was influenced by the selected independent variables.

### Instrument and Data Reliability

The 12-item questionnaire was designed based on Self-Determination Theory (Deci & Ryan, 1985) and Attribution Theory (Weiner, 1985), both are important to understand student motivation in learning mathematics. The purpose of the questionnaire was to measure students' perceptions of their own performance in mathematics courses, specifically focusing on their motivation (the dependent variable) and four independent variables: students' enjoyment (SE), students' perception of success (SPS), the significance and need of NodeBook (SN), and mathematics course organization through NodeBook (MCO).

**Table 1.**

*Reliability Analysis, KMO, Bartlett's test*

Variables' Scales	Number of Items	Cronbach's alpha coefficient	KMO values	Bartlett's test of sphericity P-values
Students' Motivation to Learn Mathematics Through NodeBook	2	0.606	0.500	<0.001
Students' Enjoyment of Learning Mathematics through NodeBook	3	0.816	0.702	<0.001
Students' Perception of Success in Mathematics through NodeBook	3	0.856	0.730	<0.001
Significance and Need of NodeBook in Learning Mathematics	2	0.755	0.500	<0.001
Mathematics Courses Organization through NodeBook	2	0.682	0.500	<0.001

The questionnaire's items were adapted from several validated instruments, including the Intrinsic Motivation Inventory (IMI) and the Motivated Strategies for Learning Questionnaire (MSLQ), while additional questions were developed to meet the specific objectives of this study. The survey included 12 items to measure the five primary variables and also collected demographic information. Two items were used to measure the dependent variable, students' motivation to learn mathematics through NodeBook. The four independent variables were measured as follows: students' enjoyment (SE) by three items, students' perception of success (SPS) by three items, the significance and need of NodeBook (SN) by two items, and mathematics course organization (MCO) by two items. Students responded to each item using a 5-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (5). This scale was chosen to enhance response rates and the reliability of the collected data.

To test the internal consistency of the items within each subscale, a reliability analysis was conducted. As shown in Table 1, the calculated Cronbach's alpha reliability coefficients were all above 0.6, indicating acceptable to good internal reliability. Furthermore, principal axis factor analysis with a Promax (oblique) rotation was used to test the correlation and cohesiveness between the questionnaire's items. The feasibility of this analysis was confirmed by the Kaiser-Meyer-Olkin (KMO) values, which were all greater than 0.5, and the P-values from Bartlett's test of sphericity, which were all less than 0.01 (see Table 1). These results confirm that factor analysis was appropriate for examining the constructs of the variables.

### Demographic profile of the participants

The demographic profile of the respondents is presented in Table 2 (see appendix). According to the data, there are more male students (54.08%) in the sample. The majority (73%) of the students were less than 22 years old. Nearly 88.68% were either in the first year or second year of the undergraduate degree. The majority (83.65%) of them were not working, which may have allowed them to dedicate more time to their studies. Additionally, 59.12% of them earned a grade of A in the course.

## FINDINGS

This section presents the findings on the relationship between student motivation to learn mathematics through NodeBook (SMLM-N) and the four independent variables: students' enjoyment (SE), perception of success (SPS), significance and need of NodeBook (SN), and mathematics course organization (MCO).

### i. Students' Enjoyment (SE)

According to Deci and Ryan's (1985) self-determination theory, motivated students are more likely to persist and put in the effort necessary to complete tasks they find enjoyable and engaging. When students find the learning process stimulating, their motivation increases. Therefore, it is plausible that students' motivation to complete mathematics courses with NodeBook technology is positively connected to their enjoyment of the subject.

**Table 3.**

*Regression Analysis - SE*

Coefficients	Unstandardized		Standardized		Sig.
	B	Std. Error	Beta ( $\beta$ )	T	
(Constant)	1.734	.537		3.229	.002
Students' Enjoyment of Learning Mathematics through NodeBook (SE)	.524	.039	.736	13.589	<.001

$R = .736$ ;  $R^2 = .542$ ;  $F = 184.666$ ;  $p < .001$

The results of the regression analysis (Table 3) show that students' enjoyment of learning mathematics (SE) with NodeBook is a positive and significant predictor of their motivation to

learn the subject ( $b = 0.524$ ,  $t = 13.589$ ,  $p < 0.01$ ). The multiple correlation coefficient ( $R = 0.736$ ) indicates a strong relationship between SE and SMLM-N, and the standard beta coefficient ( $\beta = 0.736$ ) suggests that the influence of SE is very strong.

