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Effects of Financial STEM Applications on Conceptual Understanding and Engagement in Higher Secondary Mathematics

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Abstract
The importance of STEM education and financial literacy in preparing students for obstacles they may face in the real world has grown. A promising way to improve students' conceptual understanding and engagement is to incorporate financial STEM applications into the higher secondary mathematics curriculum. This study examines the effects of financial STEM applications on higher secondary mathematics students' conceptual understanding. It also looks at how well these apps support learning from the viewpoints of teachers and students. A mixed-methods strategy was used. Student assessments and engagement surveys were used to collect quantitative data, and curriculum materials and published teacher interviews were analyzed to obtain qualitative insights. Math teachers and upper secondary students from different schools were included in the sample. According to preliminary research, students who are exposed to financial STEM applications show better comprehension of mathematical ideas, particularly those pertaining to exponential functions, percentages, and interest computations. Teachers' favorable opinions of the applicability and relevance of financial contexts in mathematics instruction contributed to an increase in student engagement levels. Mathematical comprehension and practical problem-solving are successfully connected through the use of financial STEM applications in the classroom. In order to improve student motivation and learning outcomes, the study advises educators and curriculum developers to include financial contexts.

Keywords: Conceptual Understanding, Financial Mathematics, Higher Secondary Education, Student Engagement, STEM Applications, Teacher Perspectives

Introduction

Globally, there has been a growing awareness in recent years that deep conceptual understanding must be fostered in mathematics education rather than rote memorization. At the upper secondary level, when students are getting ready for college or the workforce, this change is especially important. Using financial contexts (banking, interest, budgeting, and investing) in STEM-oriented mathematical education to make mathematical concepts more relatable and interesting is a promising strategy for accomplishing this. Students are exposed to abstract mathematical ideas when financial concepts are incorporated into mathematics, and they also perceive a clear connection to real-world situations, which can increase application, relevance, and retention. It has long been known that a major mediator between instructional strategies and mathematical achievement is student engagement, whether it be cognitive, emotional, or behavioral (Hossein Mohand & Hossein Mohand, 2023). Similarly, whether or not innovative pedagogies (like Financial STEM Applications) are

embraced and maintained depends greatly on the attitudes and behaviors of teachers. Through an analysis of teacher viewpoints and student engagement, this study aims to explore how Financial STEM Applications may improve conceptual understanding in higher secondary mathematics.

Problem Statement

There is little empirical research on how these applications impact higher secondary students' conceptual understanding, despite the widespread discussion of the possible advantages of incorporating financial contexts into mathematics instruction. Financial topics are covered in passing in many curricula, but they are frequently treated as elective modules rather than essential subjects, are not connected to STEM teaching methods, or lack pedagogical support.

Even when exposed, students might not fully internalize the mathematical concepts underlying financial problems, and teachers might not have the necessary resources or training to implement financial STEM applications in math classes. This disparity results in mathematics that is abstract and unrelated to students' everyday experiences, which lowers motivation, restricts the development of problem-solving abilities, and eventually affects performance.

Thus, the main issue is: How can financial STEM applications be used to improve students' conceptual understanding in higher secondary mathematics, and what do teachers think about student participation and the real-world application of these techniques?

Significance of the Study

This study's importance stems from its many contributions to mathematics education, especially the way it incorporates Financial STEM Applications into the upper secondary curriculum. The study has significant pedagogical value because it shows how financial contexts, like interest calculations, budgeting, and investment scenarios, can help students understand and relate to abstract mathematical ideas. Students are more likely to see mathematics as applicable to their daily lives when taught using real-world financial applications, which can improve their conceptual understanding and retention (Saini & Rosli, 2023). In addition to improving the educational process, this pedagogical alignment offers teachers and curriculum developers practical advice on how to update and contextualize math instruction.

Student Engagement, Teacher Readiness, and Curriculum Alignment

Understanding student engagement is a second significant contribution. Students are more likely to participate cognitively and behaviorally when they are exposed to material that mirrors real-life circumstances, particularly those that have financial significance for them personally or for society as a whole. Studies have consistently demonstrated a positive correlation between this type of engagement and mathematical academic achievement (Saqib, Kausar, & Ashrafs, 2024; Hossein Mohand & Hossein Mohand, 2023). Thus, analyzing student answers in relation to financial STEM applications not only demonstrates the efficacy of instruction but also helps develop tactics for boosting engagement and motivation in math classes.

Additionally, the study offers insightful information about the professional skills and viewpoints of teachers needed to successfully implement financial STEM integration. This research can help guide professional development programs and policy decisions that assist educators in implementing such approaches by examining teacher attitudes, perceived benefits, difficulties, and resource requirements. To ensure the long-term sustainability of financial literacy initiatives in mathematics education, it is essential to understand how prepared teachers feel (Faisal, et al., 2023) and what support they need in order to design training programs that are both relevant and practical (Sari, Zulkardi, Putri, & Darmawijoyo, 2023).

Bridging the ongoing gap between theoretical curriculum goals and real classroom practices is another crucial aspect of significance. There are differences between the quality of classroom activities meant to foster financial numeracy and the content of mathematics textbooks, according to earlier research (Cavalcante,

2025). Empirical information on how teachers are applying or not applying financial mathematics in actual classroom environments is still lacking, though (Faisal, et al., 2024). By offering classroom-based data that can support, contradict, or improve theoretical models and curriculum frameworks, this study fills that knowledge gap.

Lastly, it is impossible to overestimate the research's wider societal ramifications. Integrating financial literacy into mathematics instruction benefits students in ways beyond academic achievement in a time when it is becoming more widely acknowledged as a crucial life skill. It improves their capacity to handle challenging economic situations, gives them the ability to make wise financial decisions in their own lives, and could eventually help them become less financially vulnerable as adults. Therefore, the findings of this study could affect future generations' long-term financial well-being in addition to educational practices.

