DEVELOPING MULTIPLICATIVE THINKING SKILLS AMONG PRIMARY SCHOOL PUPILS WITHIN A FLIPPED CLASSROOM ENVIRONMENT FOR STEM EDUCATION, GOMBE STATE NIGERIA

BY
[1]TIMAYI, J. M., PhD., [2]SALAMI, D., & [3]GWANDUM, S. G

[1 & 3] Department of Mathematics and Computer Science,
College of Education, Billiri, Gombe State, Nigeria.
[2]Department of Science Education,
Confluence University of Science and Technology Osara, Kogi State.

*[1]timayijoe@coebilliri.edu.ng
[2]rockschamber@gmail.com
[3]sammygolly@gmail.com

Abstract
This study was on developing multiplicative thinking skills among primary school pupils within a flipped classroom environment for STEM education, Gombe state Nigeria. The study had two research questions and two hypotheses. The research design was the quasi-experimental and the population of the study comprised primary school pupils in Gombe state from which 103 pupils (51 males and 52 females) were sampled and participated in the research. The Multiplicative Thinking Skill Quiz (MTSQ) with a reliability of 0.81 was used to collect data. The hypotheses were tested using the t-test at $p \leq 0.05$ level of significance. The results revealed significant difference between the multiplicative thinking (MT) of pupils in the flipped class (F-CM) and the Traditional Method class (TM). In addition, the difference between the MT of pupils taught using the F-CM regarding gender was not significant. The study concluded that when pupils are exposed to the F-CM, their MT is better developed. Based on these findings, it was recommended that F-CM should be introduced into the primary school level in the state to teach mathematics to develop pupils' MT. Also, teachers should be trained on the use of F-CM in their teaching for STEM development among primary school pupils.
Keywords: Flipped-classroom model, multiplicative-thinking, STEM education

Introduction

STEM is an acronym that stands for Science, Technology, Engineering, and Mathematics. It is seen as an interdisciplinary approach to learning that integrates the fours disciplines it represents to solve real-world problems and promote critical thinking, creativity and innovation (Bybee, 2010; Chen et al., 2023; Berisha & Vula, 2024). Countries worldwide need STEM related experts to handle strategic sectors ranging from innovative and digital technologies, aerospace, ICT, Artificial intelligence, quantum computing and defence; amongst others (Chen et al., 2023; Zhai & Krajcik, 2024; Marzuki, 2025). Other areas are. One of the key disciplines of STEM is 'mathematics' which has been a worldwide problem among students from elementary to tertiary level (Kristensen et al., 2024). The other three disciplines of STEM rely on mathematics to thrive. A crucial area of mathematics a learner is expected to master at elementary school is multiplicative thinking, whose development is linked to improved STEM application (Siemon et al., 2018; Malola & Seah, 2024). Multiplicative thinking (MT) is a very important aspect of mathematics that should be developed as a foundation in the learning of the subject at the elementary level. This is because it is regarded as the learners' mental adaptive processing of mathematical problem contexts which underpins much of the mathematics learned beyond their elementary years (Hurst & Hurrell, 2014; 2016; Malola & Seah, 2024; Timayi et al., 2024;). MT can significantly aid the development of later mathematical concepts, and it is very useful in understanding topics such as algebraic reasoning, place value, proportional reasoning, rates and ratios, measurement, fractions, division and statistical sampling at elementary schools (Hurst & Hurrell, 2021).

Deep (2022) asserted that MT is indicated by a capacity to work flexibly with the concepts, strategies and representations of multiplication (and division) as they occur in a wide range of contexts. MT begins with the ability to construct a multiplier and multiplicand. The co-ordination of these two numbers (multiplier and multiplicand.) into one product implies multiplication is a binary operation. According to Ell (2005) and Wright (2011), four properties apply to multiplication. These properties are very crucial to understanding and developing MT. Table 1 shows the properties.

