Original article

EFFECTIVENESS OF A PROTOTYPE LESSON PLAN FOR TEACHING MATHEMATICS VOCABULARY

Benson N. Wanjiru

Abstract

Background. Low performance in mathematics in secondary schools in Kenya, especially in the Kenya Certificate of Secondary Education (KCSE), is often attributed to poor conceptual understanding. A key factor is the limited mastery of mathematical vocabulary, which hinders learners from solving word problems and grasping core concepts.

Purpose. This study aimed to design and evaluate the effectiveness of a prototype lesson plan for teaching mathematics vocabulary using an empirical case from Murang'a County, Kenya.

Materials and methods. A quasi-experimental design with nonequivalent control groups was used. Two Form 2 classes from purposively selected schools took part in a 10-week intervention. The experimental group received explicit instruction on mathematical terms using the Frayer Model and ICT tools. The control group relied on traditional definition-only strategies. Data was collected using pre- and post-tests on students' Mathematics Achievement tests (PRESMAT and POSMAT).

Results. The findings revealed that the experimental group (M = 9.13, SD =4.73) outperformed the control group (M = 5.90, SD = 2.61) in the Post-Test Students' Mathematics Achievement Test, POSMAT. Further, the findings showed that there was a statistically significant mean difference between the experimental group and the Control group in the post-test, t (214) = 6.21, ρ= <.001, at ∝ =.05. The effect size for this difference was high, with Cohen's d equal to 0.85. These findings indicate that structured vocabulary instruction using the Frayer Model significantly improves stu-

dents' conceptual understanding and mathematics performance compared to traditional definition-only approaches.

Keywords: Frayer Model; graphical organizer; mathematical language; mathematical vocabulary; mathematical vocabulary instruction

Introduction

Mathematics plays a central role in Kenya's secondary school curriculum and is considered fundamental for academic achievement, civic competence, career advancement, and personal development [21]. In a rapidly evolving, technology-driven society, proficiency in mathematical thinking is essential across diverse fields such as engineering, medicine, social sciences, and everyday decision-making, including budgeting and market participation. As a universal language, mathematics uses precise symbols and specialised vocabulary that enable the concise expression of complex ideas [19; 25].

Despite its critical importance, mathematics performance in Kenya remains low. Kenya Certificate of Secondary Education (KCSE) results reveal a concerning trend, with national mean scores in mathematics fluctuating across the years (2018-2023). This is tabulated in Table 1.0

Table 1.0.
KCSE by Sex and Mean Grade (2018 – 2023)

Year	Enrolment	Mean grade	Female	Male
2023	895,909	22.70	20.83	24.57
2022	877,293	15.16	13.61	16.69
2021	822,466	20.00	18.67	21.33
2020	746,914	18.35	16.64	20.06
2019	694,484	27.50	25.49	29.51
2018	663,066	25.71	23.05	28.24

Source: [9; 10].

Reports by the Kenya National Examinations Council [11] attribute this underperformance to limited conceptual understanding, particularly in solving word problems, where mathematical vocabulary is pivotal.

Mathematical vocabulary includes terms such as quotient, vertex, and hexagon, which label abstract concepts fundamental to mathematical reasoning [30]. These terms differ significantly from their usage in everyday language, often creating confusion for learners [17]. Moreover, many of these words describe intangible concepts rather than physical objects, making them more difficult to understand [22]. Research indicates a strong relationship between vocabulary knowledge and mathematical achievement. [29] found that direct vocabulary instruction can improve performance by up to 33 percentile points.

The mathematical register itself is characterized by unique grammar and syntactic structures, such as passive voice and comparative phrases, which further challenge learners—especially non-native English speakers [4; 2]. [14] found a direct link between students' reading comprehension and mathematics achievement, suggesting that weaknesses in language skills hinder performance on math tasks. KNEC reports consistently identify poor performance in word problems as a persistent issue, implying that limited vocabulary instruction may be a key barrier to understanding [11].

Traditional Kenyan classrooms often rely on teacher-centred, definition-only methods that do not promote deep understanding or engagement [22]. This contrasts with contemporary instructional strategies, such as the Frayer Model, which emphasize active, student-centered learning. Developed by [6], the Frayer Model is a graphic organiser that helps students analyse and internalise concepts by exploring definitions, characteristics, examples, and non-examples [5; 28].