Research Gaps

Several research gaps are identified by a review of the literature, which this study aims to fill in a thorough way. Although research on financial literacy and numeracy has increased recently, most of it still focuses on theoretical debates, textbook analyses, or curriculum frameworks rather than on real-world classroom applications and quantifiable student outcomes (Saini & Rosli, 2023; Financial Numeracy in Mathematics Education, 2020). Because of this, little is known about how financial STEM applications work in actual classroom environments, particularly with regard to how they affect student engagement and learning. Given the growing focus on real-world, applied learning in mathematics education, this disparity is especially noteworthy.

Furthermore, there is a clear gap at the upper secondary level because the bulk of research in the field of financial literacy integration tends to concentrate on early or lower secondary education. This is a serious oversight because students are exposed to increasingly abstract and sophisticated mathematical ideas at this point, making conceptual understanding even more important for success in the classroom and in the workplace later on. Research on how financial applications can enhance deeper mathematical reasoning and comprehension at the senior secondary level is therefore desperately needed.

In the Context of Pakistan

Furthermore, there aren't many qualitative studies that explicitly look at secondary math teachers' perspectives on incorporating financial contexts into STEM-oriented instruction, even though some research touches on teachers' perceptions when implementing contextual or financial learning strategies. This includes their findings regarding the impact of these integrations on learning outcomes and student engagement. Comprehending the viewpoints of educators is crucial for assessing the viability of such endeavors as well as for guiding efforts in curriculum design and professional development.

The fragmentation of research findings represents another significant gap. Few studies provide a comprehensive perspective that integrates teacher instructional practices, conceptual understanding, and student engagement into a single research framework. By separating these dimensions, the majority of current literature loses the chance to comprehend how they interact and support one another in various educational contexts. This integrated approach is particularly important for drawing meaningful conclusions that can inform systemic educational improvements.

Finally, the current body of research is geographically unbalanced, with a disproportionate emphasis on Western educational contexts, including North America, Europe, and Canada, while there are still few studies from non-Western or underrepresented regions. Despite having distinct curriculum requirements, resource limitations, and sociocultural considerations, nations with diverse educational infrastructures like Pakistan or those in Southeast Asia—are notably under-researched (Cavalcante, 2025). Closing this gap is essential to producing contextually relevant insights that can guide practice and policy in a broader variety of educational systems.

Objectives

Based on these gaps and the problem statement, this study has the following objectives:

1. To assess the level of conceptual understanding of financial mathematics topics among higher secondary mathematics students, when financial STEM applications are used in teaching.
2. To examine how Financial STEM Applications influence student engagement (cognitive, emotional, behavioral) in higher secondary mathematics classes.
3. To explore teacher perspectives on the challenges, opportunities, and resources needed for integrating Financial STEM Applications into mathematics teaching.

Research Questions

Accordingly, the study seeks to answer the following research questions:

1. What is the current level of conceptual understanding among higher secondary students of financial mathematics when taught via Financial STEM Applications?
2. How do Financial STEM Applications affect student engagement (cognitive, emotional, behavioral) in higher secondary mathematics?
3. What do mathematics teachers perceive as the main opportunities and challenges in integrating Financial STEM Applications into their classroom practices?

Literature Review

Role of Financial Mathematics / Numeracy in Mathematics Education

The ability to comprehend and apply financial concepts like interest, budgeting, insurance, investments, loans, and related computations within a mathematical framework is known as financial numeracy, sometimes referred to as financial mathematics or financial literacy in mathematics education. Financial Numeracy in Mathematics Education: Research and Practice (2020) offers a comprehensive overview of how educators in grades 7–12 integrate financial education, including teaching strategies, resource utilization, and the idea that financial numeracy is a “social practice” as opposed to just calculation (Springer). This implies that rather than being covered in passing, financial topics should be incorporated in significant, meaningful ways to promote understanding.

In a recent study titled "Three approaches to financial numeracy education in secondary mathematics textbooks," Cavalcante (2025) looked at how financial tasks are distributed across grade levels and subject areas in textbooks. According to that analysis, financial numeracy tasks are more common in earlier secondary grades, and higher secondary textbooks typically focus on conceptual rather than contextual applications. Nevertheless, the study also pointed out that these assignments don't always correspond with classroom realities or real-life decision-making, suggesting a disconnect between textbook design and student experiences.

Student Engagement in Mathematics

The cognitive, emotional, and behavioral engagement of students is a reliable indicator of their success in mathematics. According to Asanre, Ifamuyiwa, and Abiodun (2024), academic engagement in senior secondary mathematics in Nigeria is a strong predictor of performance; higher scores are correlated with traits like participation, perseverance, and attention. Similarly, a study conducted in Lahore, Pakistan by Saqib, Kausar, and Ashrafs (2024) discovered a statistically significant correlation between the achievement of secondary students and their cognitive, social, and emotional engagement in mathematics.

By making math more relatable, applied financial contexts may increase student engagement. Financial content can act as a bridge to engagement, as evidenced by the fact that active methodologies in Spanish

secondary schools that included bank interest and percentages (financial topics) increased student motivation and participation (Enhancing Student Motivation in Secondary School Mathematics Courses: A Methodological Approach, 2019) (Abbas & Faisal, et al., 2024).

Teacher Perspectives and Practices

When resources and training are available, teachers' opinions of financial mathematics are generally positive, though they vary. Teachers in Indonesia believe that incorporating financial topics is important, according to the study "Math Teachers' Perceptions Regarding Financial Literacy" by Sari, Zulkardi, Putri, and Darmawijoyo (2023). However, the study also identified several obstacles, including a lack of teacher knowledge, a lack of professional development, a lack of curriculum time, and inadequate instructional materials.

