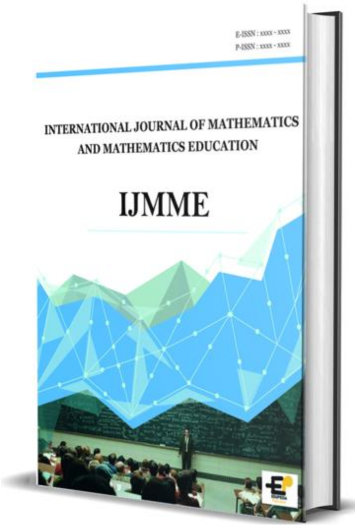

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Connection on Mathematics Motivation: Mediating Role of History of Mathematics Concepts

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Effects of Perceived Mathematics Connection on Mathematics Motivation: Mediating Role of History of Mathematics Concepts

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Abstract

The present study assessed the mediating effects of a history of mathematics concepts on the relationship between mathematics connection and motivation. The study was a descriptive survey of 390 students randomly selected from Asuoso Senior High School in the Offinso-North District of Ghana's Ashanti region. Data was collected using Likert-type structured questionnaires. Reliability analysis was computed in SPSS (V. 23), and confirmatory factor analysis was computed in AMOS (V. 23). In addition, average variance extracted (AVE), convergent validity, and discriminant validity were computed in Microsoft Excel from factor loadings. Structural Equation Modelling (SEM) was computed in Amos (V. 23) to determine direct and mediating effects among the main constructs. The study found that mathematics connection positively and significantly influenced the mathematics motivation of senior high school students. The indirect effects of mathematics connection on mathematics motivation through the history of mathematics concepts were positive and significant. The study recommended that mathematics teachers desist from merely topic explanations and rote memorisation of solution procedures. They should rather make mathematics connections and the history of mathematics concepts imminent in their lesson planning and delivery. To implement this, mathematics topics should be linked to real-life scenarios, other subjects, and students' lives, and the history behind such concepts should be explained in plain language. Teachers and NaCCA should ensure that the mathematics syllabus and textbooks for senior high schools incorporate real-life scenarios and the historical background of concepts to ensure learners develop the interest and motives for studying mathematics.

Introduction

Mathematics connection pertains to the ability of mathematics teachers to establish meaningful linkages between mathematical concepts and various facets of students' lives. This concept has garnered substantial research support. Multiple studies have demonstrated that effective mathematics connections significantly improve students' engagement with mathematics (Arthur et al., 2017, 2018; Dalby & Noyes, 2015; Latif, 2017; Ndiung & Nendi, 2018). Notably, Ndiung and Nendi (2018) found that mathematics connections explained 21.9% of the variation in mathematics performance among elementary school pupils.

Mathematics connections serve as a bridge, allowing students to recognise the practical utility of mathematics in their daily lives. By connecting mathematical ideas and real-life events, students gain a deeper understanding of the relevance of mathematics in various contexts (Clair, 2018; Selvianiresa & Prabawanto, 2017). The National Council of Teachers of Mathematics (NCTM) emphasises that mathematics connections broaden students' knowledge and integrate mathematics holistically into their education (NCTM, 2000).

Furthermore, research conducted by Arthur et al. (2018) in Ghanaian high schools underscores the pivotal role of mathematics connections in stimulating students' interest in mathematics. Connecting mathematics to real-life problems has been identified as a critical factor in enhancing students' comprehension and retention of mathematical concepts. Hasbi et al. (2019) assert that bridging the divide between abstract mathematical concepts and their real-world applications is crucial. This is essential in equipping students with the necessary skills and knowledge for their future careers and academic pursuits. Mathematics connections also have the potential to address multiculturalism issues, as highlighted by Zohar (2006), by linking mathematical concepts to various scientific disciplines.

Various innovative approaches, such as music integration (An et al., 2008), initiatives like MathePraxis (Rooch et al., 2012), and online applications (Trifunov, 2017) have shown promise in enhancing students' motivation by embedding mathematics connections into mathematics education. These strategies collectively affirm the positive impact of mathematics connections on students' mathematical experiences.

The existing studies underscore mathematics connections' positive and significant impact on student's motivation in mathematics education. However, they fall short of providing empirical insights into the mediating role of the history of mathematics concepts in this relationship. This highlights a noteworthy gap in the literature.