Table 1:

Properties of Multiplication

SN	Property	Illustration
1	Commutative Property	$p \times q = q \times p$
2	Associative Property	$p \times (q \times r) = (p \times q) \times r$
3	Distributive Property	$p \times (s + t) = (p \times s) + (p \times t)$
4	Inverse/reversibility	$p \times q = u$ so $u \div p = q$ and $u \div q = p$

Source: Compiled from Ell (2005) and Wright (2011)

The property of inverse means that division undoes multiplication and vice versa, i.e. $p \times q \div q = p$. The other properties do not hold for division. Commutative Property $u \div q \neq q \div u$ Associative Property $u \div (q \div r) \neq (u \div q) \div r$. Distributive Property $u \div (s + t) \neq (u \div s) + (u \div t)$. Inverse/reversibility $u \div q = p$ so $p \times q = u$ and $q \times p = u$. Multiplicative thinking involves application of these properties of multiplication (and division).

The development of MT in pupils is observed to be in five phases. Table 2 gives the phases

Table 2:
Phases of Multiplicative Thinking development in pupils

Phase	*Indication*
One-to-One Counting	Matching objects to numbers in order. Students do not have a concept of a group and may think they will get a different count if the collection is rearranged or if they start in a different place.
Additive Composition	Use of groups to count. Students understand that a group can be rearranged or counted in different ways, and the quantity does not change.
Many-to-One Counting	Representation of a group and counting repetitions of the same group. Students use additive thinking and individually count groups and then add them together. Implies double counting.
Multiplicative Relations	Knowing that when one quantity changes, the other quantity will change by a consistent factor. Students understand the structure of the multiplication and division algorithm.
Operating on the Operator	Knowing that operators are special symbols that indicate a specific operation to be performed. Students understand how to operate these symbols including the multiplication (x) and division (÷) symbols to solve more complex mathematical statements or equations.

Source: Compiled from (Hurst & Hurrell, 2021).

MT has been the heartbeat of mathematics advanced as 'multiplicative field theory' credited to Vergnaud (1994) where classification of problem types was presented. This was done with the structure of two or more measure-spaces, M1, M2, M3…etc., corresponding to the quantities and referents in multiplication or division problems. The importance of this classification of problem type was by both the relationship existing between the measure-spaces and the nature of the given and unknowns. Knowledge of this classification is very important in the development of MT in pupils. Table 3 is a summary of the classification.

Table 3:
Vergnaud's Classification of Multiplicative Problem Types based on Problem Sub-Type

Problem Sub-type	Definition
Isomorphism of measures (Simple proportion)	Direct proportional relationship between two measure-spaces, e.g. 6 oranges cost ₦4.00. How much do 18 oranges cost?
Product of measures (Concatenation of simple proportions)	Two measure-spaces mapped proportionally onto a third, e.g. "A sandpit is 6 metres wide and 8 metres long. What is the area of the sandpit?" or "John has 3 pairs of shorts and 4 tops. How many different outfits can he make?"
Multiple proportion (Double proportion)	The required quantity-measure-space is proportional to two different and independent measure-spaces, e.g. "Musa has 15 chickens to feed for 10 days. Each chicken eats two kilograms of feed per day. How much feed will the chickens consume altogether in 30 days?"
Comparison of rates and ratios	The proportional relationships between two rates or ratios involving comparison of the measure-spaces, e.g. "5 boys share 4 loaves of bread, and two girls share loaves of bread. Who gets more bread, a girl or a boy?"

Source: Vergnaud (1994)

At the primary school level, from primary one through six, pupils are taught multiplication in various ways to drive home its meaning. However, many learners at the primary school level in Nigeria often learn multiplication facts without gaining any real understanding of its meaning or usefulness. This creates difficulty for learners in their transition to advanced mathematical thinking. Such difficulty may be explained by a lack of understanding of MT concepts which supports the assertion that advanced mathematical thinking depends on the development of MT (Carrier, 2010; Breed, 2011; Timayi et al, 2024). The traditional method of teaching often used at the primary school level; this has often created frustration among learners who result in rote learning. Hence there is a need to try out new methods like the trending Flipped-Classroom Model (F-CM).