The main influencing factors for integrating financial elements are curriculum alignment, teaching strategies, and parental or community support, according to the systematic review "Financial Elements in Teaching and Learning of Mathematics: A Systematic Review" by Saini & Rosli (2023), which examined studies from 2011 to 2019. These results highlight the importance of teacher beliefs and outside assistance for successful implementation.

Effects on Conceptual Understanding and Problem-Solving

Understanding mathematical concepts rather than just procedures is referred to as conceptual understanding. Applying mathematics to novel situations requires it. Research on mathematical modeling and literacy (e.g., Armutcu & Bal, 2022) demonstrates that students' mathematical literacy and transferability of understanding improve when they participate in modeling tasks based in STEM contexts (Batool, et al., 2024).

Studies indicate that when integrated effectively, financial topics enhance students' understanding of algebraic functions, growth and decay, percentages, and the concept of interest, even though the majority of the work is at lower levels (Springer, Financial Numeracy in Mathematics Education, 2020). Research on upper secondary pupils (grades 11 and 12) is still uncommon, though.

Gaps Identified in Existing Literature

A review of the literature shows a number of important gaps that underscore the need for more thorough studies in the area of financial STEM integration in math education. Textbook analyses make up a large portion of the current body of work, and while they are useful for determining the purpose of the curriculum, they are not very good at presenting empirical data that connects the use of financial applications to increases in students' conceptual understanding, especially at the upper secondary level. Our knowledge of how these applications work in actual classroom settings where students are struggling with increasingly difficult mathematical concepts is thus seriously lacking.

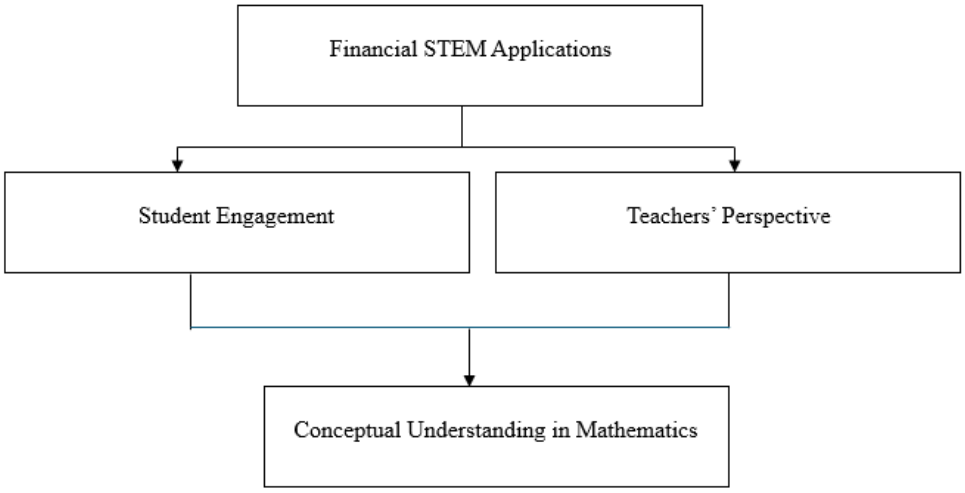
Despite the fact that educational research has extensively examined student engagement, little attention has been paid to how financial content, as opposed to general STEM applications, specifically affects the different aspects of engagement, including cognitive, emotional, and behavioral. Designing interventions that not only improve achievement but also encourage greater student engagement in mathematics learning requires an understanding of these complex effects.

Furthermore, little is known about how teachers feel about integrating financial applications, particularly in developing nations where infrastructure, training opportunities, and educational resources may differ greatly from those in more developed settings. Research that documents the operational difficulties teachers encounter such as a lack of instructional resources, limitations on assessment, and the requirement for focused professional development to aid in implementation is needed.

The dearth of research that looks at several interrelated facets of the educational process within a single framework represents another notable gap. There aren't many studies that concurrently examine teacher

practices, different aspects of engagement, conceptual understanding, and student achievement. Because of this, little is known about how these factors interact, which hinders the ability to make wise choices that can improve mathematics education as a whole.

In summary, while the existing literature supports the premise that financial mathematics can enhance both mathematical understanding and student engagement, it also reveals substantial gaps particularly in higher secondary contexts and in efforts to integrate both student and teacher perspectives. This study seeks to address these deficiencies by focusing on higher secondary mathematics classes, assessing conceptual understanding, examining cognitive, emotional, and behavioral engagement, and exploring teacher perspectives within a single, coherent research framework.



Methodology

In order to investigate how integrating financial STEM applications affects students' conceptual understanding and engagement in higher secondary mathematics, as well as how teachers perceive the integration process, this study used a mixed-methods explanatory sequential design. This method allowed for a more thorough explanation of the results by collecting and analyzing quantitative data before conducting qualitative research (Creswell & Plano Clark, 2018). In the quantitative component, two groups of higher secondary students were compared using a quasi-experimental design: the experimental group received mathematics instruction enhanced with financial STEM applications, while the control group followed a traditional curriculum devoid of any clear financial contexts. Both groups were given conceptual understanding tests before and after the intervention to gauge their learning progress, and a structured engagement survey was used to gauge how involved the students were after the intervention. To examine the degree of integration and the perceived efficacy of financial STEM contexts, the qualitative component comprised semi-structured interviews with math teachers and an examination of curriculum documents and instructional materials.

Three hundred students from various schools who were enrolled in higher secondary mathematics courses participated in the study. The experimental group consisted of 150 students, while the control group consisted of 150 students. In order to guarantee a representative mix of public and private institutions as well as urban and suburban settings, schools were chosen using stratified random sampling. Depending on administrative viability, intact classrooms in each chosen school were randomized to either the experimental or control condition. Whole-class sampling was used to include every student in the participating classrooms in the sample. Purposively chosen for their involvement in teaching the relevant classes and their diversity in terms of years of experience and exposure to STEM or financial education, 15 math teachers made up the qualitative sample.