History of mathematics concepts refers to integrating historical narratives and the evolution of mathematical ideas into mathematics instruction. This dimension has emerged as a powerful pedagogical tool to engage and motivate students. Studies by Bütüner and Baki (2020), Ho (2008) and Marshall (2000) reveal that the History of mathematics concepts diminishes students' anxieties about mathematics and transforms their perceptions. Students view mathematics as an engaging subject with historical significance, enabling them to tackle mathematical challenges enthusiastically.

Moreover, it has been found to complement mathematics connections. Arthur et al. (2022) discovered that historical acknowledgements in mathematics education heightened students' attention and comprehension, enhancing their interest in mathematics. The inclusion of history associates concepts to their practical application in real-life scenarios over centuries (Panasuk & Horton, 2013).

Research by Lit et al. (2001) indicates that teaching mathematical concepts in a historical context significantly influences students' attitudes towards mathematics. Galante's (2014) study involving pre-service teachers highlights how the history of mathematics concepts provides fresh ideas for lesson development and pedagogical content. Kapofu and Kapofu (2020) further emphasise that teaching historical aspects of mathematical concepts, such as the Pythagorean theorem, can improve students' motivation and problem-solving abilities.

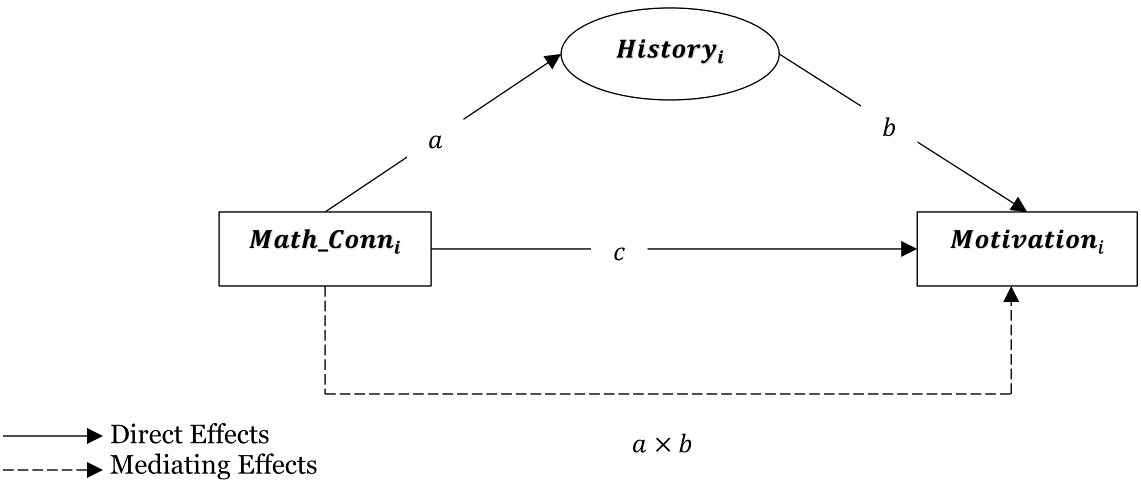

Figure 1: Conceptual Framework

The body of research supports the importance of mathematics connections and historical context in mathematics education. While mathematics connections augment students' engagement and understanding by linking mathematics to real-life scenarios, history provides historical depth, making mathematics more meaningful. Therefore, exploring their interplay and the mediating role of the history of mathematics concepts could provide further insights to optimise mathematics instruction for enhanced student motivation and achievement. This study develops into this relationship by proposing the following hypotheses. Also, Figure 1 shows the conceptual framework of the study, and Equations1 and three also represent tequationciated regression equations that mediate the mediating effects for the $\boldsymbol{i^{th}}$ subject, $\mathbf{1} \leq \boldsymbol{i} \leq \boldsymbol{n}$.

H1: Mathematics connections has a direct positive effect on mathematics motivation.

$Motivation_i = \alpha + \beta_a Math\_Conn_i + \varepsilon_{Motivation_i}$........................ *(Equation 1)*

H2: The history of mathematics concepts has a direct positive effect on mathematics motivation.

$History_i = \alpha + \beta_b Math\_Conn_i + \varepsilon_{History_i}$........................ *(Equation 2)*

H3: The history of mathematics concepts mediates the relationship between mathematics connections and motivation.

