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Research Article

Designing and Testing a Contextual Factors-Based Teaching and Learning Model for Blended Mathematics Instruction

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Abstract: The study employs design-based research (DBR) to design the mathematics teaching and learning activity model (M-TLAM) for blended learning instruction in a Tanzanian higher education context. This model utilises contextual factors, including ICT tool usage, collaborative learning with metacognitive activities, and local culture, to determine how optimising these factors boosts math students' motivation and achievement. Two DBR phases were conducted, of which Phase 1 lasted for two weeks and Phase 2 an entire semester. To evaluate M-TLAM in real-life learning settings, experiments were conducted with 225 first-year undergraduate students and seven lecturers at the College of Business Education in Tanzania. Experimental data were collected from pre-and post-tests, interviews, and questionnaires administered to students and lecturers. The study examined the perceptions and motivation of the participating lecturers towards using the M-TLAM in mathematics education and the factors influencing student motivation, academic achievement, and experience towards business mathematics courses. The evaluation results are promising and show that the M-TLAM implementation can potentially improve students' motivation and academic achievement. In addition, the pedagogical experiences of students were primarily positive, and student's attitudes towards the business mathematics course through M-TLAM were more favourable than those of students who studied the course via traditional methods. Cultural, technological, and instructional Factors contribute to students' improved motivation. Lectures demonstrated a cheerful disposition towards the potential of the M-TLAM for enhancing teaching and learning activities. The contributions of this study are highlighted through the implementation of the M-TLAM for blended learning and through the design principles and guidelines provided towards its effective implementation.

***Keywords*:** blended learning model, flipped classroom, higher education, M-TLAM, mathematics, motivation, learning achievement

MSC: 97D40, 97D50, 97U50

1. Introduction

The Mathematics is fundamental because arithmetic, logical reasoning, and problem-solving are the foundations

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of science, technology, and business-related disciplines [1]. As a result, many higher education institutions make mathematics a required subject for students from various fields. However, lecturers face challenges in developing the mathematical skills of students who enter higher education with limited prior knowledge [2]. For instance, business students with non-mathematics majors generally find mathematics difficult, and failure rates can be high [3]. Previous research suggests that these students' lack of mathematical knowledge contributes to their underperformance [3, 4]. Although these students enter the accounting, marketing, procurement, and education programmes with appropriate entry qualifications, their performance in mathematics is poor. Furthermore, factors including culture, personal experiences, language skills, confidence, and interests have been found to influence these students' learning [5]. Such factors imply that lecturers must teach students at various stages of academic readiness and instructional language proficiency with different social, emotional, cognitive, and behavioural needs that must be considered when planning instruction [5]. A classroom with such diverse students is considered heterogeneous and is defined as one without ability grouping, bilingual or multilingual, desegregated, and untracked [6].

Recent research has shown that students' learning differences must be addressed in higher education classrooms in Tanzania because lecturers prefer teacher-centred instruction such as lectures [7]. Still, this approach only works for some students [1]. Furthermore, though ability grouping and tracking have been proposed, they do not work for students placed in low-ability groups [8]. Therefore, teachers are encouraged to look to the research literature for teaching methods that improve students' mathematical achievement when assisting all students to succeed. In previous research by Mazana et al [7, 9], several teaching approaches were explored, tested, and compared for their efficacy in enhancing students learning achievement in mathematics. However, it was found that contextual problems such as scarcity of teachers and learning material, cultural factors, and a lack of innovative teaching methods such as incorporating ICT into mathematics instructions still needed to be fully addressed. Another study by Mazana et al [10] incorporated ICT tools by applying a flipped classroom (FC) model in mathematics teaching and learning and compared that approach with an approach based on guided group discussion, group work, and sharing. Their study showed comparable effects of FC and strategies similar to Amstelveen's [11]. Further, qualitative findings suggested that instructional videos, collaborative strategies, mainly guided small group discussions, and frequent quizzes and exercises can successfully boost students' achievement in mathematics. Inspired by this work, we use FC to develop an improved model for mathematics teaching and learning, the M-TLAM customised for the Tanzanian higher education context. This model considers contextual factors, including ICT tool usage, collaborative learning with metacognitive activities, and culture, to explore whether optimising these factors can influence students' motivation and, in turn, their academic achievement in mathematics.

1.1 *Research Questions (RQs)*

This study addresses the following questions:

1. What is the effect of the M-TLAM on higher education students' academic achievement in mathematics topics?
2. What is the effect of M-TLAM on higher education students' motivation towards learning mathematics topics?
3. What are the students' experiences about using the M-TLAM in learning mathematics?
4. What are the variables and the relationship among those variables that account for the observed changes in students' achievement?
5. What are the teacher's perceptions, motivations, and competencies towards using the M-TLAM?

This study, developed through the DBR framework, presents three novel contributions in line with Weerasinghe [12]: interventions (the culturally-conscious M-TLAM of this study), design knowledge (the proposed design principles), and the professional development of researchers. The M-TLAM also contributes to technology-enhanced learning by supporting a novel design of blended learning instruction to enhance mathematics skills needed in business courses and other areas. Further discussion on the contributions of this work is found in Section 7.

2. Related literature

2.1 *Active learning approaches and student achievement*

In a meta-analysis of studies on alternative pedagogies for students with poor mathematics background knowledge

[13], active learning was the most commonly used approach (38 articles out of 74). Active learning involves students taking charge of their education and working in small groups to achieve common goals [14]. Many educational academics and practitioners agree that collaborative learning is appropriate for academically and linguistically diverse classes [6]. They claim that small groups allow low-achieving students and those who don't speak the language of instruction to participate in group discussions [6]. In Tanzania, the language of instruction is English, which most students need help with [7]. Indeed, collaborative learning will serve as a helpful strategy in this situation. Collaborative learning is linked to higher achievement, increased productivity, knowledge transfer (from group to individual), new ideas and solutions, and a higher level of reasoning [14]. Despite these benefits, three pitfalls must be avoided for collaborative learning. The first area for improvement is students' failure to monitor and regulate cognitive processes while working together [15]. Low-achieving students and socially isolated people face interaction difficulties, the second danger [6]. To help students monitor and regulate their cognitive processes and fully participate in collaborative learning, teachers should equip them with metacognitive strategies (self-questioning strategies), assign them roles, and provide systematic feedback, corrective-enrichment procedures, and unique reward structures [6, 15].

Several researchers used collaborative learning models with metacognitive strategies and found improvements in various student achievement areas, including problem-solving abilities, reasoning abilities, and mathematics anxiety [15-17]. However, the positive effects of these interventions were often moderate rather than vigorous [18], implying that improving learners' competence in mathematics problem-solving requires more innovative approaches, such as incorporating Information and Communication Technologies (ICTs) to aid collaboration and metacognitive activities. Information and Communication Technologies are extremely important in collaborative learning [19]. ICTs such as computers and mobile phones support interpersonal interactions, which are critical to a successful collaborative learning process in technology-enhanced learning [20]. These interpersonal interactions between teachers and students are critical in motivating students to learn, improving the learning process and achievement [19], and improving their satisfaction [21].

In addition, researchers have been investigating the potential of different learning technologies for developing students' metacognitive competencies. According to Kramarski and Friedman [22], working in a computer-based learning environment can help students become self-regulated problem-solvers. These technologies include intelligent tutoring systems, simulations, programming, serious games, hypermedia, computer-supported collaborative learning environments, and virtual reality. The teacher can provide metacognitive pedagogies externally or integrate them into the ICT software [18]. Several design features of these learning technologies, such as learners' access to nonlinear information, multiple representations, or input ideas from other learners, play an important role in the development of learners' metacognitive skills, leading to improved learning outcomes [18] and motivation to learn [23].

2.2 *Cultural factors influencing collaborative learning*

According to Blau et al. [19], computer-supported collaborative learning is a socio-cultural phenomenon influenced by cultural differences in the use of ICT in learning. Several scholars argue that culture is essential in adopting innovations [24, 25]. Similarly, cultural beliefs and attitudes influence how teachers and students interact in collaborative learning settings [26]. Several researchers agree that different forms of collaborative learning are more likely to succeed in different cultures due to contextual factors recognised as barriers to borrowed initiatives, specifically those that do not align with the innate cultural values in the situated contexts [27-30]. For example, collaborative learning methods developed in Western cultures such as the United States are inherently culture-based (e.g., individualism) and may not be well-suited to Tanzanian culture (collectivism). As such, some researchers have demonstrated the influence of cultural variations on students learning motivation [31, 32]. In some cultures, collaborative learning is perceived as costly in terms of money and time, possibly due to the pressure to achieve individual success or an exam-driven education system. As a result, students may regard this model as a waste of time, reducing its effectiveness in improving student learning achievement [26].

Recognising the significance of culture in learning, Nguyen [26] defined pedagogy as a collection of cultures representing different contexts and behaviours inside and outside the classroom. A culturally appropriate pedagogy combines significant parts of educational policy and practice transfer while remaining sensitive to the cultural contexts of students and teachers. Previous studies in similar cultures [33] and Confucian heritage cultures highlighted essential elements of collaborative learning that may need to be addressed when working in a different context. Based on the

Hofstede cultural framework, these components are leadership, reward allocation, and group composition. The aspect of individual intelligence was treated as a confounding factor, and its effects on the student's performance were not measured in this study.

Leadership: In Hofstede's cultural framework, leadership is linked to power distance [34]. Collaboration requires successful leadership, and practical approaches differ depending on cultural contexts [35]. Research on leadership at high power distance shows that people prefer a formal, directive leadership style with top-down decision-making, indicating a hierarchical power allocation in a group. Like other countries with significant power disparities, Tanzania appears to have a hierarchical and authoritative leadership structure [34]. Less powerful members of these cultures accept an unequal power distribution [26].

On the other hand, societies with a smaller power distance and more robust democratic principles are more likely to prefer a participative leadership style in which power is distributed among group members [36]. Power distance is expected to influence student relationships in educational settings. Most formal relationships in Tanzanian societies are considered hierarchical, as seen in schools and universities. Unit prefects, different student organisation presidents, and class monitors are all readily visible in schools and colleges. This power relation implies that a leader should be involved whenever a formal group of students meets. A study examining why overseas students struggle to participate in small group discussions discovered that Asian (high power distance culture) students believe that assigning a group leader helps the group work and prevents problems [27]. Taking culture into account, having a formal leader in a group is thus crucial for the entire learning process together in collaborative learning environments in Tanzania, which has a larger power distance culture. In high-power distance societies, the leader's job is linked to organisational skills such as getting people back on task and monitoring the conversation. It should be rotated regularly, according to Nguyen [26]. It was discovered in Nguyen's study that the function and type of benevolent, humanistic leadership were advantageous. As a result, Tanzanian students will favour leaders who can maintain positive interpersonal relationships within the collaborative learning group.