## ii. Students' Perception of Success (SPS)

According to Weiner's (1985) attribution theory, students' motivation to learn academic subjects is determined by their responses to their academic achievements and failures. Students who are exposed to positive and stable attributions for their success are more motivated to pursue difficult academic subjects. It is therefore plausible that students' perceptions of success in mathematics using NodeBook technology are linked to their motivation for completing their courses.

**Table 4.**

*Regression Analysis - SPS*

Coefficients	Unstandardized		Standardized		
	Coefficients		Coefficients		
	B	Std. Error	Beta ( $\beta$ )	T	Sig.
(Constant)	1.915	.530		3.610	<.001
Students' Perception of Success in Mathematics through NodeBook (SPS)	.515	.038	.732	13.414	<.001
R = .732; R <sup>2</sup> = .536; F = 179.926; p < .001					

Regression analysis (Table 4) shows that students' perception of success (SPS) is a positive and significant predictor of their motivation to learn mathematics through NodeBook ( $b = 0.515$ ,  $t = 13.414$ ,  $p < 0.01$ ). The model indicates that SPS accounts for 53.6% of the variance in motivation ( $R^2 = 0.536$ ), and the multiple correlation coefficient ( $R = 0.732$ ) demonstrates a substantial association between students' perceived success and their motivation.

## iii. Significance and Need of NodeBook (SN)

It is plausible that students' motivation to learn mathematics is influenced by their perception of the subject's significance and need in the world. As Ernest et al. (2016) suggested, understanding the philosophy of mathematics education can provide individuals with new perspectives. Therefore, students' motivation to learn mathematics through NodeBook may be linked to their perception of the technology's specific significance and necessity in their coursework.

The regression analysis (Table 5) shows that the significance and need of NodeBook (SN) is a positive and significant predictor of student motivation ( $b = 0.759$ ,  $t = 11.606$ ,  $p < 0.01$ ). The model indicates that SN accounts for 46.3% of the variance in motivation ( $R^2 = 0.463$ ), with a strong multiple correlation coefficient ( $R = 0.681$ ) demonstrating a robust relationship between the two variables.

**Table 5.***Regression Analysis - SN*

Coefficients	Unstandardized		Standardized		
	Coefficients		Coefficients		
	B	Std. Error	Beta ( $\beta$ )	T	Sig.
(Constant)	1.896	.616		3.079	.002
Significance and Need of NodeBook in Learning Mathematics (SN)	.759	.065	.681	11.606	<.001
R= .681; R <sup>2</sup> = .463; F= 134.693; p<.001					

**iv. Mathematics Course Organization (MCO)**

Skilled educators use a variety of techniques and tools, including technology, to facilitate students' mathematical development (Anthony & Walshaw, 2023). This suggests that the organization of a mathematics course, especially when delivered through a specific technology, is likely to influence student motivation. Therefore, it is plausible that a well-structured course in NodeBook technology is a significant predictor of students' motivation to learn.

The regression analysis (Table 6) shows that mathematics course organization (MCO) is a positive and significant predictor of student motivation ( $b = 0.728$ ,  $t = 10.818$ ,  $p < 0.01$ ). The model indicates that MCO accounts for 42.7% of the variance in motivation ( $R^2 = 0.427$ ), with a good multiple correlation coefficient ( $R = 0.653$ ) demonstrating a strong relationship between the two variables.