Teachers are breaking away from the role of being knowledge providers to becoming facilitators and coordinators of students' learning process. The flipped classroom model is defined as a teaching approach that inverts the traditional structure by moving direct instruction (like lectures) outside of class time and using class time for interactive, collaborative learning activities**.** It shifts the role of the teacher from lecturer to facilitator, and the role of the student from passive receiver to active participant who applies concepts with guidance from the instructor and peers. Literature reported better outcomes in mathematical performance among students when taught using the F-CM (Makinde, 2020; Akintolure et al., 2023). However, research such as Memler (2017) and Cabi (2018) found deviations from the forgone. In addition, the F-CM produces similar gender effect when students are exposed to it (Ajai & Imoko, 2015; Ghasemi & Burley, 2019). This makes F-CM a gender friendly approach to learning. Studies such as Day et al. (2024) believe that MT is a foundational skill for STEM because it provides the conceptual framework for understanding relationships between quantities, which is essential for advanced mathematics, science, technology, and engineering. Moreover, it is the basis for a wide range of STEM topics, including proportional reasoning, algebra, geometry, and statistics, enabling the flexible and efficient solution of more complex problems. The F-CM as an innovative educational strategy, has been observed to increase student engagement and deepen comprehension of STEM disciplines (Aspridanel et al., 2022; Maspul, 2023; Egara et al., 2025).

Statement of the Problem

The teaching of the concepts of multiplication (and division) is very important, being one of the major focuses of the primary mathematics curriculum which serves as foundational topic for higher mathematics. The concept of multiplication has been observed to be difficult for pupils at the primary level hence, they demonstrate limited understanding of the concept needed for the development of MT. This is worrisome because multiplicative thinking encourages STEM education. Moreover, the teaching of multiplication at the primary schools is predominantly characterized by the traditional method which has not helped the pupils so much.
This has resulted in poor development and utilization of MT which affects pupils' future in mathematics and STEM related fields. Consequently, primary school pupils' later difficulty with higher mathematics can be traced to poor MT and teaching methodology. With the changing paradigm in learning, teachers around the world are moving from the traditional method to technologically driven or enabled methods such as the Flipped Classroom Model.
This model has been found to enhance the development of MT among pupils. This research is on developing multiplicative thinking skills among primary school pupils within a flipped classroom environment for stem education, Gombe state Nigeria.

Research Questions

The following research questions were formulated as guide to the study:

1. What is the difference between the MT of pupils when taught using F-CM

http://custechijoe.org.ng ISBN: 978-978-693-988-9

and the TM?

2. What is the difference between the MT of male and female pupils when taught using F-CM?

Research Hypotheses

The following null hypotheses were tested at P ≤ 0.05 level of significance.

HO1: There is no significant difference between the MT of pupils when taught using F-CM and the TM

HO2: There is no significant difference between the MT of male and female pupils when taught using F-CM.

Methodology

The study adopted quasi-experimental research. The population of the study comprised of 9,717 primary school pupils of public schools in Billiri and Kaltungo Local Government Areas in Gombe State (Gombe State Ministry of Education [GSME, 2022]). Using the simple random sampling method, two schools were selected and placed into Flipped-Classroom Model (F-CM) and Traditional Method ™ groups after a pretest to participate in the research. Also, one intact class was chosen from the schools. Hence, the sample for the study was 103 pupils (F-CM = 51, TM = 52) which aligns with Sambo (2008) and the central limit theorem (CLT) which recommends a minimum of 30 (N≥ 30) as sample size for experimental research such as this one. The study utilized the Multiplicative Thinking Skill Quiz (MTSQ) adapted from Hurst & Hurrell (2016) for MT of pupils. The reliability of MTSQ was computed to be 0.81 using the test-retest method. Pupils in the F-CM group were taught using an offline video which contained various 15 minutes' lesson on concepts of multiplication, division, fractions, decimals, proportion, capacity, time, weight, money, length and estimation. The TM group learnt the same concepts simultaneously with the F-CM group**.** Both groups were taught for eight (8) weeks. Thereafter, a post test was administered to compare their respective MTs. Figure 1 is the representation of the research activities.