Reward allocation: In Hofstede's [34] cultural paradigm, reward allocation involves the individualism-collectivism dimension. Rewards are distributed based on either equity or equality principles, according to Nguyen [26]. In terms of the equity rule, rewards are proportionally distributed to represent the functions performed by each group member. Regarding the equality rule, awards are granted based on consistency and fairness and are divided equally among group members, regardless of their efforts. Furthermore, equity is an ideal rule in an individualistic culture where people are often differentiated based on their performance. Collectivist societies like Tanzania embrace equality because it promotes collective harmony more effectively. In collaborative learning, the equality principle is proposed and applied in grading group-related assignments, whereby each student receives the same grade regardless of their contributions. Alternatively, each contribution is assessed, and the final group grade is the average of each member's grades. As a result, the equality rule used in collaborative learning will likely reflect Tanzanian social norms and values. Consequently, students in collaborative learning environments are more likely to be at ease with reward distribution based on an equality rule.

Group Composition: Trust and group identity, according to Nguyen [26] and Phuong Mai et al. [33], are two critical factors for group functioning. These elements are essential for anyone joining a new group. A *person's trust* refers to their belief in the goodwill of others and their expectation that others will reciprocate if they cooperate. According to Nguyen's research, trust can be classified as cognition-based or affect-based. Whereas cognitive-based trust is based on team members' knowledge, competencies, and performance, affect-based trust is derived from emotional bonds among group members. Individualistic societies highly value developing cognition-based trust, strengthening personal identities, and acting following instrumental and rational self-interest. In collectivist cultures, the new group should ideally provide a strong sense of affect-based trust and a sense of role and purpose that strengthen various social identities and collective interests. Both cognitive and emotional trust are necessary for successful group work in the classroom. However, the former relies on long-term social relationships, while the latter relies on short-term social bonds. In collectivist cultures, affect-based trust and socially shared identity, according to Nguyen's [26] study, are crucial components for collaborative grouping and group operation. The study discusses further that in collectivist cultures where personal relationships play a crucial role in demining the nature of group collaboration, personal affinity may be a more significant factor to consider in establishing groups. This study showed that grouping based on existing friendships was more critical than grouping based on upcoming cognitive abilities. As a result, in Tanzania, as in other collectivist cultures, students will work more effectively within friendship-based groups than cognitive-ability-based groups.

2.3 *Collaborative learning and metacognitive strategies*

Collaboration is a philosophy of interactions and personal lifestyle in which people are held accountable for their actions and respect each other's abilities and contributions [17]. Collaborative learning is a learning approach in which students work together to maximise each other's learning through cooperation among group members [10]. Cooperation is a type of interaction that aims at achieving a specific goal related to the content [37]. In collaborative learning, students interact in purposely structured groups to support the learning of themselves and others in the same group, whereby competent students work together with less capable ones, helping each other solve mathematical problems, learning from their mistakes, and at the same time gaining a deeper understanding of the subject matter [38]. This teamwork implies that one student's success will increase other students' success [39]. As Mevarech and Kramarski [15] put it, students can share ideas, explain their reasoning, and assist one another when they work together. In doing so, students learn how to conduct constructive conversations in small groups by justifying their arguments and explaining how rather than doing the work for others [40]. In this arrangement, students in the group can work together to solve problems, complete tasks, or learn new concepts.

Collaborative activities can range from classroom discussions combined with short lectures through entire class periods to studies on research teams that last the entire semester. There are a variety of forms of collaborative learning involving different organisations of the classroom environment, teachers' and students' roles, and types of tasks [41]. Table 1 displays the different models of collaborative learning for mathematics found in the literature. In some collaborative learning models, students work on separate tasks, contribute to a standard solution, or work together on a shared task. Other forms require students to be assigned specific roles, such as recorder or calculator [41], to make collaboration more effective. In many of these models, the group size ranges between four and six participants. Details of each model are presented in Table 1.

Table 1. Collaborative learning models

Model	No. of students	Group composition	Focus (Group study/Task)	Reward structure
STAD [42]	4-5	Heterogenous	Group study	-Group reward for individual learning
TGT [43]		Heterogenous	Group study	-Group reward for individual learning
JIGSAW (JIG) I [44]	6	Homogenous	Task specialization	-Individual reward
JIG II [42]	4-5	Homogenous	Task specialization	-Group reward for individual learning. -Team competition
Think pair share (TPS) [45]	Pair	Heterogenous	Group study	-Group reward
Learning together (LT) [46]	Small group	Heterogenous	Task specialization	-Group reward.
Complex instruction (CI) [40]	4-5	Heterogenous	Group study	-
IMPROVE [15]	4	Heterogenous	Group study	-

According to research, collaborative learning appears to have significant social, psychological, academic, and assessment benefits [17]. Several scholars argue that various forms of collaborative learning have significant advantages over individual student learning. Many of these studies have found that small-group learning produces better outcomes than individual learning (e.g., [47-49]). The reasons for the observed benefits are linked to social constructivism, which holds that learning occurs through social and collaborative activities in which students construct knowledge by interacting with one another to achieve a common goal. These interactions can help students make sense of what they have learned and reorganise it.

Although research has consistently found that collaborative learning positively impacts mathematics outcomes, there needs to be more concern about students' inability to actively monitor and regulate cognitive processes during collaborative problem-solving [15]. Conversely, teachers are concerned about some students needing to participate in group activities fully. In contrast, others do all the work because classrooms are academically, culturally, and linguistically diverse [7, 40]). In their study, [40] discovered that students with high academic ability talk and learn more than low-ability students. Mathematics learning is a social activity that requires students to discuss and acknowledge their mathematical understanding and strategy use [50]. Thus, students must be able to communicate with others, understand others' procedural and declarative knowledge of mathematics, and regulate their cognitive processes and those of their peers [50]. Some researchers believe that students should be trained in metacognitive processes to improve the success of collaborative learning [15, 16, 51]. Metacognition is defined by Stillman and Mevarech [52] as thinking about one's thinking and includes components such as planning, monitoring, control, and reflection. The role of metacognitive strategies in collaborative learning has been explored, for instance, by Kwon et al. [53], who showed that the application of metacognitive strategies helped enhance group activity in computer-supported collaborative learning.

IMPROVE is an example of a successful collaborative metacognitive method in mathematics [15]. This model utilises metacognitive questions that motivate students to think about the problem and provide detailed explanations about it, the relationship between prior and new knowledge, and various strategies that could be used to solve it [22, 54]. These questions are adopted in the current study to guide students through collaborative problem-solving.

2.4 *Blended learning in mathematics education*

Blended learning (BL) is a way to make learning more dynamic and interactive by combining traditional classroom teaching with e-learning. It is a careful mix of online and in-person teaching methods, such as lectures, self-paced exercises, and online discussion groups. According to Bonk and Graham [55], blending can occur at the activity, course, programme, or institutional levels. The activity level of blended learning is when a learning activity consists of both face-to-face and online elements. Tsai et al. [56] say that this method helps the learning process by using a mix of activities, such as online lectures, media-guided lessons, and face-to-face interactions. It is seen in the related literature that studies about the use of BL were conducted in higher education [57, 61] in order to find out whether BL affects students' academic achievement and motivation. All the studies above show that when BL is used, students perform better in school and are more motivated. BL can be implemented via several models, including face-to-face instruction, rotation, online lab, Flex, online learning, and flipped classrooms (FC) [56].

Each of these models has its benefits and limitations. The flipped classroom is the most widely adopted in mathematics education among these models. A flipped classroom is a reversed traditional classroom model whereby instructions are given online, outside the classroom. In contrast, all other activities that used to be given as homework, projects, group work, and the like in a traditional setting are completed in the classroom. In the flipped classroom, students watch online video clips before the class, and then later meet with their lecturers for group discussions and hands-on activities [62]. Research studies about flipped classrooms in mathematics education have positively impacted students' achievement [62-65]. Other studies reported challenges with the flipped classroom [66], but this literary theory study proposed ten design principles and guidelines on how well an FC can be implemented. A recent study about the effect of flipped classrooms on mathematics motivation and achievement was conducted in Tanzania, and the findings were that flipped learning produced comparable impacts as traditional classroom models. According to Sointu et al. [67], pedagogical, social, and technological factors that determine FC success may have contributed to these findings.

From the studies that were reviewed, it is clear that the current BL models were only made for some educational settings; they need to be adjusted to fit a specific cultural setting. The mathematics teaching and learning activity model (M-TLAM) is a BL model meant to help solve the problem of low motivation and poor performance as a result of contextual challenges, including poor teaching strategies, scarcity of teaching and learning resources, and the handling of large classrooms in Tanzanian higher education math classes for first-year non-mathematics major students. Moreover, there is a need to continuously improve instructional practices based on scientifically proven theories and emerging frameworks such as DBR.

3. Materials and methods

3.1 *Design based research*

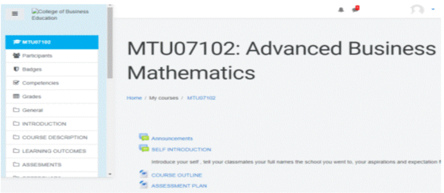
A design-based research (DBR) approach systematically enhances educational practices by analysing, designing, and evaluating educational interventions iteratively in partnership with researchers and practitioners [68, 69]. DBR begins with actual educational challenges supported by educational theories and concludes with continually refined and improved design principles, learning theories, instructional strategies, or tools [70]. The iterative design process consists of several design cycles and in-situ design testing, in which the knowledge gained at each stage of the process is used to improve the design and implementation of the intervention at the subsequent level [68].

This study adopted the DBR approach to conduct an experiment in which different research methods in different phases were integrated into iterative cycles. Two DBR implementation phases were conducted; however, this study focuses on the second implementation phase. Nevertheless, for clarity, the first DBR implementation phase, which is reported in [10], is highlighted here. After analysing practical problems in Phase 1, the flipped classroom model was adopted for the blended learning course design. The design components that led to course enjoyment and academic self-efficacy were identified. Hence, Phase 2 customised these components, focusing on using ICT tools (Edmodo and Moodle LMS), teaching-learning strategies, and culture to design a better-blended learning model for the Tanzanian higher education context. Additionally, since Lin et al. [64] define academic achievement as the student's performance measured by tests and exams, academic achievement is determined in this study using pre-and post-test results.

3.2 *ICT tools used*

During each phase of the DBR study, several learning technology tools were used to make teaching and learning easier. This was done to meet a variety of research goals. In Phase 1, the WhatsApp social media platform was selected for sharing short lecture videos. WhatsApp allowed students to interact with their lecturer and one another regardless of time or location; they could share videos and text files and discuss educational issues. In Phase 2, Edmodo social media for learning and the Moodle e-learning platform were used to share course material and group discussion. Edmodo is a social-media-focused microblogging platform that enables educators to interact, collaborate, share content, and access assignments, grades, and school announcements (see [71], p. 43). Edmodo is accessible from any smartphone or mobile device, and its use has been linked to enhanced science subject comprehension [72] and students' learning responses in computer science [73].