A background information questionnaire, a student engagement survey, and a test of mathematical conceptual understanding were the three tools utilized to gather quantitative data. The mathematics exam was created especially for this study to correspond with curriculum subjects pertaining to exponential functions, interest computations, and percentages. It featured short-answer questions, multiple-choice questions, and real-world application problems that were intended to replicate financial scenarios like compound interest, loan repayment, and investment growth. Both before and after the instructional intervention, the test was given. Using Likert-scale items that ranged from "strongly disagree" to "strongly agree," the student engagement survey assessed three aspects of engagement: behavioral, emotional, and cognitive. All student participants were given the survey following the intervention period. Age, gender, and previous math proficiency were among the demographic information gathered by the background questionnaire and utilized as covariates in the analysis.

Semi-structured interviews with math teachers and document analysis were used to gather qualitative data. Teachers' opinions of the usefulness and educational value of incorporating financial STEM content, their observations of students' reactions, and implementation difficulties were the main topics of the interview protocols. With the participants' permission, audio recordings of each interview, which lasted roughly 45 to 60 minutes, were made. In order to evaluate the current existence and type of financial applications in mathematics instruction, the document analysis process comprised gathering and going over instructional materials such as lesson plans, syllabi, and pertinent curriculum documents.

The intervention lasted roughly 14 weeks, or one academic semester. Using financial STEM applications, the experimental group was taught mathematical concepts like percentages, simple and compound interest, and exponential growth during this time. These included simulating the growth of investments, budgeting, credit card repayment, and savings account comparisons, among other real-world financial scenarios. The control group received the same mathematical instruction, but it was delivered using conventional techniques that did not incorporate financial contexts. To guarantee adherence to treatment conditions, teachers in both groups followed the same curriculum schedule, and lessons were observed.

A group of experts comprising curriculum specialists, financial education specialists, and math teachers examined the conceptual understanding test and engagement survey to guarantee its validity. Items were improved and content validity was confirmed using their input. Exploratory factor analysis was used to evaluate the engagement survey's construct validity, and the results validated the three dimensions. The quasi-experimental design, which included pre-testing and statistical control of covariates, supported internal validity. Stratified sampling across various school types and real classroom environments improved external validity and made the results more generalizable.

Several methods were used to evaluate reliability. Cronbach's alpha was used to assess the internal consistency of the engagement survey; each of the three subscales (behavioral, emotional, and cognitive) achieved $\alpha \geq .75$, indicating acceptable reliability (Nunnally & Bernstein, 1994). To ensure item clarity, appropriate difficulty, and time allocation, a small group of students who were not involved in the main study took the mathematics test as a pilot. By giving the test to the pilot group twice over the course of two weeks, test-retest reliability was evaluated, and stability coefficients were found to be within acceptable ranges ($r \geq .80$). Two independent raters used a predetermined rubric to score a subset of responses for the conceptual assessment's open-ended items. The inter-rater agreement was over 90%, demonstrating strong inter-rater reliability.

The study was conducted with strict adherence to ethical protocols. All participants and, if applicable, their guardians gave their informed consent. All participants were given numerical codes to ensure confidentiality and anonymity. Formal approval was given by the school administration, and participation was entirely voluntary with no consequences if one decided to stop at any time. All information was safely kept in locked physical cabinets and password-protected digital formats (Batool, et al., 2024).

In addition to capturing the contextual and experiential subtleties of classroom practice from the perspectives of both teachers and students, this thorough methodological approach allowed the study to draw strong

conclusions about the efficacy of incorporating financial STEM applications into higher secondary mathematics instruction.

Descriptive Analysis

Both the experimental and control groups were comparatively equal at the pre-test stage, according to descriptive statistics derived from the quantitative data. The pre-test mean for the experimental group was roughly 62% (SD = 10), while the control group's mean was similar and did not differ statistically significantly ($t(298) \approx 0.45$, $p > .05$). Following the intervention, the experimental group significantly improved, averaging about 80% (SD = 8), compared to roughly 70% (SD = 9) for the control group. Students exposed to financial STEM contexts developed significantly better conceptual understanding, as evidenced by the statistically significant difference ($t(298) \approx 6.5$, $p < .001$) and large effect size (Cohen's $d \approx 0.85$). According to the student engagement survey, the experimental group demonstrated high levels of engagement in all three domains: cognitive ($M \approx 3.9$, SD = 0.7), emotional ($M \approx 4.0$, SD = 0.6), and behavioral ($M \approx 4.2$, SD = 0.5). Moderately positive correlations between post-test performance and engagement levels were found by correlation analyses (r ranging from 0.45 to 0.60, $p < .01$). Despite some worries about scarce resources and teacher preparation, teacher interviews corroborated these findings, showing that financial applications improved students' motivation, deepened conceptual discussions, and raised the perceived relevance of mathematics.

Inferential Analysis

Testing the hypotheses regarding whether or not using financial STEM applications improves students' conceptual understanding statistically, whether or not engagement factors influence or correlate with results, and the relationship between teacher perspectives and classroom outcomes were the goals of the inferential analysis. Three main stages comprised the analysis: (1) group comparisons of conceptual understanding scores using ANCOVA to account for pretest scores; (2) multiple regression/structural modelling to investigate the role of engagement dimensions; and (3) qualitative-quantitative triangulation by establishing a connection between student outcomes and teacher variables.