$Motivation_i = \alpha + \beta_b Hisory_i + \beta_c Math\_Conn_i + \varepsilon_{Motivation_i}$......... *(Equation 3)*

Method

Population, Sample, and Data Collection

The study was conducted among Asuoso Senior High School students in the Offinso North District within Ghana's Ashanti region. The study encompassed students in various academic disciplines, including Home Economics, Visual Arts, Business, General Arts, Agricultural Science, and General Science. The total student population eligible for participation in the study amounted to approximately 1,500 individuals. A breakdown of the population distribution is presented in Table 1.

The study employed the Daniel Soper Sample Size Calculator for Structural Equation Modeling (SEM) to establish the minimal sample size necessary for detecting effects. This web-based tool utilises Monte Carlo simulations and assumes normal distributions, generating synthetic datasets based on user-specified criteria, including effect size, significance level, and statistical power. The calculator indicated that a minimum sample size of 100 was sufficient for the study, but we chose a larger sample size of 390 to ensure more robust and dependable results. The participants were chosen using the simple random sampling technique, a probability-based method ensuring that each student has an equal chance of being selected.

The researcher gathered data using structured questionnaires featuring Likert scale close-ended items. Three hundred ninety questionnaires were prepared and personally administered after obtaining school authority consent. All the questionnaires were completed and returned. We ensured data protection and confidentiality.

Measures and Questionnaires

The survey utilised structured questionnaires featuring standardised items, and it employed a closed-ended format with a response scale ranging from strongly disagree to strongly agree. Before the main survey, a pilot study was conducted to identify necessary revisions in the questionnaire. The survey consisted of four sections, with the first section collecting demographic data such as age, gender, academic level, and course of study. The second section included four items adapted from Arthur et al. (2018) to assess perceived mathematics connections, while the third section consisted of three items adapted from Arthur et al. (2022) to capture students' opinions on the history of mathematics concepts. The final section measured students' perceived mathematics motivation using four items adapted from Lang and Fries (2006).

Validity and Reliability Analysis

A Confirmatory Factor Analysis (CFA) was executed in AMOS to assess the fit between the hypothesised model and the observed data. CFA has been employed in studies such as reference. This involved establishing factor the expected correlations between latent factors and observable variables. Items with factor loadings below 0.5 were iteratively exited from the analysis. To ensure the overall fit of the measurement model, various model fit indices were assessed based on Hu and Bentler's (1999) criteria. The Comparative Fit Index (CFI) exceeded the threshold at 0.955 (>0.90), indicating a strong fit. The Goodness-of-Fit Index (GFI) also reached a satisfactory value of 0.956 (>0.90). The PCLOSE value, assessing differences between observed and expected models, was 0.085 (>0.05), indicating notable differences. The chi-square to degrees of freedom ratio (CMIN/DF) fell within the desired range at 2.510 (between 1 and 3), signifying a good fit. Additionally, the Tucker-Lewis Index (TLI) showed a robust fit with a value of 0.940 (>0.90), and the Root Mean Square Error of Approximation (RMSEA) was deemed acceptable at 0.062 (<0.08). The Root Mean Square Residual (RMR) reading of 0.045 further supported the overall model fit. Table 1 shows the CFA results. Figure 2 also displays the structure of the measurement model.

Table 1: Results of Confirmatory Factor Analysis

Model Fit Indices: *CMIN=0.940; DF=41, CMIN/DF=2.510, RMR=0.045, GFI=0.956, TLI=0.940, CFI=0.955, RMSEA=0.062, PCLOSE=0.085*	Std. Loadings
MATHEMATICS MOTIVATION (Motivation): CA=0.814; CR=0.815; AVE=0.597	
Motiv1	.703
Motiv2	.732
Motiv3	.746
Motiv5	.715
HISTORY OF MATHEMATICS CONCEPTS (History): CA=0.639; CR=0.648; AVE=0.530	
Hist5	.667
Hist7	.677
Hist10	.500
MATHEMATICS CONNECTIONS (Math_Conn.): CA=0.827; CR=0.828; AVE=0.637	
MCon7	.776
MCon8	.696
MCon9	.770
MCon10	.710

Cronbach's alpha (Cronbach, 1951) and composite reliability coefficients were computed to determine the internal consistency of the variables (Streiner, 2003) since reliability is critical in multi-item surveys (Tavakol & Dennick, 2011). Cronbach's alpha was computed in SPSS, whilst composite reliability was calculated online at https://www.thestatisticalmind.com/composite-reliability/. These reliability estimates gauge the extent to which various items on a scale measure the same underlying variable. Their interpretations are based on their magnitude. Their values lie between 0 and 1, with higher values indicating better internal consistency. A value of 0.70 or higher is generally deemed acceptable, indicating high internal consistency. The reliability coefficients are indicated in Table 1. Table 1 shows that all CA and CR values met their required thresholds except the CA and CR values for HMC. However, since these values are closer to 0.70, according to Shrestha (2021), they were accepted.