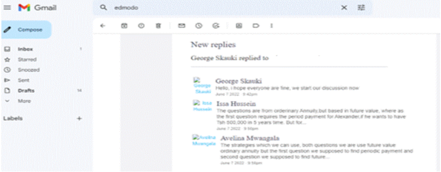
According to Oyelere et al. [73], using social media enhances students' social connections and collaborative learning. In this study, Edmodo was adopted as the learning platform to facilitate small group discussions in which discussion questions for each study unit were posted to each group after class hours. Initially, instructional videos and lesson materials were shared through the Edmodo platform, but after its closure, the lessons shifted to the Moodle e-learning system. Moodle is a free web application for e-learning that is based on the idea that learning is a social process. It allows lecturers to post lesson materials in text, audio, and videos; make announcements; present quizzes; and grade class activities. Lecturers can provide feedback on quizzes and assignments that are electronically submitted and scored automatically. This study adopted Moodle as the learning platform to facilitate the learning activities in MTU 07102, a business mathematics course for first-year bachelor's degree students. The course materials, such as PPT slides, assignments, quizzes with immediate feedback, and short videos, were provided on Moodle (see Moodle at http://lms.cbe.ac.tz/course/view.php?id=303).



MTU07102: Advanced Business Mathematics

Introduce your self , tell your classmates your full names the school you went to, your aspirations and expectation

a. Advanced business mathematics Moodle page



New replies

George Skauki replied to

George Skauki
Hello, i hope everyone are fine, we start our discussion now
June 7 2022 · 9:42pm

Issa Hussein
The questions are from orderinary Annuity,but based in future value, where as the first question requires the period payment for Alexander,if he wants to have Tsh 500,000 in 5 years time. But for...
June 7 2022 · 9:50pm

Avelina Mwangala
The strategies which we can use, both questions we are use future value ordinary annuity but the first question we supposed to find periodic payment and second question we supposed to find future...
June 7 2022 · 9:58pm

Edmodo log in details.pdf
52 pages · 220 kB · PDF
9:48 PM

Judith [redacted] Log in Details.pdf
1 page · 66 kB · PDF
9:48 PM

Login details 9:48 PM

Forwarded
Attached files contain your username log in details for Edmodo platform e-learning system. Access the system you will find some activities. The first activity is to watch a video, then you get discussion question for small groups I have created. Start discussion or you may take the quiz then proceed to discussion. Any questions?

b. Sample small group discussion from Edmodo C. WhatsApp platform used for math

Figure 1. Example ICT tools for learning adopted in this study

4. M-tlam for blended instruction

4.1 *Phase 1 analysis of practical problem*

The study began with a survey of students' attitudes towards mathematics, followed by an analysis of students' mathematics performance, an exploration of teachers' perceptions regarding the causes of failure, and a probing of the way forward. Findings showed a high failure rate at all levels of education and that the learning situation is hampered by several factors, including aptitude (e.g., declining math enjoyment), instructional (dependent on teacher-centred instruction, lack of innovativeness, e.g., failure to use ICTs for teaching, scarcity of teaching-learning resources), social, environmental (e.g., large class), and cultural. Further, the study explored the teaching approaches that mathematics teachers use to teach mathematics and their effect on students learning. The findings showed that teachers prefer teacher-centred approaches, which were found to be less effective [7], and that the choice of this approach was motivated by, for example, quick syllabus coverage and providing students with the right content.

4.2 *Phase 1 Preliminary M-TLAM model design*

After analysing the course situation, we consulted the literature, and it was found that the use of blended learning, particularly flipped classrooms, can positively affect motivation to learn math and academic achievement. It can also help with easy access to teaching and learning materials, giving students extra time to access lectures outside of class. We decided to pilot the flipped classroom model shown in Figure 2. In the pilot study, short video lectures were shared through the WhatsApp social media platform, used mainly by students of higher education in Tanzania [3]. WhatsApp allows lecturers and students to share learning materials such as lecture notes and instructional videos, make announcements, and support students.

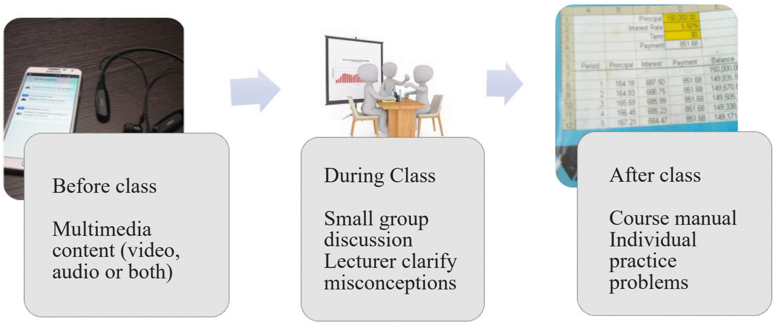


Figure 2. The flipped classroom -pilot model

4.3 *Phase 1 testing and evaluation*

A quasi-experimental design was adopted to test and evaluate the preliminary M-TLAM model. The pilot study was conducted at the College of Business Education (CBE) in Dar es Salaam, Tanzania. In this pilot study, three decision theory classrooms were compared during the second semester of the 2018-2019 academic year, where one classroom was flipped, and the other two classes were taught using active learning strategies (guided small group discussion, group work, and presentation) in face-to-face settings. The pilot aimed to emphasise the course's mathematical aspects to improve overall course achievement. Before arriving in class, the next day, students in the flipped class watched the online video lectures, which could last up to 10 minutes. The class time was used for discussions, where the lecturer provided them with a set of questions to discuss in groups while the lecturer cleared up misconceptions and checked for the completeness and correctness of their answers.

4.3.1 *Participants*

The participants were 121 first-year bachelor's degree students who studied decision theory topics in 2018-19. The flipped classroom consisted of 18 (12 males and six females) students; the first non-flipped class consisted of 47 students (26 males and 21 females); and the second non-flipped class consisted of 56 (34 males and 22 females) students.

4.3.2 *Quantitative data analysis*

To determine whether the FC led to more outstanding student achievement, all students attended a lecture for 120 minutes and then took a pre-test on prior knowledge before attending the flipped classroom. The average pre-test scores were calculated, and the class with the lowest mean score was selected for the flipped classroom, while the rest used student-centred active learning strategies. After completing the decision theory topic, all students took a post-test exam and completed a survey to assess their course enjoyment and academic self-efficacy. Data were sourced from pre-test, post-test, and questionnaire responses. The course instructor prepared both the pre-test and post-test and checked for validity by an experienced lecturer from the same college. The survey questionnaire consisted open-ended and Likert scale-type questions related to course enjoyment and academic self-efficacy. These scales consisted of six statements, each with a 5-point Likert scale ranging from 1 to 5, with 1 being strongly disagree and 5 being strongly agree. We analysed the collected data using descriptive statistics (mean and standard deviation), one-way ANOVA, and Kruskal-Wallis tests [10].

A one-way ANOVA test showed no significant difference between the group's post-test scores ($H(2) = 1.280$, $p = 0.527$), $\eta^2 = 0.01$. Further, the analysis of learning gain (post-test-pre-test) represented the statistically significant differences between the groups: $F(2,118) = 6.894$, $p = 0.001$, $\eta^2 = 0.15$. However, the effect is minimal. The analysis of course enjoyment showed no significant difference between the three groups: Kruskal-Wallis $H(2) = 0.620$, $p = 0.773$, $\eta^2 = 0.005$. When grading students' academic self-efficacy, non-significant differences were found. Kruskal-Wallis $H(2) = 2.067$, $p = 0.356 > 0.05$, $\eta^2 = 0.017$.

4.3.3 *Qualitative data analysis*

The qualitative analysis of the open-ended questions of the questionnaire was done by using content analysis, where responses to the questions were read, then re-read while writing phrases related to enjoyment or self-efficacy. After coding five transcripts, we generated initial codes, which were used to code the remaining transcripts. We recorded the five transcripts used to generate initial codes while allowing new ones to emerge. Finally, the obtained codes were used to describe major issues regarding lesson enjoyment and the academic self-efficacy of students [74].

Analysis of course enjoyment revealed several themes related to students' pleasant experiences, perceptions, and attitudes towards the teaching strategies used. The following quotes illustrate the finding: Students' responses suggested that FC provides an enjoyable learning experience: *"I enjoyed the lessons"*, *"Very motivating" "I was active in the mathematics classroom"*, and *"It is the sum of knowledge and joy"*. Students also showed their attitude towards mathematics: *"I do not enjoy math lessons because I don not like it"*.

Qualitative analysis regarding academic self-efficacy revealed various themes, including increased academic ability, perceptions about teaching strategies, time to study, assessment, and classroom environment. Concerning academic ability, students related FC to increased academic ability: *"My performance in mathematics is getting better due to lessons..."* Regarding instructional strategies, it was revealed that cooperative learning improves performance: *"Through cooperation, it is easy to perform better"*. Further, students in FC class relate classroom involvement to understanding the subject matter: "Our lecturer allows everyone to contribute, which makes the topic more understandable". Findings also revealed that students need more time to study (*"I need more time to practise than other subjects"*), regular tests and exercises ("frequent tests and questions are needed"), and the use of technology in teaching and learning math ("... "Academic self-efficacy in math will improve if we get good classrooms with projectors" to improve their academic self-efficacy.

4.3.4 *Reflection on Phase 1*

The results of Phase 1 showed that, even though students enjoyed learning and were motivated, linking the FC to high academic self-efficacy did not help them learn well enough. Despite the improved learning gains, the effect size was small. Besides, students requiring more time to study suggested that the FC model used in Phase 1 provide less time for learning than expected. Besides, the findings of Phase 1 provided helpful feedback on what features to consider in an improved blended learning model. The findings suggested that using instructional videos, collaborative strategies, and frequent quizzes and exercises can successfully enhance student achievement in mathematics.

4.4 *Phase 2 analysis of practical problem*

After getting feedback from Phase 1, M-TLAM elements included FC design features to enhance students' motivation and academic achievement. It was decided that Phase 2 would customise these components, focusing on how to use ICT tools (Edmodo social media for learning and Moodle LMS), teaching-learning strategies (collaborative learning and metacognitive strategies), and embracing local cultural aspects to design a better blende-learning model for Tanzania's higher education context and solve the challenges observed in Phase 1. Further, we consulted the literature to determine more design elements to improve students' achievement and solve the practice challenges hampering the teaching and learning situation. We found that culture and metacognitive strategies are essential elements of effective collaboration among student groups.