Studies have shown that the Frayer Model is effective in developing deeper vocabulary understanding and improving academic performance [18; 3]. However, despite programs like KESSP and SMASSE aiming to enhance teacher pedagogy and resources [15; 1], national performance in mathematics remains below expectations, indicating that vocabulary instruction is a missing but critical component.

A comprehensive review of local and international literature reveals a significant gap in empirical studies on vocabulary instruction in mathematics achievement in the Kenyan context, particularly in Murang'a

County. No published studies have investigated the effect of structured vocabulary instruction, such as the Frayer Model, on student performance in Kenya. This absence of literature underscored the need for the current study. In the rest of Africa, some studies have been carried out on the subject. For instance, [12] carried out an investigation of the impact of learning mathematical vocabulary of functions on conceptual understanding and mathematical performance of Grade 11 learners. The study found a moderately high correlation (r =.61) between the correctly defined mathematical terms and learners' performance in the mathematical test.

In Asia, [16] carried out a study to investigate the impact of using the Frayer teaching model on 3rd-grade learners' acquisition of mathematical concepts. He employed a quasi-experimental design with a sample size of 100 learners, comprising 50 in the experimental group and 50 in the control group. The study revealed a statistically significant difference between the average scores of the experimental and control groups over the acquisition of mathematical concepts in the multiplication unit. The experimental group performed better in mathematical concepts than the control group.

Problem statement

Students in Kenyan secondary schools face challenges in mathematics achievement due in part to inadequate vocabulary instruction. Traditional methods do not effectively promote conceptual understanding, and there is a lack of empirical evidence on innovative vocabulary teaching strategies such as the Frayer Model.

Purpose of the study

This study aims to develop and evaluate a prototype lesson plan for mathematics vocabulary instruction using the Frayer Model in secondary schools in Murang'a County, Kenya.

Research objectives

1) To develop a practical, ICT-supported prototype lesson plan for use in competency-based education.

2) To evaluate the effects of the Frayer Model for mathematics vocabulary instruction on students' mathematics achievement.

Hypothesis

HO_1: Structured vocabulary instruction using the Frayer Model does not affect students' conceptual understanding and mathematics performance compared to traditional definition-only approaches

HA_1: Structured vocabulary instruction using the Frayer Model significantly improves students' conceptual understanding and mathematics performance compared to traditional definition-only approaches.

Materials and methods

This study adopted a nonequivalent control group pretest-posttest quasi-experimental design to assess the effectiveness of mathematical vocabulary instruction using the Frayer Model in secondary schools in Murang'a County, Kenya [26]. The quasi-experimental approach was considered appropriate given the ethical and administrative constraints in educational settings that prevent random assignment of learners into experimental conditions [19]. This design enabled the researcher to observe the impact of the intervention while maintaining the integrity of naturally occurring classroom groups.

The logic behind the design stemmed from its capacity to control threats to internal validity using pretests, which helped establish baseline equivalence between groups [30]. The design was represented using the notational schema of [3] as in Fig. 1.

Experimental Group	Pretest(O_1)	Treatment	Post test (O_3)
Control Group	O_2	Not treatment	O_4

Fig. 1. Quasi-experimental study design

Study sites and participants were selected using purposive and simple random sampling techniques. Two county secondary schools in Kahuro Sub-County, Murang'a County, were purposively selected based on three criteria: comparable KCSE performance, similar student demographics, and accessibility to ICT infrastructure, particularly computer labs with internet access. This control of contextual variables minimizes potential confounding effects. Each school provided two intact Form Two classes, one assigned to experimental condition and the other to the control,

comprising a total of 216 students (108 per school). All learners in the selected classes participated in the study. Six mathematics teachers, who were already teaching the selected classes, were also purposively sampled to ensure instructional consistency and pedagogical expertise [19].

The intervention spanned 10 weeks and involved the explicit instruction of one mathematical vocabulary word per week. Students in the experimental group were instructed using the Frayer Model, which incorporated graphic organizers and ICT-supported materials from www.amathsdictionaryforkids.com. This blended method fostered multi-modal vocabulary engagement—visual, textual, and interactive. In contrast, the control group received traditional, definition-only instruction commonly used in Kenyan classrooms. This comparative setup enabled the measurement of differential learning outcomes attributable to instructional approach.