**Table 6.***Regression Analysis - MCO*

Coefficients	Unstandardized		Standardized		
	Coefficients		Coefficients		
	B	Std. Error	Beta ( $\beta$ )	T	Sig.
(Constant)	2.223	.629		3.535	<.001
Mathematics Courses Organization through NodeBook (MCO)	.728	.067	.653	10.818	<.001
R= .653; R <sup>2</sup> = .427; F= 117.023; p<.001					

**Comprehensive Regression Model**

This section presents the results of a comprehensive regression analysis examining the relationship between student motivation to learn mathematics through NodeBook (SMLM-N) and all four independent variables: students' enjoyment (SE), students' perception of success (SPS), the significance and need of NodeBook (SN), and mathematics course organization (MCO).

The comprehensive model, as summarized in Tables 7-9, demonstrates a strong fit to the data. The coefficient of determination,  $R^2 = 0.640$ , indicates that the four independent variables

together explain 64% of the variance in students' motivation. The adjusted  $R^2$  of 0.630 suggests that only a small portion of the model's explanatory power is due to chance. The model as a whole is highly significant, as indicated by the F-statistic ( $F(4, 151) = 67.077, p < 0.001$ ).

The coefficients in Table 9 show that three of the four variables are statistically significant predictors of student motivation.

- Students' enjoyment (SE) is the strongest predictor ( $\beta = 0.397, p < 0.001$ ).
- Students' perception of success (SPS) is the second strongest predictor ( $\beta = 0.366, p < 0.001$ ).
- The significance and need of NodeBook (SN) is a significant, but weaker, predictor ( $\beta = 0.209, p = 0.010$ ).
- Mathematics course organization (MCO) was not found to be a significant predictor in this comprehensive model ( $b = -0.104, p = 0.314$ ).

**Table 7.**

*Model Summary*

Model	R	R Square	Adjusted Square	RStd. Error of the Estimate
5	.800	.640	.630	.81116

**Table 8.**

*ANOVA*

Model		Sum of Squares	Df	Mean Square	F	Sig.
	Regression	176.542	4	44.136	67.077	<.001
5	Residual	99.355	151	.658		
	Total	275.897	155			

The findings from this model lead to the rejection of three of the four null hypotheses ( $H_{01}, H_{02}, H_{03}$ ), while the null hypothesis for MCO ( $H_{04}$ ) cannot be rejected. The standardized coefficients are graphically depicted in Figure 4.

The analytical model can be expressed by the following linear regression equation:

$$Y' = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + u$$

$$Y' = 0.225 + 0.280 X_1 + 0.267 X_2 + 0.233 X_3 - 0.104 X_4 + u$$

Where:

$Y'$  = Dependent variable of Students' Motivation to Learn Mathematics with NodeBook

$X_1$  to  $X_4$  = The four independent variables in the model

$a$  = Intercept

$b_1$  to  $b_4$  = The coefficients that indicate the relationship between the independent variables and the dependent variable

$u$  = Stochastic error evaluating the importance of other plausible explanatory factors

**Table 9.**  
**Coefficients**

Model	Unstandardized Coefficients		Standardized t Coefficients		Sig.
	B	Std. Error	Beta ( $\beta$ )	t	
(Constant)	.225	.555		.406	.685
Students Enjoyment of Learning Mathematics through NodeBook (SE)	.280	.058	.397	4.858	<.001
Students Perception of Success in Mathematics through NodeBook (SPS)	.267	.063	.366	4.216	<.001
Significance and Need of NodeBook in Learning Mathematics (SN)	.233	.089	.209	2.604	.010
Mathematics Courses Organization through NodeBook (MCO)	-.104	.103	-.095	-1.009	.314

Figure 4 (see appendix).

## DISCUSSION

This research developed a mathematical model to bridge the gap between students' motivation to learn mathematics and their use of NodeBook technology. The four independent factors together explain 64.0% of the variation in students' motivation to learn mathematics through NodeBook ( $R^2 = 0.640$ ).

The comprehensive model identified three significant predictors of student motivation. As the visualization in Figure 4 shows, students' enjoyment (SE) was the strongest predictor ( $\beta = 0.397$ ). This finding aligns with Self-Determination Theory (Deci & Ryan, 1985) and contributes to the literature on the role of enjoyment and technology in education. This result is consistent with Fadda et al. (2022), who found that video games can serve as effective teaching aids that increase students' motivation. Similarly, Christensen and Knezek (2020) reported a strong correlation between students' enjoyment of mathematics and their overall confidence in the subject.