4.5 *Phase 2 M-TLAM updated design*

Table 2. The updated mathematics teaching and learning activity model (M-TLAM)

Component	Aspect	Description
Teaching strategies	Collaborative learning	In class guided small group discussion and online metacognitive practices in groups of 5 to 6 students
	Metacognitive tasks	The four metacognitive self-directed questions in the IMPROVE Model [15]
Local culture	Group formation aspects i. Leadership ii. Group composition iii. Reward allocation	Aspects of culture that can influence collaborative learning. i. Benevolent leader ii. Friendship grouping iii. Equality reward rule
ICT	i. Edmodo-social media platform for learning ii.Moodle LMS iii. WhatsApp social media	i. To cater for online group interactions during metacognitive activities, sharing videos, quizzes (Edmodo) ii. Sharing learning materials (videos, text files) and quizzes (Moodle) iii. Provide support and additional explanations (WhatsApp) iv. Sharing video lecturers to students (WhatsApp 1st Phase)

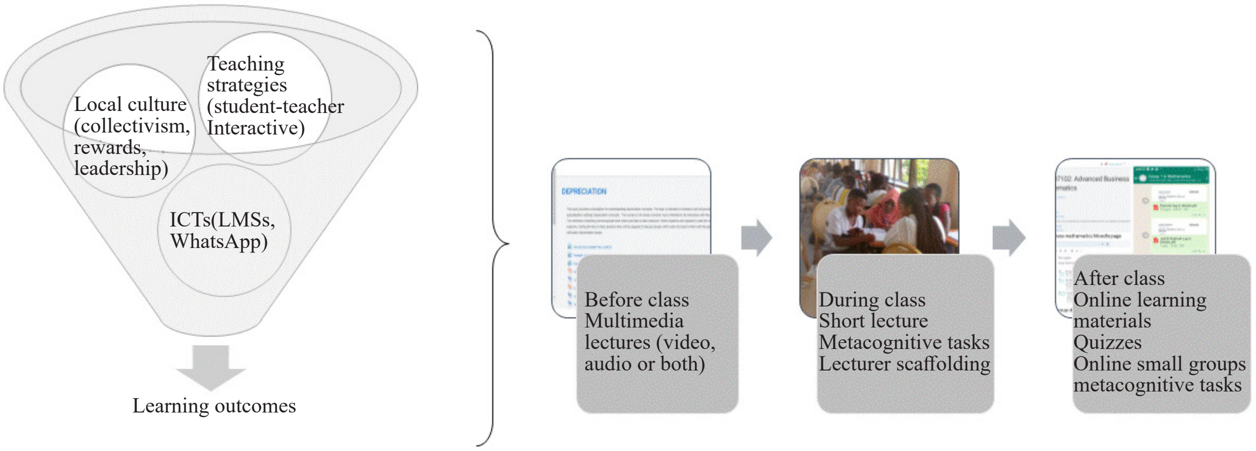


Figure 3. Left: the conceptual mathematics teaching and learning activity model (M-TLAM) for blended math instruction. Right: the model's practical implementation

The reviewed literature indicates that culture, teaching and learning strategies and ICT variables can influence students' mathematics learning outcomes. The conceptual model showing the combination of these variables is shown in Figure 3. The M-TLAM is a blended learning model combining face-to-face interactions and e-learning. Table 2 describes the model components.

5 Redesigned M-tlam implementation

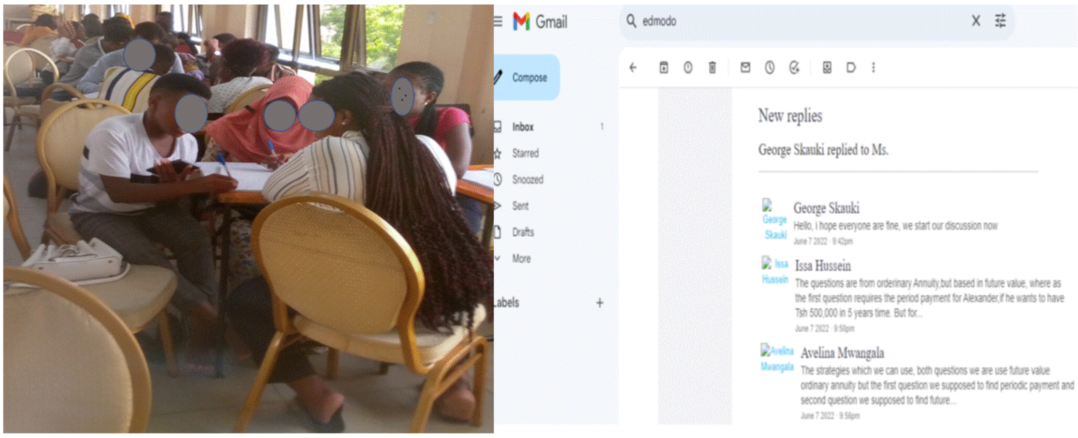
5.1 *Phase 2 testing and evaluation*

5.1.1 *Procedure*

A two-group pre-test/post-test control group design is adopted in which the experimental group is taught using the M-TLAM blended instruction approach while the control group is taught using a traditional lecture approach. The study was conducted in one of the researcher's classrooms at a higher education institution in Tanzania. Two classrooms (M-TLAM blended learning and traditional lecture) were compared during the first semester of 2021-2022. Students in the M-TLAM class watched instructional videos that lasted for up to 10 minutes before the next class. The 120-minute class period was used partly for a 30-minute short lecture and demonstration modelling metacognitive activities. The remaining 90 minutes were used for small group discussions where the lecturer provided them with a set of questions to discuss in groups of 5 to 6 students (see Figure 4a). In contrast, the lecturer cleared misconceptions and checked for completeness and correctness of their answers. After the class lecture, text files for learning material and practice questions were uploaded on the Edmodo platform or Moodle e-learning system for students to download further reading. The practice questions were meant for metacognitive activities outside the classroom (see Figure 4b, sample discussion threads from Edmodo). The experimental and control groups' course content, practice questions, and tests were the same. Thus, the only difference was that students in the experimental group watched video lectures before they attended class, had small group metacognitive practises within and outside the classroom, and received additional online learning materials and practice questions after the class. After the experiment, all students took a post-test exam and completed a survey to assess their course motivation, perception of the classroom environment, and experience. In addition, the experimental group completed another survey to ascertain factors (metacognition, ICTs, and culture) that account for the changes observed in their learning achievement. The experiment focuses on business mathematics fundamentals (compound interest, net present value, annuity, and depreciation topics). Table 3 shows the course activities' design for each unit lesson.

Table 3. The design of a business mathematics course using M-TLAM blended instruction-description and features of learning activities

Course units	Brief description	Learning activities
Compound interest	This unit introduces the concept of interest, differences between simple and compound interest, calculation of the interest rate, time and compound amount.	-Pre-lecture outside classroom preview (video) -Modelling metacognitive activities -Online post lecture material and metacognitive activities
Present value	Students learn the technique of present value and its application to future cash flows. This introduces them to the calculations of discounted cash flows for investments and methods of investment appraisals such as Net present values and internal rate of return.	-Pre-lecture (video) -Lecture and classroom activities -Online post lecture material and metacognitive activities
Net present values and Internal Rate of Return	Students learn investment appraisal techniques. They learn to calculate the net present value (NPV) and internal rate of return (IRR) for comparing projects, as well as to interpret the calculated values of NPV and IRR.	-pre-lecture video -Lecture -Post lecture test
Annuities	This unit introduces students to techniques associated with fixed payments over time. They learn the types, calculation of the future value, present value, and net present value of annuities.	-Pre-lecture video -Lecture and classroom activities -Online post lecture material and metacognitive activities -Post lecture test
Amortization and Sinking fund	Through this unit students learn methods of dept repayment and setting up funds to meet future obligations as well as their application in mortgage repayment, bank loans etc.	-Pre-lecture video -Lecture and classroom activities -Post lecture test -Post lecture online material and metacognitive activities
Depreciation	This unit introduces the meaning and methods of depreciation. Students learn to calculate the rate of depreciation and to prepare the depreciation schedule.	-Pre-lecture video -Lecture and classroom metacognitive activities -Post-lecture test -Online post lecture learning material



New replies

George Skauki replied to Ms.

George Skauki
Hello, i hope everyone are fine, we start our discussion now
June 7 2022 · 9:42pm

Issa Hussein
The questions are from orderinary Annuity,but based in future value, where as the first question requires the period payment for Alexander,if he wants to have Tsh 500,000 in 5 years time. But for...
June 7 2022 · 9:50pm

Avelina Mwangala
The strategies which we can use, both questions we are use future value ordinary annuity but the first question we supposed to find periodic payment and second question we supposed to find future...
June 7 2022 · 9:56pm

a. Students engaging in small groups classroomdiscussion

b.Sample of discussion threads from EdmodoNote:The Edmodo platform was closed before weconcluded lessons.

Figure 4. Students engaging in small groups discussion

The activities were designed so that students could access an outside classroom pre-lecture video preview, an inside classroom lesson lecture, inside classroom exercises and lecturer guidance, outside classroom post-lecture online material and metacognitive activities, and a class test after every 240 minutes of study. The experimental procedure is displayed in Figure 5.

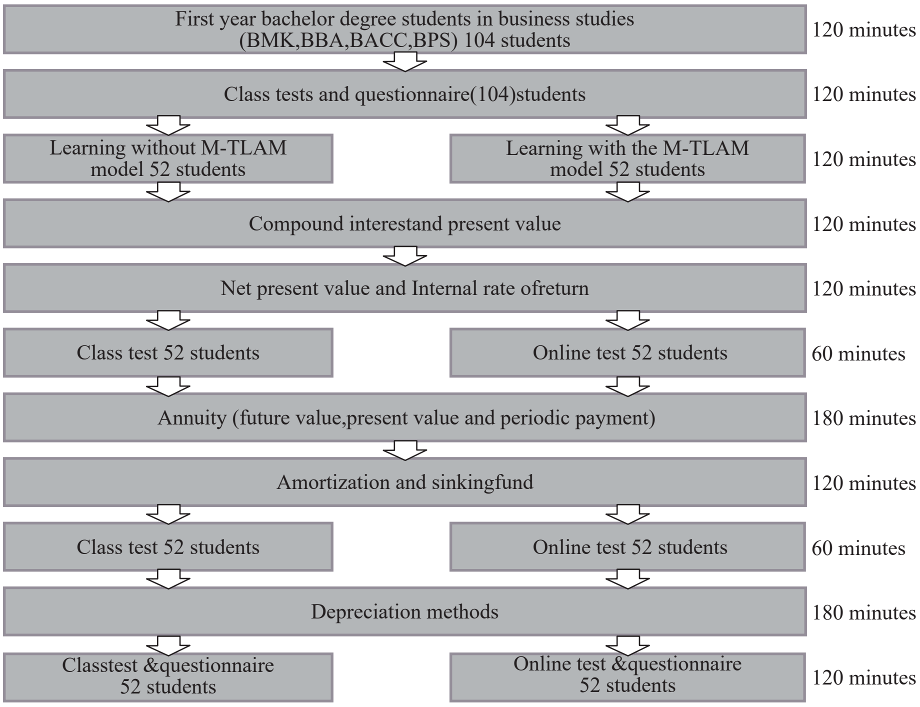


Figure 5. The experimental procedure of Phase 2

5.1.2 *Participants*

The participants in this study were 104 first-year bachelor's degree students (52 males and 52 females) studying business mathematics in 2021-2022. The business mathematics course applies several basic mathematics concepts and mathematics of finance concepts that students find difficult. Our interest was to emphasise the finance and mathematics aspects of the course to improve the overall course achievement. The students were pursuing full-time business studies, notably business administration, marketing, procurement and supplies, and accountancy. The M-TLAM classroom consisted of 52 students (24 males and 28 females), and the control group class consisted of 52 students (28 males and 24 females).