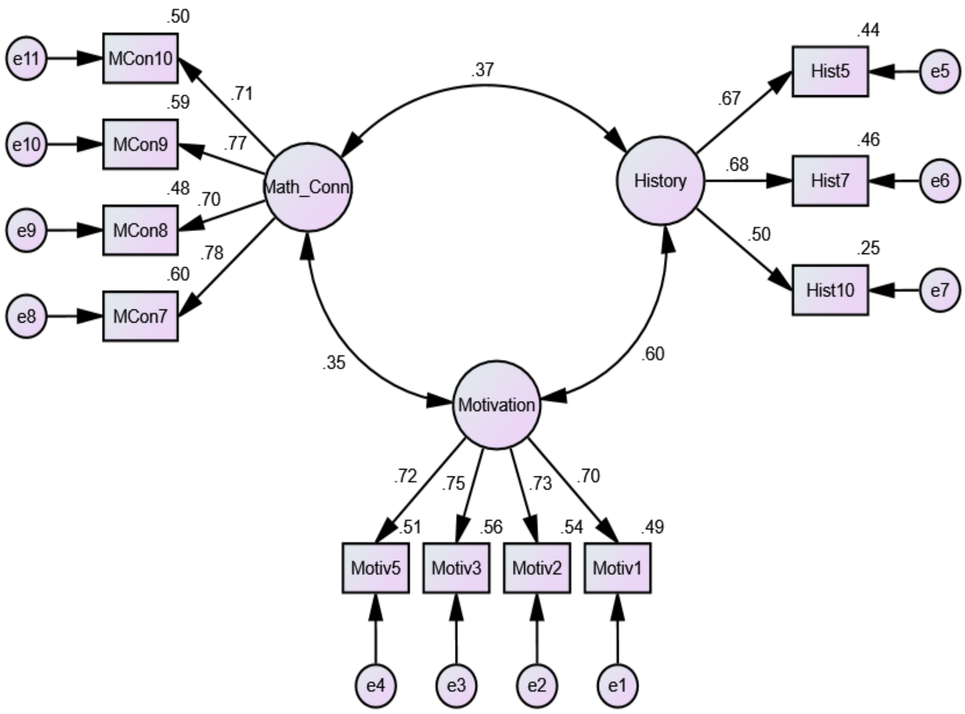

Figure 2: Diagram of Confirmatory Factor Analysis

Note*: √AVE are bold*
**p-value significant at 1% (0.01)*

Table 2: Descriptive Discriminant Validity

Constructs	Math_Conn.	History	Motivation
Math_Conn.	0.798		
History	0.336*	0.728	
Motivation	0.351*	0.596*	0.773

Convergent validity evaluates how well different indicators of the same construct are correlated with each other. In this study it was assessed using the Average Variance Extracted (AVE) method, following the approach of Bornmann et al. (2009) and Carlson and Herdman (2012). The results in Table 3 indicate that the AVE values exceeded the minimum threshold of 0.50, as Mendes dos Santos and Cirillo

(2021) suggested, demonstrating that the variables possessed the necessary convergent validity. On the other hand, discriminant validity determines the distinction among variables in a study, focusing on the degree to which separate indicators are not strongly correlated. The Fornell and Larcker Criterion, a widely used method employed in various studies, including those by Hamid et al. (2017) and Roemer et al. (2021), was evaluated to assess discriminant validity in the present study. According to this criterion, the minimum value of the square root of AVEs should be greater than the highest correlation among the variables. Per Table 2, the minimum value of the square root of the AVEs is 0.728, greater than the highest correlation value; therefore, discriminant validity was achieved.