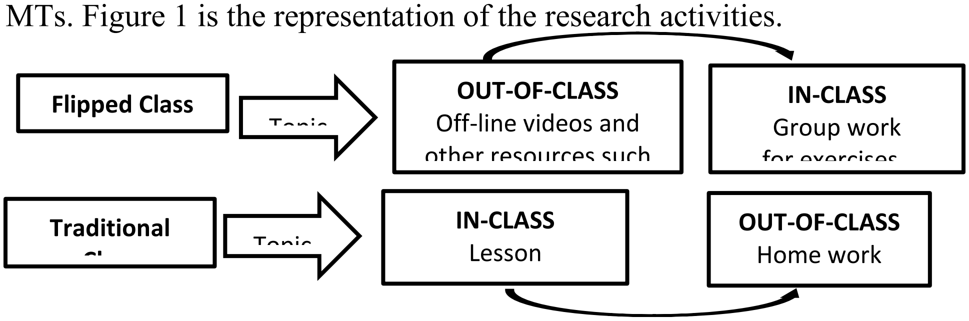

Figure 1: *Summary of Activities in F-CM and TM Classrooms*
Source: Adopted Cabi (2018) and Timayi et al. (2024)

The Statistical Packages for Social Science (SPSS version 27) software was used in the analysis of data. Consequently, the mean and standard deviation scores and t-test statistics at p≤ 0.05 level of significance were computed.

Results

Research Question One: What is the difference between the MT of pupils when taught using F-CM and the TM?
Null Hypothesis one: There is no significant difference between the MT of pupils when taught using F-CM and the TM
Research question one and null hypothesis one was answered and tested using the summary of independent t-test in Table 4.

Table 4:
Independent t-test on Multiplicative Thinking of Pupils

Groups	N	Mean	SD	df	t-value	p-value	Remarks
F-CM	51	61.75	9.22	101	9.41	0.000*	Reject H_{o1}
TM	52	47.46	5.84				
Total	103						

*Significant at p ≤ 0.05

From Table 4, the MT (F-CM = 61.75, TM = 47.46) of the groups differ by 14.29 in favour of the F-CM. Also, the independent sample t-test revealed that the difference in MT scores between the F-CM (n = 51, M = 61.75, SD = 9.22) and TM (n = 52, M = 47.46, SD = 4.09) groups were statistically significant (t = 9.41, p = 0.000) at α = 0.05. Therefore, the null hypothesis one (H_{o1}) was rejected. This implied a significant difference exists between the MT of pupils in favour of those exposed to the F-CM. Hence, the result therefore showed that the F-CM is more effective than the Traditional Method at developing and enhancing pupils' MT.
Research Question Two: What is the difference between the MT of male and female pupils when taught using F-CM?
Null Hypothesis two: There is no significant difference between the MT of male and female pupils when taught using F-CM.
Research question two and null hypothesis two were answered and tested using a summary of independent t-test in Table 5.

Table 5:
Independent t-test on Multiplicative Thinking of Pupils by Gender

Groups	N	Mean	SD	df	t-value	p-value	Remarks
Male MT	30	60.03	8.77	49	1.61	0.676**	Retain H_{o2}
Female MT	21	64.19	9.51				
Total	51						

**Not Significant at $p > 0.05$

Table 5 revealed, the MT (Male MT = 60.03, Female MT = 64.19) of the groups differ by 4.16 in favour of the Female MT group. In addition, the independent sample t-test showed that the difference in MT scores between the Male MT (n = 30, M = 60.03, SD = 8.77) and Female MT (n = 21, M = 64.19, SD = 9.51) groups was statistically significant (t = 1.61, p = 0.676) at $\alpha = 0.05$. Therefore, the null hypothesis two (**H_{o2}**) was retained. This means that the difference in MT of pupils regarding gender taught using the F-CM is not significant. Therefore, it can be concluded that the F-CM is a gender friendly approach to teaching MT to pupils.

Discussion

The results in Table 4 indicated that the F-CM group had better MT skills compared to the TM group, evidenced by a higher mean score which was found to be significant when the t-test statistics were computed. This finding aligns with the results of Makinde (2020) and Akintolure et al. (2023) who reported that when learners are active within the right intervention such as the Flipped Classroom Model their MT is enhanced. The finding also negates Cabi (2018), who found no significant differences between the flipped and non-flipped classroom in mathematics. Regarding gender, Table 5 showed that the Female MT was slightly improved above the Male MT. However, the computed t-test on the data was not significant. This finding corroborates with Ajai, & Imoko (2015) and Ghasemi & Burley (2019). This portrays the gender friendliness of the F-CM.