5.1.3 *Data collection instruments*

The research data in this study is drawn from six primary sources: a pre-quiz, three post-quizzes, a focus group discussion, and two questionnaires. The four quizzes were developed to evaluate students' academic achievement. The pre-quiz was designed to ensure that experimental and control group students had equal essential knowledge of the finance mathematics topic. The four quizzes consisted of 10 multiple-choice items, where students were required to solve a math problem and finally choose the correct answer. The total score for each quiz was 15 marks. The three post-quizzes covered various sections that focused on assessing students' knowledge of the mathematics of finance topics in the business mathematics course. Although quiz questions were prepared by one of the lecturers' researchers, three expert instructors evaluated the questions to ascertain their validity. The focus group discussion was conducted with eight students who participated in the course. The focus group discussion aims to assess students' pedagogical experiences, perceptions, and attitudes towards using the M-TLAM model for mathematics education. Furthermore, the classroom environment questionnaire was administered to all students to gather their perceptions, motivation, and pedagogical experiences about the mathematics of finance topics. The classroom environment questionnaire had 5 scales measured by teacher support (5 items scale, $\alpha = 0.8$), involvement (2 item scale $\alpha = 0.7$), cooperation (4 item scale, $\alpha = 0.7$), relevance (3 item scale, $\alpha = 0.7$), and motivation (5 item scale, $\alpha = 0.8$) scored on a five-point Likert scale, with 1 representing strongly disagree and 5 representing strongly agree. Respondents completed the questionnaire within 30 minutes. The second questionnaire, which we called the M-TLAM perception questionnaire, had five scales, including metacognition (7 items, $\alpha = 0.92$), culture (8 items, $\alpha = 0.96$), ICTs usage (5 items, $\alpha = 0.91$), collaboration (5 items, $\alpha = 0.92$), and pedagogical experience (6 item scale, $\alpha = 0.92$). Three experienced lecturers reviewed the questionnaire's content to ensure its validity. Thus, the tests and questionnaires were completed based on comments from specialists.

5.2 *Phase 2 data analysis*

We analysed data using qualitative and quantitative methods to answer the research questions. Research questions 1 and 2 were analysed through quantitative methods where means, standard deviations, and percentages were determined; t-tests, analysis of covariance (ANCOVA), and non-parametric ANCOVA were performed using SPSS IBM version 23 software. First, the dependent variables were examined to see if they met the requirements for the parametric ANCOVA. However, when the parametric ANCOVA assumptions were looked at, the Shapiro-Wilk test showed that the assumptions of equality of variance and normality of the distribution of outcome variables (measured by Levene's test) were not true. According to Kuznetcova [75], ANCOVA remains robust to the violation of equality of variances if the design is balanced, that is, if sample sizes in the control and experimental groups are the same, which is the case for the current study (the control group has 52 students and the experimental group has 52 students). Kuznetsova adds that when this condition is met, and the distribution outcome variable is moderately non-normal, the ANCOVA test still produces acceptable results. It is worth noting that parametric and non-parametric ANCOVA were used to cross-check the results in the same study, . In some circumstances, some deviations occurred, and the author used the non-parametric ANCOVA to interpret the results because this test decreased the probability of obtaining biased results. Since the data in the current study violated the parametric ANCOVA assumptions of normality and equality of variances, the non-parametric alternative to ANCOVA proposed by Quade [76] was applied. A confidence interval of 95% (0.05 significance level) was used to interpret of the data. To answer research question 3, we gathered both quantitative and qualitative data. Quantitative data were analysed through descriptive statistics such as the t-test, mean, and standard deviation, while qualitative data were analysed through content analysis. Regression analysis was used to analyse the data collected for research question 4, while content analysis and descriptive statistics were used to analyse the data for research question 5.

5.3 *Phase 2 quantitative results*

5.3.1 *RQ1: Student academic achievement*

To answer the research question, what is the effect of the M-TLAM model on higher education students' academic achievement in mathematics topics? We first analysed the data obtained from the pre-test to check the group's equivalence in terms of prior knowledge before the experiment. An independent t-test was used to analyse the pre-test (test 1) data, confirming that students in the two groups had equal prior knowledge about the topic before the experiment. The descriptive statistics results are displayed in Table 4.

Table 4. Descriptive statistics results of pre-test academic achievement

DV	Group of students	N	Mean	SD	t	p
Pre-test (Test 1)	Control	52	5.1152	0.3153	-1.896	0.061
	Experimental	52	5.2673	0.48502		

Results displayed in Table 4 show that there was no significant difference (t = -1.896, two-tailed p = 0.061) between the control and experimental groups. The two groups of students considered in the experiment had statistically equivalent prior knowledge at the beginning of the course. Further, a Quade's ANCOVA was performed to determine the differences between M-TLAM and traditional lecture classes on tests 2, 3, and 4, controlling for test 1 scores, and the results are presented in Table 5.

Results show that students who used the M-TLAM model performed significantly better than students who used the traditional lecture method in all three tests: F (1, 102) = 105.125, $p < 0.001$; F (1,102) = 9.580, p = 0.003; and F (1,102) = 116.89, $p < 0.001$ for tests 2, 3, and 4, respectively. Furthermore, we computed the effect size, d, which measures of the magnitude of a treatment effect between the two groups (Cohen, 1988). According to Cohen's benchmark, the effect size is defined as small (d = 0.2), medium (d = 0.5), and large (d = 0.8). In this study, Cohen's d values (see Table 5) range from 0.695 to 2.259, indicating a medium to large effect size. This result shows that using the M-TLAM approach has helped improve students' academic achievement.

Table 5. Descriptive statistics and Quade's ANCOVA result for the post-test academic

DV	N	Meancontrol (SD)	Mean experimental (SD)	F	p	d
Test 2	104	22.69 (17.91)	74.18 (30.82)	105	0.000	2.04
Test 3	104	43.90 (29.76)	61.10 (23.20)	9.58	0.003	0.695
Test 4	104	31.29 (21.27)	73.71 (16.33)	116.89	0.000	1.92

Note. DV = dependent variable. Test1 = covariate; The means and SD were calculated based on raw ranked data

5.3.2 *RQ2: Motivation towards learning mathematics*

To answer the research question, what is the effect of the M-TLAM model on higher education students' motivation towards learning mathematics topics? We first conducted an independent t-test on pre-motivation scores, confirming that students in the two groups had equal prior motivation towards mathematics. The descriptive statistics results are displayed in Table 6.

Table 6. Descriptive statistics results of students' motivation before the M-TLAM were applied

DV	Group of students	N	Mean	SD	t	p
Pre-motivation	Control	50	55.74	31.35	-1.292	0.199
	Experimental	51	48.19	27.85		

Note. The means and standard deviations were calculated based on the raw ranked data

Results displayed in Table 6 show no significant difference (t = -1.292, two-tailed p = 0.199) between the control and experimental groups in their motivation towards mathematics before the experiment. A Quade's ANCOVA was used to estimate the effect of M-TLAM on students' motivation towards learning mathematics (the normality assumption was violated), predicting students' motivation at post-motivation scores while controlling for pre-motivation scores. The results are presented in Table 7.

Table 7. Descriptive statistics and Quade's ANCOVA result of students' post-motivation

DV	Group of students	N	Mean	SD	F	p	d
Post-motivation	Control	50	41.46	33.00	10.296	0.002	0.68
	Experimental	50	60.35	21.34			

Note. The means and standard deviations were calculated based on the raw ranked data

Results show that students who used the M-TLAM model had significantly higher motivation compared to those who used the traditional lecture method (F (1, 98) = 10.296, $p < 0.05$, $d = 0.68$), indicating a medium effect size. This finding shows that using the M-TLAM approach has helped to improve students' motivation towards learning mathematics.

5.3.3 *RQ3: Student experience about using the M-TLAM model*

To answer the research question, what are the students' experiences using the M-TLAM model in learning mathematics? Students' experiences were assessed based on their perceptions of the classroom environment and pedagogical experiences. First, a questionnaire containing both open-ended and closed-ended questions was administered to both the control and experimental groups to obtain their perceptions of the classroom environment. Further, students from the experimental group were asked about their experience using the M-TLAM model for learning mathematics. The data gathered were analysed using both quantitative and qualitative methods. In the case of quantitative analysis, descriptive statistics results obtained from the t-test analysis of the questionnaire are presented in Table 8. Results displayed in Table 8 show that the perceptions of experimental group students were significantly better ($t = 5.87$, $p < 0.05$, $d = 1.15$) than those of the students in the control group.

Table 8. Descriptive statistics results on students' perception about classroom environment

Variable	Group of students	N	Mean	SD	t	p
Classroom environment	Control group	52	3.86	0.35	5.87	0.000
	Experimental group	52	4.23	0.29		

Furthermore, we analysed the perceptions of the experimental group regarding their pedagogical experiences using the M-TLAM model. In order to say that students using the M-TLAM model had a better learning experience, they have to score a mean value of 3.0, the midpoint of the scale. As presented in Table 9, the values vary between 4.19 and 4.55 for individual items measuring learning experience. These values are far above 3.0, indicating that students had a pleasant experience; the overall mean score = 4.43.