Results

Structural equation modelling (SEM) was computed in AMOS to test the proposed hypotheses, and the results are presented in Table 2. The analysis employed a corrected bootstrapping approach with 5000 samples at a 95% confidence level. Model fit indices were ensured at their appropriate levels per the criteria set by Hu and Bentler (1999). According to Table 3, the effect of Math_Conn. on Motivation was positive and significant ($\beta = 0.123$, C.R. = 2.413, $p = .016$).

Table 3: Path Estimates

Direct Relationships	Unstandardised Estimate	Standard Error	Critical Ratio	P-Value	Path
Motivation <--- Math_Conn.	0.123	0.051	2.413	0.016	*c*
Motivation <--- History	0.527	0.086	6.135	<0.001	*b*
Indirect Relationship	**Unstandardised Estimate**	**Lower Bound**	**Upper Bound**	**P-Value**	**Path**
<--- History <--- Math_Conn. Motivation	0.158	0.084	0.288	<0.001	$a \times b$
Model Fit Indices: *CMIN=102.930; DF=41, CMIN/DF=2.510, RMR=0.045, GFI=0.956, TLI=0.940, CFI=0.955, RMSEA=0.062, PCLOSE=0.085*					

Source: Field Data (2023)

H1: *Mathematics connections directly positively affect mathematics motivation* was supported.

The effect of History on Motivation was positive and significant ($\beta = 0.527$, C.R. = 6.135, $p < 0.001$). As a result:

H2: *History of mathematics concepts directly positively affects mathematics motivation,* was supported.

The indirect effect of Math_Conn. On Motivation was 0.158 ($a \times b = 0.300 \times 0.527$), which was positive and significant ($p < 0.001$) because the confidence interval (0.084, 0.288) excluded zero. In the presence of the mediator (History), the direct effect of Math_Conn. on Motivation was also discovered significant ($\beta = 0.123$, $p < 0.001$). Hence, History partially mediated the relationship between Math_Conn. And Motivation.

H3: *The history of mathematics concepts mediates the relationship between mathematics connections and mathematics motivation, which* was supported.