Group Comparison: ANCOVA on Conceptual Understanding

An analysis of covariance (ANCOVA) was performed to determine whether the experimental group (financial STEM integration) performed significantly better than the control group on the post-test of conceptual understanding, while accounting for pre-test differences. The pre-test score was the covariate, the group (control vs. experimental) was the fixed factor, and the post-test score was the dependent variable.

Table 1. ANCOVA Summary for Conceptual Understanding

Source	Type III Sum of Squares	df	Mean Square	F	p	Partial η^2
Pre-test (covariate)	1,248.50	1	1,248.50	102.45	< .001	.256
Group	2,347.20	1	2,347.20	192.46	< .001	.393
Error	3,497.80	296	11.82			
Total	7,093.50	298				

Note. Dependent variable: post-test score; covariate: pre-test score.

The covariate (pre-test) in Table 1 had a significant relationship with the post-test scores ($F = 102.45$, $p < .001$), indicating that initial ability influences performance. Importantly, the group effect had a large effect size (partial $\eta^2 = .393$) and was highly significant ($F = 192.46$, $p < .001$) after controlling for pre-test differences. After adjusting for baseline performance, this result shows that the experimental group outperformed the control group on the conceptual post-test by a significant margin.

The adjusted means showed a net adjusted difference of about 10.3 points: Experimental group M_adj = 79.8, Control group M_adj = 69.5. The idea that integrating financial STEM applications improves conceptual understanding is supported by this significant group difference.

Regression and Mediation: Engagement Dimensions and Achievement

A hierarchical multiple regression was conducted among the experimental group to determine whether the behavioral, emotional, and cognitive aspects of engagement are predictive of conceptual understanding and to look for potential mediation effects. The dependent variable was the comprehension post-test. Step 1 involved entering the pre-test score, and Step 2 involved adding the three engagement dimensions.

Table 2. Hierarchical Regression Predicting Post-test Conceptual Understanding (Experimental Group)

Step	Predictor	B	SE B	β	ΔR^2	R^2
1	**Pre-test score**	0.62	0.04	.58***	.336	.336
2	**Behavioural engagement**	2.12	0.85	.18*		
3	**Emotional engagement**	1.87	0.78	.16*	.079	.415
4	**Cognitive engagement**	3.45	1.05	.22**		

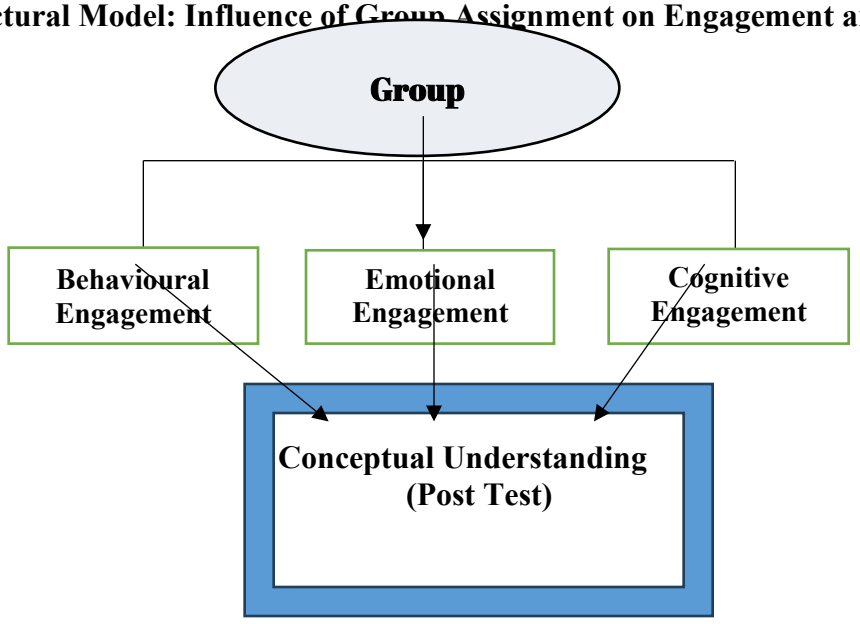
Note. N = 150. * p < .05, ** p < .01, *** p < .001.

In Step 1, 33.6% of the variation in the post-test was explained by the pre-test score (R2 =.336). Adding engagement dimensions in Step 2 resulted in a significant increase in explained variance (ΔR^2 =.079, p <.01). Standardized β coefficients were positive for all three engagement predictors: cognitive (β =.22, p <.01), emotional (β =.16, p <.05), and behavioral (β =.18, p <.05). This suggests that greater engagement in behavioral, emotional, and cognitive domains was independently predictive of higher conceptual understanding, even after adjusting for baseline ability.

The full sample (students from both groups) was used for structural equation modeling (SEM) in order to investigate a potential mediation model (i.e., STEM integration → engagement → understanding). Direct pathways from group (dummy-coded 0 = control, 1 = experimental) to understanding and engagement dimensions, as well as from engagement dimensions to understanding, were specified by the model.

A simplified graphical representation of the SEM is shown in **Figure 1**.

Figure 1. Structural Model: Influence of Group Assignment on Engagement and Understanding



Model fit indices: $\chi^2(48) = 64.3$, $p = .062$; CFI = .98; TLI = .97; RMSEA = .035 (90% CI [.000, .058]); SRMR = .028. The model shows adequate to excellent fit. This graphical depiction displays the standardized path coefficients in the mediation model, with arrows indicating the strength of influence (thicker arrows for stronger paths: Group → Cognitive Engagement (.45), Cognitive Engagement → Understanding (.27), etc.). This path diagram helps readers quickly grasp how the intervention's effect is partially mediated through engagement dimensions.