Table 9. Descriptive statistics of questionnaire results about student experience with M-TLAM approach

Students pedagogical experience	Mean	SD
Q1. Where the M-TLAM model was used, the blended learning (face to face and online) experience helped me to learn mathematics of finance topics	4.19	0.48
Q2. Resources on Edmodo/Moodle course platform and face to face lecturers have supported my learning	4.55	0.57
Q3. My online group discussion experiences helped me on engaging actively in my learning of mathematics of finance topics	4.42	0.56
Q4. Communicating online with peers and course instructor helped my learning	4.52	0.45
Q5. The online learning experiences on this course was well-integrated with my face-to-face learning context	4.45	0.57
Overall pedagogical experience	4.43	0.43

5.3.4 *RQ3-Qualitative data-Open-ended questionnaire*

Table 10. Analysis of students' opinion regarding the M-TLAM

Theme	Aspects	Example quotations
Improved academic achievement	Improved grades	I am sure that I will get good grades at the end (Student 6)
	Increased self-efficacy	My ability in math has increased because we practice (Student 38) I found it very easy not difficult as I thought in my previous education level (Student 2)
Improved learning motivation	Lesson enjoyment	I am an enthusiastic learner who enjoys mathematics class (Student 21).
	The usefulness of mathematics in real life	… am about to engage in business, and I am thrilled to learn topics like annuities and depreciation because they help me to understand what I am about to do with my business. (Student 12)
Pedagogical experience	Enhancement of teamwork and cooperation	Math is perfect when you do in teamwork (Student 27); We have high cooperation (Student 38)
	Active learning experience	Solving and repeating questions that the lecturer provides us enable me to be an active learner (Student 7)
	Opportunities for self-paced learning	Face-to-face classes include many students, while others are not paying attention to learning, so they disturb others, but online, participants participate based on the topic. (Student 13)
	Enhancement of peer support	They are helping me to gain more knowledge about mathematics (Students 25), They give me complete support, and I give them support (Student 28)
	Aspects of teacher support	Our lecturer is understandable, loves to help, and wants to share more quizzes with us (Student 9) Support from our teacher is good, especially when doing online activities (Student 5)
	Perception about assessment frequency and practice questions	… provide tests or more diverse assessments, begin with simple questions too complex to give students opportunities to better understand the topics (Student 7) In order to be good at mathematics, you should solve more questions every day. (Student 13)
Technical and contextual issues	Time allocation for quizzes	I will change the time for working on the online quiz because I need more time. (Student 3)
	Quiz question's structure	Students should practise answering different, from simple to complex, topic-specific questions to improve their accuracy and speed (Student 10)
	Teaching facilities	Not all students have the devices that will allow them to learn online. (Student 27). ... to use projectors when teaching due to the large class (Student 20). … lecturers use voice devices to improve teaching and learning in large classes. (Student 34)
	Classroom environment	…We cannot hear properly because the class is large. Backbenchers find it challenging to learn, so online learning is ideal. (Student 44)
Perception and attitude towards blended learning environment (M-TLAM)	Attitude towards e-learning	E-learning through the internet would help students learn a lot, especially if tests and assignments are done online. (Student 37)
	Attitude towards blended learning	I recommend both methods because some calculations cannot be done online and must be taught face-to-face to fully understand. (Student 21)
	Immediate feedback	It helps that you attempt the quiz and immediately receive your grade and feedback. (Student 38)
	Perception about discussion with metacognitive questions	I could not find future value or original cost before the discussion. I used to understand the formula but I did not know how to use it. Thanks to the self-questioning method and my colleague's support, I can now do so. (Student 30)
	Opportunity for anywhere and time learning	Online learning is ideal because I can complete exams, quizzes, and tests anywhere outside of the classroom. (Student 15)
	Enhanced self-efficacy	I will opt for blended learning because it improves the overall efficiency and efficacy of the learning process. (Student 28)
	Opportunities for frequent assessment	I would change the lecture-based only approach to studying online in order to get more quizzes and tests to evaluate my level of understanding (Student 31)
	Opinion about rewards structure	Also, reward those who volunteer to do arithmetic in order to inspire others to work hard and succeed completely (Student 31)

In the case of qualitative data, we provided an open-ended questionnaire to determine students' pedagogical experiences, perceptions, and attitudes about the M-TLAM blended learning model. The data from open-ended questions was first transcribed verbatim. Then it was analysed through content analysis, where the analysis began by reading the transcripts, highlighting relevant pieces, deciding which codes were the most important, and creating categories (themes) by bringing several codes together. Finally, the final categories were used to describe significant issues about students' experiences, perceptions, and motivation towards the M-TLAM blended learning model concerning each research question. Oyelere [77] articulates that a study's value is shown by how well it finds themes and how those themes relate to the research questions. The identified themes are summarised in Table 10.

5.3.4 *RQ4-Variables that account for the observed changes in students' achievement*

To answer the research question, what are the variables and relationships between them that account for the observed changes in students' achievement? We performed a linear regression analysis of culture, ICT use, and strategies identified as collaboration on academic achievement and motivation. Academic achievement consisted of motivation measured by course enjoyment and academic performance measured by test scores.

The relationship between academic achievement as measured by test score and motivation

First, it was examined whether motivation to learn math and academic achievement are related. A simple linear regression analysis was performed to test if the motivation to learn math significantly predicted academic achievement. The results showed that motivation to learn math significantly predicted academic achievement (see Table 11); $R^2 = 0.27$, $F(1, 90) = 7.25$, $\beta = 0.91$, $p < 0.05$, 95% CI [0.24, 1.58].

Table 11. Regression analysis of motivation on academic achievement (Test scores)

Model	Variable	Coefficient	t-stat	p-value	95% LCI	95% UCI	R2	F
	Motivation	0.91	2.69	0.01	0.24	1.58	0.27	7.25

Determinants of motivation as measured by course enjoyment.

Next, it was examined whether ICT usage and culture predict motivation as mediated by collaboration. The Sobel test was utilised to examine if collaboration mediated the relationship between ICT usage, culture, and motivation to learn math. First, results of multiple linear regression shows that ICT usage was a statistically significant predictor of motivation ($b = 0.55$, beta = 0.30, $t = 2.31$, $p < 0.05$), as was culture ($b = 0.59$, beta = 0.55, $t = 4.25$, $p < 0.05$). Next, when the mediator, collaboration, was entered into the regression analysis, ICT usage was no longer a significant predictor of motivation ($b = 0.30$, beta = 0.16, $t = 1.35$, $p = 0.18$). However, culture was a statistically significant predictor of motivation ($b = 0.42$, beta = 0.39, $t = 3.23$, $p < 0.05$). On the other hand, the mediator, collaboration, emerged as a significant predictor of motivation ($b = 1.13$, beta = 0.76, $t = 8.07$, $p < 0.05$; 95% CI = "0.85" to "1.41"). The Sobel test was utilised to examine if collaboration significantly mediated the relationship between ICT usage, culture, and motivation, to investigate the mediator further. The results confirmed that collaboration significantly mediates the relationship between culture and motivation ($Z = 2.09$, $p < 0.05$), but the relationship between ICT usage and motivation was not significant ($Z = 1.89$, $p = 0.06$). This result confirms that collaboration is a partial mediator of culture, and a full mediator of ICT usage.

Furthermore, we examined if there was a relationship between metacognition and collaborative learning. Results of linear regression show that metacognition was a statistically significant predictor of collaboration ($b = 0.28$, beta = 0.467, $t = 3.655$, $p < 0.001$; 95% CI = "0.13" to "0.44").

Table 12. Predicting motivation to learn from culture and ICT usage mediated by collaboration

Model	Variable	b	beta	t-stat	p-value	95%CI LCI	95% CI UCI	R2	F
Without mediator	culture	0.59	0.55	4.25	< 0.05	0.31	0.86	0.64	41.52
	ICT	0.55	0.30	2.31	0.03	0.07	1.03		
With mediator (collab)	culture	0.42	0.39	3.23	< 0.05	0.16	0.68	0.72	40.28
	ICT	0.30	0.16	1.35	0.18	-0.15	0.74		
	collab	0.60	0.40	3.78	< 0.05	0.28	0.92		
Mediator	collab	1.13	0.76	8.07	< 0.05	0.85	1.41	0.58	65.12
Sobel test	Variable	z	SE		p-value				
	ICT	1.89	0.13		0.06				
	culture	2.09	0.08		0.04				
Met→collab	Variable	b	beta	t-stat	p-value	95% CI LCI	95% CI UCI	R2	F
	met	0.28	0.47	3.66	< 0.05	0.13	0.44	0.47	13.36

Note: LCI = lower confidence interval, UCI = upper confidence interval, cult = culture, collab = collaboration, Met = metacognition

5.3.4 *RQ5. Lecturers' perception on motivation, and competencies towards using the M-TLAM model*

To answer the research question, What is the teacher's perception of their motivation and competencies towards using the M-TLAM model? A questionnaire comprising ten statements on the Likert scale and one open-ended question was distributed to seven mathematics lecturers at the CBE. Five items represented the lecturers' perceptions of their motivation to use the M-TLAM, and five represented their perceived competencies. The mean score ($M > 2.5$) indicates positive perception, and the mean score ($M < 2.5$) indicates negative perception. The lecturers' perceptions of using of M-TLAM in teaching and learning mathematics are shown in Table 13.

Table 13. Lecturer's perception on motivation and competency towards using the M-TMLAM model in mathematics education (N = 7)

Statements	Responses %					
	Not at all	small extent	Moderate extent	Large extent	Mean	SD
The M-TLAM model is suitable for teaching and learning mathematics.	0.00	0.00	14.30	85.70	3.86	0.38
I believe that the use of M-TLAM can improve my teaching performance.	0.00	0.00	14.30	85.70	3.86	0.38
The use of M-TLAM can make learning activities more interesting and enjoyable.	0.00	0.00	0.00	100.00	4.00	0.00
I am sure that the use of M-TLAM can facilitate student-centred learning.	0.00	0.00	28.60	71.40	3.71	0.49
The use of M-TLAM provides convenience in assessing thestudent's progress.	0.00	0.00	42.90	57.10	3.57	0.53
The use of M-TLAM comes with a lot of technical challenges.	0.00	42.90	57.10	0.00	2.57	0.53
I can organize and supervise my students' collaborative activities (both online and face-to face).	0.00	0.00	28.60	71.40	3.71	0.49
I can distribute learning materials, assignments, and grades and organize instructional videos and quizzes via online platforms.	0.00	0.00	42.90	57.10	3.57	0.53
I believe in my ability and knowledge to use the M-TLAM model in teaching activities.	0.00	0.00	42.90	57.10	3.57	0.53
I can continue to integrate M-TLAM into my teaching activities in the future.	0.00	0.00	28.60	71.40	3.71	0.49

As shown in Table 13, lecturers' ratings of their motivation towards using the M-TLAM indicate that the M-TLAM is suitable for mathematics teaching ($M = 3.86$), that it can improve their teaching performance ($M = 3.86$), that it provides an enjoyable and exciting learning environment ($M = 4.00$), that it facilitates student-centred learning ($M =

3.71), and that it is convenient when it comes to students' progress assessment (M = 3.57). However, to a moderate (M = 2.57) extent, the lecturer believes that the adoption of the M-TLAM comes with technical challenges, such as limited internet connectivity ("In many parts of the college environment, there is limited access to the internet, which makes students struggle to access the online material") and a lack of support ("there is ambiguity in getting clarification at the moment they need explanations while using e-learning").

Furthermore, the rating of their capability to use the M-TLAM indicates that the majority believes in their ability and knowledge (M = 3.57) to implement the M-TLAM model in teaching math, as they believe in their ability to organise and supervise students' collaborative activities (M = 3.71), set and distribute online quizzes, as well as instructional videos (M = 3.57).