Conclusion

The study concludes that MT is needed for problem solving and development of advanced mathematical thinking useful in STEM education. F-CM is effective at improving the MT skills of primary school pupils. The MT skills of male and female pupils exposed to the F-CM was similar which indicated that the F-CM is gender friendly. Hence, the F-CM can be used extensively in all forms of schools at the primary school level whether it is co-education or not because it has the same effect on gender.

Recommendations

Based on the findings of the study, the following recommendations were made:

1. The Flipped-Classroom Model (F-CM) should be used by teachers at the primary school level to teach mathematics because it provides an exciting learning environment for pupils which can help enhance and develop their Multiplicative Thinking (MT) skills.
2. Conferences, seminars and workshops should be organized by professional associations/bodies and research organisation like Mathematical Association of Nigeria (MAN), Science Teachers Association of Nigeria (STAN) and the Nigeria Educational and Research Development Council (NERDC) to incorporate the Flipped-Classroom Model (F-CM) in mathematics curriculum and textbooks at all primary school levels.
3. The F-CM should be used by primary school teachers in teaching STEM related subjects like Basic Science.

References

Ajai, J.T. & Imoko, I. I. (2015). Gender differences in mathematics achievement and retention scores: A case of problem-based learning method. *International Journal of Research in Education and Science (IJRES), 1*(1), 45- 50.

Akintolure, S. O., Akinola, V. O., Olaleye, E. O., & Braimoh, D. S. (2023). effect of flipped classroom on students' academic performance in practical physics amongst secondary schools in Lagos state. *IJELICT, 2*(1),132 – 141**.**

Aspridanel, A., Abdurrahman, A., Lengkana, D., & Jalmo, T. (2022). STEM-Integrated Flipped Classroom in the Teacher's Perspective: Could its Implementation in E-Module Improve System Thinking Ability*? Indonesian Journal of Science and Mathematics Education. 5.* 43-52. 10.24042/ijsme.v5i1.10663.

Bhagat, K. K., Chang, C. N., & Chang, C. Y. (2016). The Impact of the Flipped Classroom on Mathematics Concept Learning in High School. *Educational Technology & Society, 19* (3), 134–142.

Breed, M. H. (2011). *Constructing paths to multiplicative thinking: breaking down the barriers.* PhD Thesis, RMIT University Australia.

Cabi, E. (2018). The impact of the flipped classroom model on students' academic achievement. *International Review of Research in Open and Distributed Learning, 19* (3), 202 – 221.

Carrier, J. A. (2010). *Indicators of multiplicative reasoning among fourth grade students. The University of North Carolina at Greensboro, ProQuest Dissertations Publishing, 2010. 3403677.* Retrieved from https://search.proquest.com/docview/366627761.

Charles-Ogan, G., & Williams, C. (2015). Flipped classroom versus a conventional classroom in the learning of mathematics. *British Journal of Education, 3*(6), 71-77. ISSN 2054-636X (online).

Chen, S. C., Y. C. Yang, C. Lin, and S. S. J. Lin. 2023. "Dispositions of 21st-Century Skills in STEM Programs and Their Changes Over Time." *International Journal of Science and Mathematics Education* 21 (4): 1363–1380. https://doi.org/10.1007/s10763-022-10288-0.

Clarke, D.M., Clarke, D.J. & Sullivan, P. (2012). Important ideas in mathematics: What are they and where do you get them? *Australian Primary Mathematics Classroom*, *17*(3), 13 - 18.

Day, L., Siemon, D., Callingham, R., & Seah, R. (2024). Connecting threads: the role of multiplicative thinking in algebraic, geometrical, and statistical reasoning.

Deep, A. (2022). Transition from additive thinking to multiplicative thinking. Retrieved from https://melbournetutorials.com.au/transition-from-additive-thinking-to-multiplicative-thinking/#:~:text=Multiplicative%20thinking%20is%20characterised%20by,expressions%2C%20and%20written%20algorithms).

Egara, F., Mosimege, M., & Mosia, M. (2025). *Enhancing Mathematics Education through Flipped Classroom Approaches: Insights and Best Practices.* IntechOpen. doi: 10.5772/intechopen.1006949.