The second strongest predictor was students' perception of success (SPS) ( $\beta = 0.366$ ). This finding is consistent with attribution theory, which suggests that students' responses to academic achievements determine their motivation (Weiner, 1985). Students who attribute success to positive, stable, and controllable causes are more motivated for future success. The results of this study are in line with Hammoudi and Grira (2023a, 2023b), who found a positive

relationship between students' self-perceptions and their motivation for success in mathematics courses.

The third significant predictor was the significance and need of NodeBook in learning mathematics (SN) ( $\beta = 0.209$ ). This suggests that when students perceive the technology as meaningful and necessary, their motivation is positively impacted. This outcome aligns with research by Ernest et al. (2016), who argued that the philosophy of mathematics education and the tools it provides are important for giving individuals new perspectives.

In contrast, the study found that the organization of mathematics courses through NodeBook (MCO) was not a significant predictor of students' motivation ( $\beta = -0.095$ ). This is a noteworthy finding, which requires future research, particularly regarding specific elements of organization that may influence student engagement.

Overall, the findings of this research provide mathematics educators, STEM programs administrators, and higher education institutions with a good rationale to utilize NodeBook technology. By focusing on creating an enjoyable, successful, and meaningful experience, NodeBook can be a valuable tool for enhancing students' motivation to learn mathematics.

### **CONCLUSION AND RECOMMENDATIONS**

This study was conducted in the United Arab Emirates (UAE), a developing country in the Gulf Cooperation Council's (GCC) with a fast-growing higher education system focused on smart technologies. The study adds to the body of literature by developing a model that mathematics educators, administrators, and higher education institutions can utilize to increase student motivation and ultimately benefit society.

The results indicate that students' motivation to learn mathematics is most strongly impacted by how much they enjoy using NodeBook technology in learning mathematics, which is followed by how successful they believe while using the technology, and the perceived significance and need of it. Accordingly, the following recommendations are suggested for mathematics educators and higher education institutions to promote students' motivation:

- Enhance enjoyment by encouraging students to explore the non-linear, tree-based navigation of mathematics content within NodeBook technology.
- Boost perceived success by demonstrating how NodeBook effectively summarizes content for various summative assessments, such as exams and projects.
- Emphasize significance and need by showcasing NodeBook as a versatile tool for organizing and displaying content across different mathematics courses for both students and instructors.

### **Limitations and Future Research**

This study was conducted in the UAE to investigate the use of NodeBook technology in mathematics courses. A primary limitation of this research is its geographic focus. Since the participants share similar cultural characteristics, the findings may not be generalizable to universities in different cultural contexts. Therefore, it is recommended that the model be

tested in mathematics courses at various universities across continents to validate and broaden the study's findings.

A secondary consideration for future research is the finding that mathematics course organization (MCO) was not a significant predictor of student motivation in this study. This result is noteworthy and warrants further exploration to better understand the relationship between course structure and student motivation. Future studies could investigate specific elements of course organization or replicate the model with a different sample to determine if this finding is consistent.

### **Declarations**

#### **Availability of data and materials**

The analyzed datasets in this research study are available from the authors upon request. The website of NodeBook technology can be visited at this URL: <https://nodebook.ae/>.

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Not Applicable.

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**Table 2.***Demographic profile of the participants*

Characteristic	Details	Number of Students	Percentage
<b>Gender</b>	Male	86	54.08
	Female	73	45.91
<b>Age(years)</b>	17-18	65	40.89
	19-20	57	35.84
	21-22	16	10.06
	23-24	12	7.55
	25 or more	9	5.66
<b>Education Level</b>	First Year	81	50.94
	Second Year	60	37.74
	Third Year	12	7.55
	Fourth Year	9	3.77
<b>Employment Status</b>	Yes	26	16.35
	No	133	83.65
<b>Grade</b>	F	4	2.52
	D	1	0.63

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D+	2	1.26
C	5	3.14
C+	7	4.4
B	11	6.92
B+	35	22.01
A	94	59.12

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**Figure 4.**

*Visualization of the Model*