6. Discussion

The aimed to test and evaluate a blended learning model developed especially for the context of an emerging economy such as Tanzania. Our focus was not only on M-TLAM's potential to improve students' academic achievement and motivation but also on teachers' and students' pedagogical experiences and attitudes and the factors accountable for the observed learning outcomes. It is anticipated that teachers' and students' familiarity with and experience with the M-TLAM model will be indispensable to ensuring positive usage in mathematics education. Therefore, the current study investigated the potentials offered by blended learning models and ascertained users' perceptions and variables accounting for the observed potentials of the model.

6.1 *RQ1: Student academic achievement*

Concerning academic achievement and motivation, it was discovered that there was a significant improvement in students' academic achievement after using the M-TLAM model in mathematics education in a Tanzanian higher education institution. At the start of the study, all students had equivalent prior knowledge about math topics. We used an independent t-test to compare the academic achievement and motivation of two groups of students (those who used M-TLAM and those who did not) by looking at their pre-quiz and pre-motivation scores. The two groups did not statistically differ before the experiment. We then administered treatment over 11 weeks of lessons, conducted a post-treatment test, and offered a post-motivation questionnaire. The non-parametric ANCOVA analysis performed on students' test scores and motivation scale indicated that the experimental group, which used M-TLAM to support their learning, had higher scores and was highly motivated than the control group, which did not use M-TLAM.

These results were consistent with other studies that have shown that the application of blended learning models could improve students' academic achievement and motivation [57-59]. However, it differs from other studies that applied the flipped classroom model to math education and found comparable results or no improvement in students' performance [11, 10]. The current study is slightly different in focus from previous work. For example, Lee et al. [58], Lopez and Soares [59], Umam et al. [65], Carter et al. [63], Vo et al. [57], and Amstelveen [11], which predominantly explored flipped classroom from different perspectives, such as designing a general model for guiding the design and implementation of flipped classroom, satisfaction factors with flipped classroom, adequacy and perceptions of flipped classroom, the impact of flipped classroom on students attitudes and performance, and the meta-analysis of the effects of flipped classroom integration on learning performance. While these reports are interesting, our findings extend current research with the novel combination of contextual factors such as culture, pedagogical strategies, and ICTs in the design of blended instruction bringing about noticeable improvements in academic achievement and motivation.

Our findings regarding academic achievement represent a significanly large effect of using the M-TLAM model (d = 0.70-2.04) compared to traditional lectures. This difference in performance between blended learning and traditional lecture was evident in our study and much higher than that reported by Vo et al. [57]. Their meta-analysis, found that BL is linked to a significantly higher mean effect size ($g+ = 0.496$) in learning performance in STEM courses than in non-STEM disciplines. This finding may be because M-TLAM implementation may have increased the accessibility of learning materials, making students' learning activities available anytime, anywhere, which may prove advantageous [77]. In the current study, we provided online learning resources such as videos, text-based materials, and quizzes with immediate feedback features. These features were designed to be interactive, enjoyable, and attractive for students to engage with rather than reading a book [60]. The improvement in academic performance may also have been attributed to the discussion problem sets coupled with metacognitive questions, which were designed to facilitate student-to-student interactions as well as those with their lecturer and, consequently, the development of critical thinking skills. The after-class discussion questions and assignments had a manageable cognitive load. They included instructor guidance on problem-solving using metacognitive questions, which might have helped students less proficient in higher-order thinking skills close the learning gap. Another reason could be that the M-TLAM model encouraged collaborative learning and a peer-teaching environment convenient for each group member to access anytime and anywhere. This learning environment might have opened opportunities for students to interact with the lecturer and learn from other group members. Considering these features, the study extends previous FC studies by adding after-class online collaboration with metacognitive tasks to enhance students interactions and boost their critical thinking abilities, resulting in higher academic achievement.

6.2 *RQ2: Motivation towards learning mathematics*

Regarding motivation, blended learning had a significant medium-positive effect ($d = 0.68$) on student motivation compared to traditional lecture. Lin et al. [64] also said that students in the blended learning classroom had a better attitude, had more fun, and were more motivated to learn math than students in the traditional lecture classroom. However, the effect size was slightly smaller (for the motivation component in [56] compared with the current study. Based on these findings, the increased motivation was likely a result of teaching strategies that encouraged students to pay more attention during class discussions and online learning activities. Using both a virtual environment and face-to-face interactions, the M-TLAM model encourages a good attitude and a desire to learn. This model makes it easier for students to talk to each other and their lecturers. Through these conversations, students could have become more interested in math. This good motivation shows potential for the M-TLAM blended learning model's effectiveness.

6.2 *RQ3: Student experience about using the M-TLAM model*

Regarding the student's learning experience, the perception of the classroom environment by students who used the M-TLAM was significantly better ($t = 5.87$, $p < 0.05$) than that of those who did not, with a large effect size of $d = 1.15$. Furthermore, regarding the analysis of the M-TLAM pedagogical experience, students showed a considerably better experience (the overall mean of the scale was 4.43, SD 0.43). The item-by-item scale analysis shows that students believe the blended learning approach helped them improve their learning ($M = 4.19$, $SD = 0.48$). They also believe that the online learning resources ($M = 4.55$, $SD = 0.57$), collaborative activities ($M = 4.42$, $SD = 0.56$), and communication with peers and the lecturer ($M = 4.52$, $SD = 0.45$) helped them learn math better, indicating the potential for the M-TLAM model's effectiveness.

Also, qualitative results showed that students think blended learning is the best way to learn math. Frequent online quizzes and immediate feedback are good ways to help students feel better about their math skills and get more interested in the course. They also linked M-TLAM to better grades, active learning, learning at your own pace, and getting more help from peers and teachers. Students also believe that metacognitive questions improved their learning of mathematics. Consequently, students had really positive experiences using the M-TLAM in mathematics education. The results obtained are aligned with previous studies reinforcing the role of a blended learning approach in enhancing learning outcomes, active engagement with the course, increasing students' interest in participating in learning activities, collaborating with peers, the role of regular quizzes and instant feedback, and the role of teachers in providing clear instructions and guidance [64]. However, our results slightly differ from those of Sointu et al. [67], as they showed that feedback, collaborative learning, and support from other students were not directly related to a positive experience with the FC model.

The reason for this was that students could not fully take advantage of the collaborative learning situations or that the collaborative activities did not serve the learning goals set for the course. In our study, the collaborative activities played a more significant role in students' positive experiences with the course as they were designed to fit the cultural perspectives of the students, which we believe might have made students freely contribute to discussions as they were comfortable talking in front of a close friend or the fact that the use of metacognitive questions helped in achieving effective group discussions. In this study, we framed culture around friendship grouping, equality-based reward structure, and formal leadership, which effectively enhanced group discussion. These results indicated good prospects for the M-TLAM model's effectiveness; however, there are some contextual challenges regarding time allocation for online quizzes, quiz composition, access to ICT tools (e.g., mobile phones, laptops) for accessing the online activities, as well as classroom projectors. Nevertheless, higher education students in Tanzania usually have easy access to technologies like networks, devices, and skills, and the college offers free internet access and desktop computers to give students even more ways to use technologies [10]. Therefore, students are encouraged to access ICT facilities in computer laboratories or the college library, including desktop computers and internet connections. The college administrators should also provide 24/7 access to these facilities to students and lecturers to facilitate the online learning component of the model.

6.3 *RQ4-Variables that account for the observed changes in students' achievement*

About the variables that account for the observed changes in students' learning achievement, we considered those variables that affect motivation measured by enjoyment [3], which consequently affects academic achievement. The aim was to provide a comprehensive picture of the factors that create a successful M-TLAM model. We first predicted academic achievement from motivation, and the results showed that motivation, as indicated by lesson enjoyment, is a significant predictor of academic achievement. This result matches other studies [3] that found enjoyment is a positive and significant predictor of student learning motivation. Also, Garca et al. [49] say that motivation from enjoying math significantly affects academic success more than other affective factors. This finding means that lecturers need to find ways, such as adopting the M-TLAM, to make math lessons fun, which will encourage students to learn the subject.

Regarding motivation to learn math, it was found that both ICT usage and culture significantly predicted motivation to learn mathematics. Collaboration was also found partially mediate the relationship between culture and motivation to learn mathematics (based on enjoyment of mathematics scores). This finding is consistent with previous literature stating that students' cultural backgrounds can affect their motivation to learn [31]. For instance, Ramburuth and McCormick [32] found that Australian students (individualistic culture) scored significantly higher on surface motivation than Asian students (collectivist culture), who tended to be deeply motivated. Since culture was a positive predictor of students' motivation, the model predicted that the more the teaching strategies were aligned with the students' cultural characteristics, the more they would be motivated to learn mathematics. Collaboration was a significant predictor of motivation and a partial mediator of culture, accounting for significant variance in the relationship between culture and motivation. This result is consistent with earlier literature suggesting a strong link between culture and collaborative learning. It was explained in the study of Tang [30] that Asian students' more robust collaborative learning styles than their Australian counterparts are sometimes attributed to Confucian beliefs that emphasise the group over the individual.

ARPACI [29] also investigated the relationship between cultural orientations and collaborative learning and illustrated the importance of culture in predicting collaborative learning behaviours [29]. On the other hand, the results show that collaboration fully mediates the relationship between ICT usage and motivation to learn mathematics. The finding implies that ICT usage results in increased collaborative activities, which enhances students' motivation to learn math. This coul result from incorporating the online small-group discussion feature into our model, where students had to discuss math problems using metacognitive questions. The relationship between ICT usage, collaborative learning, and motivation has also been discussed in earlier research. For example, Higgins [23], in a meta-analysis of 24 articles, showed that ICT usage in mathematics education has a moderate positive effect (mean effect size = 0.53) on student motivation to learn. Wang et al. [78] showed that using mobile social apps for learning can support collaborative learning through knowledge sharing, which may enhance students' satisfaction. Further, Resta and Laferrière [48] depict strong and consistent evidence showing that collaborative learning, whether online or face-to-face, results in increased motivation to learn the subject and satisfaction with the course. Furthermore, our findings showed that metacognition was a positive and statistically significant predictor of collaboration. The metacognitive tasks feature is a new addition to collaborative activities in FC classrooms.

6.4 *RQ5-Lecturers' perception on motivation, and competencies towards using the M-TLAM model*

Regarding lecturers' perceptions of motivation and competencies towards using the M-TLAM, results show that most lecturers have responded positively to each questionnaire statement. The lecturers believe that using M-TLAM will improve teaching performance and support student-centred learning, consistent with the curriculum requirement for a competency-based approach adopted in higher education in Tanzania. urther, lecturers believe that M-TLAM increases students' motivation to learn, making learning exciting and enjoyable. They also believe that the M-TLAM is a convenient approach to conducting student assessments. Regarding lecturers' competencies, most believe in their abilities to integrate M-TLAM into mathematics education. The majority believes in their ability to organise and supervise online and face-to-face group discussions and distribute online learning materials, video lectures, and quizzes. These positive responses indicate that lecturers are motivated and competent to use M-TLAM in teaching and learning mathematics. Despite the excellent motivation and competencies, lecturers think that challenges such as technical support and the unreliability of internet access might hinder the successful usage of M-TLAM in mathematics teaching and learning. This is contrary to an earlier study by Mazana et al [3], which found that the majority of teachers and students had the required skills to use ICTs in learning and were optimistic about the internet's accessibility and speed, and their budget capacity to buy internet bundles possibly. Online learning requires stable internet access and affordable data packages.