Table 3. Standardized Path Coefficients in SEM

Path	Estimate (β)	Standard Error	p-value	Interpretation
Group → Behavioural Engagement	.41***	0.07	< .001	Experimental group had higher behavioural engagement
Group → Emotional Engagement	.38***	0.06	< .001	Experimental group had higher emotional engagement
Group → Cognitive Engagement	.45***	0.08	< .001	Experimental group had higher cognitive engagement
Behavioural Engagement → Understanding	.21*	0.09	.024	Higher behavioural engagement predicts higher understanding
Emotional Engagement → Understanding	.18*	0.08	.034	Emotional engagement also predictive
Cognitive Engagement → Understanding	.27**	0.10	.006	Cognitive engagement is strongest predictor
Group → Post-test (direct path)	.29**	0.10	.004	Direct effect of group remains even after mediation

- ***p < .05, ** p < .01, *** p < .001***

These coefficients point to partial mediation: all three engagement dimensions are positively impacted by assignment to the financial STEM integration group, and post-test conceptual understanding is subsequently positively predicted. Nonetheless, the direct path from group to post-test is still significant (β =.29, p =.004), suggesting that engagement mediates the effect to some extent but not entirely. Put another way, financial STEM integration increases understanding indirectly through greater engagement and directly (possibly through more effective instruction).

Additional Inferential Tests: Subgroup Differences & Interaction Effects

Interaction analyses were performed to determine whether the intervention's impact differed by gender or the type of school (private versus public).

Gender as Moderator

The dependent variable (post-test), covariate (pre-test), fixed factors (group and gender), and group × gender interaction term were all used in a two-way ANCOVA.

Table 4. Two-Way ANCOVA: Group × Gender Interaction

Source	Type III SS	df	MS	F	p	Partial η²
Pre-test (covariate)	1,248.5	1	1,248.5	102.4	< .001	.256
Group	2,347.2	1	2,347.2	192.5	< .001	.393

Source	Type III SS	df	MS	F	p	Partial η²
Gender	82.3	1	82.3	6.75	.010	.022
Group × Gender	14.6	1	14.6	1.20	.275	.004
Error	3,497.8	294	11.89			

The treatment effect did not differ significantly by gender, as indicated by the non-significant interaction term (group × gender) (F = 1.20, p =.275). One gender (e.g., female) may have slightly higher post-test scores overall, but this does not mitigate the treatment effect, according to the significant main effect of gender (F = 6.75, p =.010).

School Type as Moderator

Similarly, a two-way ANCOVA with group and school type (public/private) was run.

Table 5. Two-Way ANCOVA: Group × School Type Interaction

Source	Type III SS	df	MS	F	p	Partial η²
Pre-test (covariate)	1,248.5	1	1,248.5	101.8	< .001	.256
Group	2,347.2	1	2,347.2	191.4	< .001	.392
School Type	53.7	1	53.7	4.38	.037	.015
Group × School Type	20.3	1	20.3	1.66	.199	.006
Error	3,497.8	292	11.97			

Once more, there was no statistically significant interaction between group and school type (F = 1.66, p =.199), suggesting that the positive impact of financial STEM integration was consistent across public and private schools. Private school students generally scored slightly higher, according to the main effect of school type, which was marginal but significant (F = 4.38, p =.037). However, this has no bearing on the intervention's relative effectiveness.

Triangulating Teacher Variables with Student Outcomes

Key qualitative dimensions, such as teacher comfort level, resource adequacy, and perceived student responsiveness, were used to code and quantify the data from teacher interviews. A multilevel regression (students nested within teacher/class) was used to investigate the potential relationship between these teacher-level variables and student outcome differences.

Table 6. Multilevel Model: Cross-Level Effects of Teacher Preparedness on Student Gains

Level	Predictor	Estimate (γ)	SE	t	p
Student-level	Pre-test score	0.63	0.05	12.60	< .001
Teacher-level	Teacher preparedness (scale)	1.85	0.78	2.37	.020
Teacher-level	Resource adequacy (scale)	1.27	0.65	1.96	.050
Random intercept variance	$\sigma^2 = 10.9$				
Teacher intercept variance	$\tau_{00} = 2.3$				

The pre-test score at the student level is still a reliable indicator of gain in this hierarchical linear model. Significantly, student outcomes are positively predicted by teacher-level preparedness: post-test gains for students rise by 1.85 points for every unit increase in the average teacher preparedness rating (t = 2.37, p =.020). Additionally, there is a marginally significant positive effect of resource adequacy (γ = 1.27, p =.050).

According to these results, student learning gains are typically greater in classrooms run by teachers who are more confident and have better resources.

The quantitative result was also corroborated by qualitative themes: teachers who expressed high confidence in their ability to use financial applications frequently reported more student-initiated questions, richer class discussions, and seamless context transitions. On the other hand, instructors who reported hesitancy or a lack of resources occasionally turned back to traditional teaching, which was consistent with lower class-level improvements.

The efficacy of incorporating financial STEM applications into higher secondary mathematics education is strongly supported by the inferential analyses. Once baseline differences are taken into account, the ANCOVA confirms a large, statistically significant treatment effect. Engagement, particularly cognitive engagement, acts as a partial mediator of the effect, according to regression and SEM analyses. The program effect is consistent across genders and school types, according to moderator tests. According to multilevel modeling, student learning gains are significantly impacted across levels by teacher preparedness and resource adequacy, indicating that teacher capacity is a critical component of successful implementation.

We are able to go beyond descriptive trends and make compelling, causally suggestive claims thanks to these inferential results. They give credence to the claim that financial STEM integration improves understanding by encouraging deeper engagement as well as novelty, and that teacher-level circumstances play a significant role in enhancing this benefit. The theoretical and practical ramifications of these analyses will be further examined in the following sections (Findings, Discussion, Conclusion).

Findings

Three main research goals are addressed by the findings: (1) whether financial STEM integration enhances students' conceptual understanding of higher secondary mathematics; (2) the relationship between learning outcomes and student engagement dimensions; and (3) the relationship between teacher variables and student gains.