Ghasemi, E., Burley, H. (2019). Gender, affect, and math: a cross-national meta-analysis of Trends in International Mathematics and Science Study 2015 outcomes. *Large-scale Assess Educ* **7,** 10 (2019). https://doi.org/10.1186/s40536-019-0078-1

Gombe State Ministry of Education [GSME, 2022]. *Statistics of Students enrolment.* Gombe State Ministry of Education.

Hurst, C., & Hurrell, D. (2014). Developing the big ideas of numbers. *International Journal of Education Studies in Mathematics, 1* (2), 1 – 18.

Hurst, C., & Hurrell, D. (2016). Investigating children's multiplicative thinking: implications for teaching. *European Journal of STEM Education, 1* (3), 1 – 11.

Kristensen, M. L. A., Larsen, D. M., Seidelin, L., & Svabo, C. (2024). The Role of Mathematics in STEM Activities: Syntheses and a Framework from a Literature Review. *International Journal of Education in Mathematics, Science and Technology*, *12*(2), 418-431. https://doi.org/10.46328/ijemst.3357

Lin, P., & Chen, H. (2016). The effects of flipped classroom on learning effectiveness: using learning satisfaction as the mediator. *World Transactions on Engineering and Technology Education, 14* (2), 231 – 244.

Makinde, S. O. (2020). Impact of Flipped Classroom on Mathematics Learning Outcome of Senior Secondary School Students in Lagos, Nigeria. *African Journal of Teacher Education, 9*(2), 23-42.

Malola, M., & Seah, W. T. (2024). Primary school teachers' knowledge for teaching multiplicative thinking. *Journal on Mathematics Education*, *15*(4), 1175-1196. https://doi.org/10.22342/jme.v15i4.pp1175-1196

Maspul, Kurniawan. (2023). Elementary School Flipped Learning STEM Education as a Medium for Engaging and Innovative Learning. *Jurnal Pendidikan LLDIKTI Wilayah 1 (JUDIK). 3.* 44-51.

Marzuki, O. F., Teo, E. Y. L., Abdullah, W. N. Z. Z., Khairuddin, N., Inai, N. H., Saad, J. M., … Asmawi, N. N. M. (2025). Drone STEM Education: Revolutionizing Learning for the Future. *International Journal of Academic Research in Progressive Education and Development*, *14*(1), 1416–1433. Retrieved from https://ijarped.com/index.php/journal/article/view/3415

Memler, J. (2017). *The effect of a flipped classroom on student academic achievement and the gender gap in high school physics.* PhD Dissertation, University of Georgia, USA.

Sambo, A. A. (2008). *Research methods in education.* Lagos: Stirling-Horden Publishers (Nig.) Ltd pg 341 – 354.

Siemon, D., Banks, N., & Prasad, S. (2018). Multiplicative Thinking: A Necessary Foundation: An Emerging Field of Inquiry. 10.1163/9789004391413_006.

Thakare, R. (2018). *8 Types of flipped learning classrooms and tools to build them.* Retrieved from https://elearningindustry.com/flipped-learning-classrooms-tools-build-types.

Timayi, J. M., Bolaji, C., & Kajuru, Y.K. (2024). *Flipped classroom model and multiplicative thinking among middle basic pupils of varied abilities in Gombe State, Nigeria. FNAS Journal of Mathematics and Science Education, 5*(4), 69-77.

Unamba, E. C., Izuagba, N. J., & Ogbonnaya, C. N. (2016). Engagement and promote active learning among Primary school pupils in algebra. *Journal of Teacher Perspective, 11*(1), 189 – 210.

Vergnaud, G. (1994). Multiplicative conceptual field: What and why? In G. Harel, J. Confrey (Eds.), *The development of multiplicative reasoning in the learning of mathematics* (pp. 41-59). Albany: State University of New York.

Zhai, X., & Krajcik, J. (2024). Artificial Intelligence-Based STEM Education in Zhai, X., & and Krajcik, J. (eds), *Uses of Artificial Intelligence in STEM Education* (Oxford, 2024; online edn, Oxford Academic, 21 Nov. 2024), https://doi.org/10.1093/oso/9780198882077.003.0001,