7. Contributions

The current study used the DBR framework, which according to Weerasinghe [12], supports three-fold contributions, notably interventions, design knowledge, and professional development.

7.1 *Intervention*

The intervention could be a teaching and learning guide, learning content, an online course environment, a pedagogical model, and so on. The output of the current research is a pedagogical model, so the contribution in terms of intervention is the teaching and learning activity model for mathematics blended learning instruction (M-TLAM). The model was evaluated for learning effectiveness (academic achievement and motivation) and student experience with the course. The findings indicated that the students had a positive experience and that their academic achievement was enhanced. The lecturers also found the model helpful in enhancing mathematics teaching and learning activities. Further analysis of the data revealed that the variables and design features of the M-TLAM model could lead to enhanced motivation to learn math, which improves academic achievement. The M-TALM model reported in this study contributes to the field of blended learning by supporting the design of blended learning instruction aimed at enhancing mathematics skills needed in business courses and other fields. Mathematics lecturers can use the M-TLAM model to guide designing blended learning instructions to enhance teaching and learning in higher education institutions. It can also support curriculum developers and instructional designers in developing effective blended learning courses that are in line with indigenous cultural perspectives.

7.2 *Design knowledge-implication for teaching and learning design*

The second output of the DBR process is design knowledge, which could be in the form of design principles, theories, or lessons learned. Our study aimed to determine factors and their relationships that could promote students' learning achievement. Regression analysis of the factors showed that both culture and ICT usage led to improved motivation through collaboration. Specifically, culture, directly and indirectly, affected motivation, while ICT usage was found to affect motivation only through collaboration. These findings mean that the online group discussions with metacognitive questions led to improved motivation. Additionally, students' experiences and perceptions of the classroom environment reported in the open-ended questionnaire revealed that students appreciated the combination of online and face-to-face lessons, support from both lecturers and peers, frequent quizzes with immediate feedback, video lessons before class time, online learning material, collaboration with peers, reward structure, and online group discussions. They also proposed to have more time during the online quizzes and were sceptical about access to ICT devices, as reported in Tables 9-10. Students' opinions and suggestions were used to identify a set of instructional design principles and guidelines in Table 14.

Table 14. M-TLAM design principles

General guidelines	Specific guidelines
Principle 1: Consider students culture in designing collaborative learning	
The instructional design, precisely the collaborative learning strategy, should be designed in line with the local culture.	-Consider grouping structures based on positive social interdependency, such as friendship grouping. -Consider a mechanism for appointing a group leader, and let students select their group leaders. -Consider applying reward structures based on equality whereby each student in a group receives the same grade regardless of their contributions. Alternatively, assess each student contribution, and the final group grade is the average of each member's grades. -Consider individual rewards in the form of teacher approval when individual students volunteer to answer questions or explain a concept to motivate others to contribute to the learning process.
Principle 2: Facilitate metacognitive training through small-group learning	
Design small-group discussions using metacognitive questions.	-Prepare metacognitive tasks for each lesson. -Facilitate small-group problem-solving using metacognitive questions. -The lecturer can upload the metacognitive questions and a set of math problems for group discussion or post them into the group discussion forum as required.
Principle 3: Identify ICT tools to be used to deliver the course	
Identify ICT tools for sharing lecture videos/audio and quizzes as well as out-of-class online group discussions.	-Use a learning management system to deliver videos, audio, and quizzes to students. -Use a social media platform for online group discussion, metacognitive tasks, guidance, and support. -teach students to use their mobile phones or smartphones for educational benefits, i.e., accessing online videos, audio, and lecture notes. -Help those who do not have smartphones access computers in computer laboratories to facilitate online discussions. -Send video, audio, and other materials via their emails to those without smartphones.
Principle 4: Structure the Lessons	
The lessons should be structured in line with the FC model, with an addition to the online group discussions after the face-to-face sessions. For each lesson, a lesson begins with a video before the class; during the class, give a short lecture, followed by small group discussions; after the class, send lecture materials and metacognitive tasks, which end with a quiz.	-Online lessons: The online lessons begin with a video sent to students three days before the class. After the class, send lecture materials in the form of PowerPoint and Word documents, as well as math problems for metacognitive activities, and end with an online quiz. -Face-to-Face: The face-to-face session begins with a short lecture of about 20 minutes exemplifying problem-solving with metacognitive questions regarding the lesson materials watched in the pre-video. -The small group discussions follow the short lecture about the video students watched before the class. A lecturer oversees these discussions.
Principle 5: Allow effective multimedia learning by using short video or audio lessons for out-of-class prior to a lesson	
Record videos or add audio to the PPT slides you have prepared as appropriate.	-The video or audio should be short (6-10 minutes) to motivate students to engage in the lessons. -Instructional videos can be self-created or adopted from the available quality resources
Principle 6: Structure the learning content	
-Display the course's outline and each session's learning outcomes at the start of each segment. -Course content should be arranged logically in accordance with the syllabus. -Each learning unit should have practice questions and metacognitive tasks. -Put a quiz at the end of each course lesson material	-Organise the course content (video, ppt, word, PDF files, quizzes) sequentially to allow students to start with the first activity they're supposed to do. -Organise discussion forums for each section of a course unit.
Principle 7: Design support system	
-Facilitate lecturer support both online and face-to-face through guidance and feedback. -Facilitate peer support through small group discussions.	-Create a WhatsApp group that the lecturer will moderate, or use any other social media platform, for students to share questions and answers with their peers. -students can use this platform to ask questions and give each other feedback on their questions. -From time to time, the lecturer should check for continuation and offer corrective enrichment where students have gone astray. -Create online-based small groups based on friendships with a formal leader who can monitor and regulate discussions. -Ask students questions at the end of each video lesson to begin their discussions. -Guide their discussion by teaching them to use metacognitive questions to go about solving math problems.

Table 14. (cont.)

General guidelines	Specific guidelines
Principle 8: Design evaluations (online quizzes) to students learning achievement	
-Place the quiz at the end of each course content. -The quiz questions should be in line with the course curriculum. -Give enough time to think and solve the questions (1 hour-1:30 hours). -The quiz questions should be based only on the materials covered in the course section placed. -Prepare enough questions to allow random assignment of the questions. -The quiz should contain content-specific questions ranging from simple to complex tasks and real word problems.	-To encourage students to answer correctly, give them a second chance to take the quiz. -Add constructive feedback on how to answer the questions for students.

7.3 *Professional development*

The third contribution is the professional development of researchers, as elaborated in the following paragraphs:

Professional development: experience gained. The authors of this article used a set of FC design principles and guidelines to design the blended learning model (M-TLAM) for mathematics courses in a bachelor's degree programme at the CBE. One of the authors also used this model in teaching a business mathematics course. Additionally, the M-TLAM was introduced to other mathematics lecturers at the college, whereby one lecturer participated in the design of the teaching sessions of Phase 2 in collaboration with the first author of the article and found it beneficial. Therefore, these outputs could contribute to the author's professional development and other lecturers' development at the CBE.

Professional development: understanding how ICT usage, culture, metacognition, and collaborative learning factors that make up the M-TLAM model can be combined to enhance students' mathematics learning. In order to study how students' learning of mathematics can be enhanced through the implementation of the M-TLAM, we analysed qualitative and quantitative data gathered through a questionnaire regarding these factors collected from 50 students and seven lecturers. The analysis helped the study's authors broaden their understanding of the factors and their relationships that could enhance students' motivation to learn, which in turn enhanced their academic achievement. This understanding will help improve the structuring of the mathematics learning activities for the business mathematics course at the CBE and design better blended-learning instructions for mathematics instruction in higher education in Tanzania.

8. Conclusions and limitations

The research presented in this study represented design-based research (DBR), which develops, tests, and evaluates educational interventions to address complex issues in educational practices while advancing design knowledge. The study's outputs were the intervention, design knowledge, and professional development of the research participants. In order to boost students' academic performance in a developing economy like Tanzania, this design-based research study is a first step towards the design of a better pedagogical approach for higher education mathematics instruction. This study used DBR to create a culturally-conscious flip-blended learning model for mathematics instruction, which differs from earlier studies on the same topic in similar contexts. As a result, the results are meaningfully contextualised in this setting. In addition, the following conclusions illustrate the significance of this research:

A flipped blended learning strategy is offered for developing and delivering mathematics courses at the university level, using metacognition and cultural considerations in the context of group work.

Our research suggests that academic achievement and motivation improve when cultural, metacognitive, and technological factors are considered in the design of blended instruction.

Based on the results of this study, it seems that the use of discussion problem sets with metacognitive questions, which were made to encourage conversation between students and between students and teachers in order to help students develop their critical thinking skills, may also be a reason why students' grades are getting better.

The study suggests that the after-class discussion questions and exercises pose a manageable cognitive burden because of the instructor's guidance on problem-solving through metacognitive inquiries.

The study proposes that online group work and metacognitive exercises after class can improve students' interactions, critical thinking skills, and grades.

The M-TLAM framework promotes a positive mindset and a desire for knowledge through online and offline activities. As a result of this structure, student-teacher communication is facilitated. These discussions sparked students' interest in the subject of mathematics.

Our research suggests that students' positive attitudes towards the course were mainly attributable to the collaborative activities, tailored their cultural backgrounds and may have encouraged them to speak up in class discussions more freely because they felt they were in the company of peers.

In this research, we propose that centring cultural norms on concepts like friend networks, equitable systems of rewards, and the presence of group leaders improves group dynamics.

This study has three limitations that suggest directions for future research. Firstly, the M-TLAM was evaluated with 52 bachelor's degree students at one higher education institution in Tanzania, which may affect the representativeness of higher education students. Therefore, future research could test the M-TLAM in other higher education institutions, possibly enlarging the sample size and broadening the scope of participants to include students undertaking diploma and certificate programmes. Secondly, design-based studies are preferred to be conducted in natural, messy environments. However, this study used a quasi-experimental design, which might have yet to capture the breadth of the design-based research. Therefore, future research could also be conducted in a natural classroom setting to determine the model's efficacy further. Thirdly, this study brought to light several factors that could influence mathematical academic achievement and motivation, so it must be noted that, for cultural factors, we have considered only the aspects of leadership, reward structure, and group composition in terms of friendship grouping. Other studies could focus on other aspects of culture, such as gender. Nevertheless, even though only a small number of students in one college of higher education participated in the intervention's testing, this implementation provided insights into potential factors that could influence students' mathematics learning in higher education and shed light on the efficacy of the designed model.

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Conflict of interest

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