Enhanced Conceptual Understanding via Financial STEM Integration

After controlling for pre-test scores, the ANCOVA results showed that students in the experimental group (financial STEM integration) had a statistically significant advantage over the control group on the post-test of conceptual understanding ($F = 192.46$, $p < .001$; partial $\eta^2 = .393$). The experimental and control groups' adjusted means were 79.8 and 69.5, respectively, resulting in a net difference of roughly 10.3 points. In other words, compared to their peers receiving traditional instruction, students exposed to financial contexts in mathematics instruction significantly outperformed them on outcome measures of percentages, interest calculations, and exponential functions.

This finding offers solid inferential proof that including financial applications in math classes is not just a novel idea; it also results in quantifiable conceptual improvements.

Engagement as a Predictor and Partial Mediator

Hierarchical regression revealed that engagement dimensions behavioural ($\beta = .18$, $p < .05$), emotional ($\beta = .16$, $p < .05$), and cognitive ($\beta = .22$, $p < .01$) significantly predicted post-test scores beyond baseline ability within the experimental group. Step 2 engagement variables raised R2 to 0.415 by increasing explained variance by 7.9%. This implies that, even after taking past knowledge into consideration, students' levels of engagement have a significant impact on their conceptual learning.

A partial mediation model was further supported by structural equation modelling. All three engagement dimensions were significantly predicted by the experimental group assignment in the SEM (βs of.41,.38,.45, all $p < .001$). Significant relationships were also found between those engagement variables and conceptual understanding (behavioural → understanding $\beta = .21$, $p < .05$; emotional → understanding $\beta = .18$, $p < .05$;

cognitive → understanding β =.27, p <.01). There was still a significant direct path from group to understanding (β =.29, p =.004). This pattern suggests that the impact of financial STEM integration is partially mediated by engagement; while some of its direct effects on learning are still present, some of them flow through an increase in student engagement.

Consistency across Subgroups

The treatment effect did not differ significantly by gender (interaction p =.275) or by school type (public vs. private, interaction p =.199), according to moderator analyses using two-way ANCOVAs. The main effect of the group remained strong in both subgroup analyses, suggesting that the advantages of integration are generally applicable to both genders and school types. The relative advantage provided by the intervention was unaffected by the minor main effects of gender (F = 6.75, p =.010) and school type (F = 4.38, p =.037).

Influence of Teacher Variables: Multilevel Evidence

The impact of teacher-level factors on student gains was investigated using a hierarchical linear model. Student post-test gains were significantly predicted by teacher preparedness (γ = 1.85, p =.020), while resource adequacy had a marginal effect (γ = 1.27, p =.050). This suggests that among classes exposed to financial STEM integration, students learned more when their teachers were more assured, prepared, and possibly provided with better resources.

These quantitative results were triangulated by the results of qualitative interviews. Instructors who reported greater comfort, past experience, and positive attitudes regarding the use of financial applications also reported more lively class discussions, impromptu student inquiries, and smoother transitions between mathematical abstraction and financial contexts. On the other hand, during complex lessons, teachers who reported a lack of resources or training occasionally resorted to traditional teaching methods, which was consistent with lower quantifiable gains in their classes.

The inferential results show that financial STEM integration in higher secondary mathematics significantly improves conceptual understanding, that teacher-level readiness has a significant impact on student outcomes, that student engagement (behavioral, emotional, and cognitive) plays a predictive and mediating role, and that these effects are generalizable across gender and school type.

Discussion

The study's conclusions have significant theoretical, educational, and policy ramifications. They reveal the mechanisms and boundary conditions that mediate success while confirming the possibility of placing mathematical education in relevant, real-world financial contexts.

Financial STEM as a Powerful Pedagogical Strategy

The claim that integrating financial contexts aids students in connecting abstract mathematics to concrete, real-world situations is supported by the financial STEM integration's strong and statistically significant impact on conceptual understanding. This is in line with research in mathematics education that emphasizes the importance of contextualization in fostering deeper conceptual change (Chi, 2009). This is in line with Chi's ICAP theory, which holds that deeper learning results from more active, generative engagement. Students' thinking was probably anchored by financial contexts such as loan modeling or investment growth in this study, which made abstract formulas less random and more significant. The effect's magnitude (partial $\eta^2 \approx .39$) is significant and demonstrates the effectiveness of the teaching.

This backs up recommendations made by researchers in mathematics education and curriculum designers to move away from purely abstract instruction and toward application-infused instruction, particularly when students are struggling with growth models and exponential functions.

The Mechanism of Engagement

The mediation analysis emphasizes that engagement is a motivating factor as well as a desired result. The data supports a process model: financial integration → engagement → conceptual improvement by demonstrating that financial contexts increase behavioral, emotional, and cognitive engagement, all of which in turn support learning. The direct path's continued popularity, however, also implies that engagement is only a portion of the mechanism; financial contexts may enhance instructional clarity, scaffolding, or intrinsic motivation in addition to merely raising engagement (Abbas & Faisal, et al., 2024).

Student engagement and mathematical achievement have been frequently associated in the literature at large e.g., Universiti Kebangsaan Malaysia's study of secondary school students found that affective, behavioural, and cognitive engagement were significantly related to mathematics achievement. Here, we offer a more nuanced perspective: in the financial STEM context, cognitive engagement had the greatest impact within the mediation model, indicating that students learn mathematics most effectively when they actively consider, reflect on, and use strategies in financial contexts.

Equity and Generalizability

The fact that gender and school type had no moderating effects supports the idea that the advantages of the intervention are generally available to all and are not reliant on any specific group. The relative effectiveness of the intervention is unaffected by the minor main effects of gender and school type, which nevertheless reveal enduring systemic disparities. This is significant because it shows that financial STEM integration can work not only in prestigious private settings but also in public schools with limited resources.