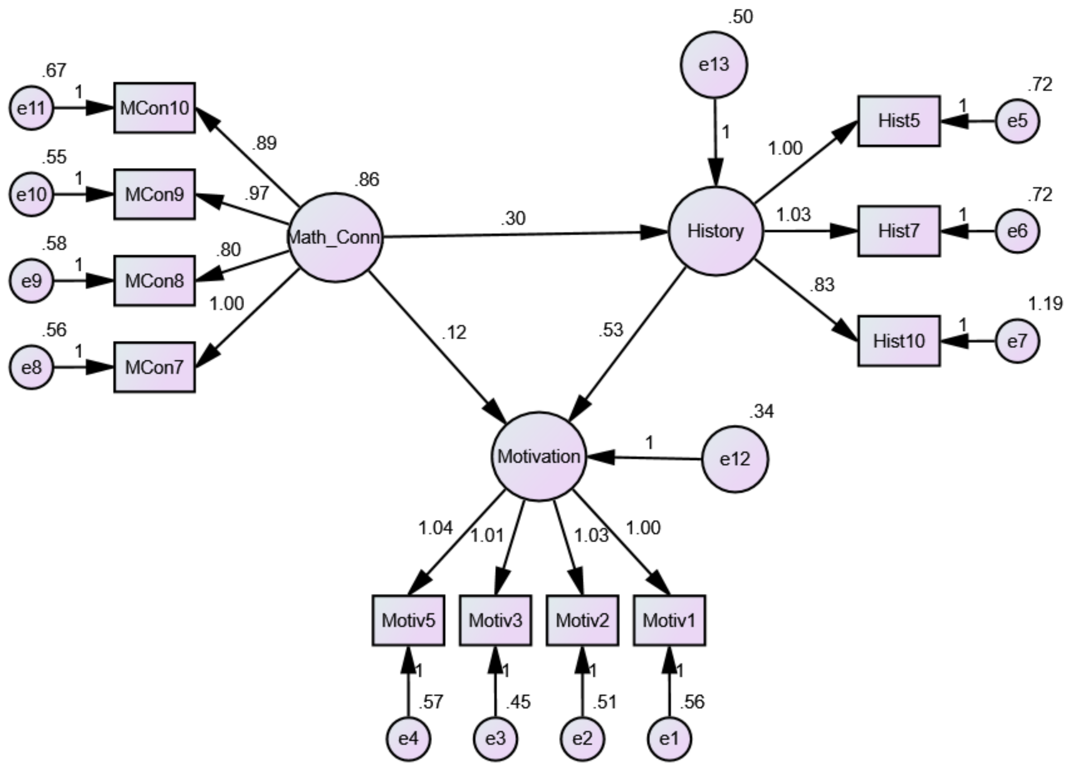

Figure 3: Path Diagram

Discussion

According to the responses of senior high school students selected for the study, mathematics connections positively and significantly affect mathematics motivation ($\beta = 0.112$, $t = 2.548$, $p = 0.011$). The results predicted that for every 1% rise in mathematics connections, mathematics motivation is expected to increase by 11.2%. This result coincides with that of Bannor et al. (2023), who found that mathematics connection, teaching quality, and teaching competence positively affect students' mathematics achievement motivation. Teachers' ability to make mathematics practical is relevant as it was perceived as significant for students' achievement motivation growth. This is also consistent with studies that found mathematics connections very important in instruction and learning (Abdulrahim et al., 2023; Cejka et al., 2006; Kwon, 2016; Rodionov & Dedovets, 2017; Rooch et al., 2012; Trifunov, 2017). These studies stressed that linking mathematics to practical applications increases learners' engagement, interest, or achievement. Such benefits have been seen in various educational contexts, including STEM and TVETs (Abramovich et al., 2019). According to Wigfield and Eccles (2000), in expectancy-value theory, students' realisation of the usefulness of mathematics for future occupations and jobs harnesses their intrinsic motivation, gratification, and appreciation of the development of positive achievement-related beliefs (Hulleman et al., 2008). This study also confirms that mathematics connections significantly improve self-efficacy beliefs and result in expectations (Ozgen, 2013). When students see a strong relationship between mathematics and their lives, their self-efficacy beliefs grow, contributing to higher motivation and achievement levels (Schunk & Pajares, 2002). Per Crawford (2001), students get motivated when confident in solving real-life problems with their mathematical knowledge. Also, these findings align with Groenendijk et al. (2013), who found observational mathematics learning is effectual with mathematics connections, and Hulleman and Harackiewicz's results of the positive effects of values-affirmation interventions on mathematics motivation and achievement. This study consistently supports that connecting mathematics to real-world applications improves motivation, self-efficacy, and performance in mathematics.

The study also discovered that the history of mathematics concepts mediated the relationship between mathematics connections and mathematics motivation among senior high school students. This result suggests that historical context is very important if students' motivation needs to be invigorated. History does not only provide richer knowledge of the evolution of mathematical concepts and their applications but also serves as the basis for planning interesting and encouraging practical problem-based lessons (Arthur et al., 2022; Baah-Duodu et al., 2021; Bütüner & Baki, 2020; Ho, 2008; Liu, 2003; Marshall, 2000). These findings correspond to Arthur et al. (2022), who found that history positively affects student interest. Therefore, historical techniques for solving real-world problems should be consulted for students' motivation growth. As such, this study supports the findings that history-infused lessons improve learners' motivation and attitudes in mathematics (Doz, 2021). Betül (2012) noticed that students' enthusiasm for active learning participation increased as history is corrective to mathematics anxiety. Bütüner and Baki (2020) support the idea that students experienced the age-old utilitarian value of mathematics as they engaged in history-rich lessons. Also, Arthur 2012 identified that teachers' explanations of historical events underlying topics spark students' comprehension, leading to increased mathematics interest.

Conclusion

The study concluded that mathematics connections and the history of mathematics concepts all positively and significantly affected mathematics motivation among senior high school students. The relationship between mathematics connection and mathematics motivation was found to be partially mediated by the history of mathematics concepts.

Recommendations

The study recommended that mathematics teachers desist from merely topic explanations and rote memorisation of solution procedures. They should rather make mathematics connections and the history of mathematics concepts imminent in their lesson planning and delivery. To implement this, mathematics topics should be linked to real-life scenarios, other subjects, and students' lives, and the history behind such concepts should be explained in plain language. Teachers and NaCCA should guarantee that the mathematics syllabus and textbooks for senior high schools incorporate real-life scenarios and the historical background of concepts to ensure learners develop the interest and motives for studying mathematics.

Acknowledgements or Notes

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