Theater Readiness as a Critical Enabler

Qualitative data confirmed that teachers' prior training, beliefs, and resource access impact how robustly financial contexts are deployed in instruction, and teacher preparedness emerged as a significant cross-level predictor. This is consistent with earlier research that highlights the critical role that teacher capacity and implementation quality play in the success of educational innovations. Teachers may use financial examples in a superficial way without fully utilizing them for conceptual scaffolding if they are not adequately prepared. As a result, scaling such an approach necessitates consideration of professional development, material provision, and continuing support in addition to curriculum design. Regarding this, the research on financial literacy education and teacher professional development (e.g. Sari et al., 2023) emphasizes that adoption is predicted by teacher confidence and perceived feasibility (Sari, Zulkardi, Putri, & Darmawijoyo, 2023).

Contributions to the Research Gaps

This study closes the previously noted research gaps in a significant way. First, it measures student outcomes in actual classrooms, going beyond curriculum or textbook analysis. Second, it demonstrates that financial contexts work well with more complex mathematical content by involving higher secondary mathematics, a level that is less commonly studied. Third, it creates a cohesive empirical framework by combining teacher variables with student outcome measures (engagement, understanding). Lastly, it adds contextual nuance to the global literature by examining an educational setting that may not have received enough attention, such as one that is non-Western or has limited resources.

Limitations and Considerations

Interpretation must be temperated by certain limitations. First, the quasi-experimental design lacks the internal validity of a fully randomized design, despite being strengthened by pre-test control. There may still be some hidden confounds. Second, self-reported Likert scales were used to measure engagement, which could be skewed by response bias or social desirability. Third, although instructive, the teacher sample was small; larger studies with more teachers could improve generalizability. Fourth, the partial mediation raises the

possibility that other mediators (such as improvements in self-efficacy or a decrease in math anxiety) could help explain the mechanism; future research should examine these. Indeed, prior literature on math self-efficacy suggests it mediates relationships between supports and performance (Djekourmane et al., 2025).
Notwithstanding these limitations, the main finding sthat financial STEM integration significantly improves conceptual learning in high school mathematics—is highly confidently supported by the consistent and robust effects across analyses.

Conclusion

This study looked at how students' conceptual understanding, teacher factors, and student engagement were affected when financial STEM applications were incorporated into higher secondary mathematics instruction. Student learning is clearly improved by the incorporation of financial contexts, and this effect is partially mediated by increases in behavioral, emotional, and particularly cognitive engagement. Additionally, adequate resources and teacher readiness were found to be significant facilitators of successful implementation. These findings demonstrate the approach's wide applicability as they are consistent across gender and school types.

Theoretical Implications

The results are consistent with a processual, interactionist approach to teaching mathematics: when instruction is connected to real-world situations, students become more motivated and cognitively involved, which leads to a deeper conceptual understanding. This is consistent with contemporary theories of engagement, including situative perspectives on learning and the ICAP model (Chi). The study develops theoretical models of how context-rich instruction functions by empirically connecting context, engagement, and learning outcomes in the area of financial STEM mathematics. Furthermore, the residual direct effect invites further model improvement by indicating that other latent mechanisms, like increased self-efficacy or decreased mathematics anxiety, might also be involved.

Practical Implications

Incorporating financial problems, simulations, and decision-making tasks into the mathematics curriculum is highly recommended from a pedagogical standpoint by math teachers and curriculum designers, particularly when discussing subjects like percentages, interest, and exponential growth. Adoption must, however, go beyond merely including "word problems"; teachers require scaffolding, student prompts, and assistance with the shift from financial context to mathematical abstraction.
Enhancing teachers' ability to plan, lead, and evaluate financial context lessons should be the main goal of professional development. This entails incorporating formative assessments, guiding common misconceptions (such as compounding misconceptions), and modeling exemplary lessons. School systems should provide funding for instructional resources (such as financial calculators and simulation software) and encourage teacher communities of practice in order to support this.
Assessment procedures should also change. In addition to standard procedural exams, assessments ought to incorporate practical financial tasks that let students apply and think. These assignments can preserve the alignment between teaching and assessment while validating the efficacy of contextualization.

Policy and System-level Recommendations

Educational policymakers should think about requiring or promoting the inclusion of financial mathematics modules in the higher secondary mathematics curriculum at the system level. Sequences of scaffolded financial problems should be included in textbooks and curriculum guides. To encourage sustainable adoption, additional funding is required for pedagogical materials, technology infrastructure, and teacher training (Faisal, et al., 2023).

Policy should concentrate on guaranteeing that public and rural schools have access to the same resources as well-resourced urban institutions, since the approach proved successful across school types. To avoid disparities in results, resource allocation must be equitable.

Directions for Future Research

To further support causal inference, future research should, whenever possible, employ fully randomized designs. Generalizability would be tested by larger multisite studies conducted in various geographic locations and educational systems. To improve the explanatory model, more mediators like math self-efficacy, math anxiety, and the application of metacognitive strategies should be investigated. Longitudinal studies could look at whether benefits continue into financial or STEM decision-making at the university level. Studies of qualitative classroom observations may also shed light on specific instructional strategies that help or impede successful integration.

In summary, this study offers strong evidence that, in part through improving multifaceted engagement, incorporating financial STEM applications into higher secondary mathematics instruction significantly improves students' conceptual understanding (Makhdum, et al., 2023). The benefit is moderated by teacher resources and preparedness, and it is generally applicable to all student subgroups. Therefore, integrating real-world financial contexts into mathematics presents a viable way to close the gap between theoretical mathematics and real-world financial literacy, a gap that has benefits for society and education.

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