The researcher, in collaboration with teachers in the experimental group designed a total of 60 lessons, covering the entire period of study of 10 weeks: 6 lessons per week. The lesson plans had three parts: Introduction, development, and conclusion. The learning experiences (activities) were learner-centred and based on Students' experimentation, Improvisation (ASEI) using locally available resource materials. In the class, core competencies such as communication, collaboration, digital literacy, creative thinking, and problem-solving to be demonstrated. In addition, pertinent contemporary issues such as the integration of technology in Learning and the promotion of environmental conservation through responsible use of the learning materials should be incorporated in the lesson to provide relevant and holistic learning experience.

To ensure effective implementation, the participating teachers were trained by the researcher on how to utilize the developed lesson plans. The training involved a lesson study approach, where the teachers engaged in collaborative planning, actualization, observation, and reflection of the modelled lessons. The teachers in the experimental group taught the Frayer Model-based lessons, while those in the control group used the traditional methods of only defining the mathematical terms and then applying them. At the end of the instructional period, the students in both

groups were subjected to the Post-Test Students' Mathematics Achievement Tests (POSMAT) to measure the learning outcomes.

A total of three (3) quantitative instruments were employed to capture multiple dimensions of learning outcomes:

- Pre-and Post-test Students' Mathematics Achievement Tests (PRESMAT, POSMAT): Measured overall conceptual grasp and problem-solving ability, with test items aligned to Bloom's taxonomy and adapted from past KNEC exams [11].
- Students' Mathematical Vocabulary Dictionary (SMVD): Served as a learning and tracking tool for vocabulary acquisition.

Validity and reliability were rigorously established. A pilot study with 20 Form Two students in Kirinyaga County helped refine the instruments for clarity, relevance, and psychometric quality. Content validity was achieved through expert review by specialists in educational research and mathematics pedagogy at Kenyatta University. Reliability indices for the PRESMAT and POSMAT were computed:

- PRESMAT: KR-20 = 0.83
- POSMAT: KR-20 = 0.89

These indices surpassed the recommended threshold of 0.70, indicating high internal consistency [7].

Data collection followed a systematic procedure: pretest (PRESMAT) was administered in Week 1, followed by the 10-week instructional intervention. The post-test, POSMAT, was administered in Week 11. Data analysis was conducted using SPSS version 25.0. Statistical techniques included descriptive statistics to summarize data, and an independent samples t-test was used to analyze between-group comparisons. The significance threshold was set at $p \leq .05$ [19].

Full ethical compliance was ensured for the study. Approval was obtained from the National Commission for Science, Technology, and Innovation (NACOSTI) as well as the Kenyatta University Ethics Review Committee. Informed consent was obtained from all participants and their guardians, with assurances of confidentiality and the right to withdraw at any time.

A sample lesson Plan based on the Frayer model for teaching the concept of integers is presented in Fig. 2.

Name of school**: X School**   Teacher's Name: **Y**
Form: **2** Class: **WEST** Topic: **Integers**
Date: **17/7/2023** Time**: 2.40-3.20 pm** Duration: **40 minutes**
Objectives:
By the end of the lesson, the learner should be able to:
     i.   Define the term integer
     ii.   Graphically represent the term integers on a Frayer model diagram and the number line
References
     i.   [8] (2023). Secondary Mathematics Students' Book One. Nairobi: Author. Pgs 28-35
     ii.   Frayer model
Pre-requisite Knowledge
     i.   Number line
     ii.   Natural numbers

Materials
• Pencils, Markers, Graphic organizers, white and red wooden "1 x1" tiles, foldable ruler, computers connected to the internet.

Learning experiences (LE)	Teaching-learning Points (Core points)	Key Inquiry Question (KIQ)
Introduction (5mins) • Introduction of the mathematical Vocabulary word -integers **Definition** • The teacher tells the students that they will do certain activities to help them understand the vocabulary, distribute the materials, and worksheets • The teacher explains how the Frayer Model diagram works and how to fill it out	**Definition of vocabulary.** • An integer is a number that can be written without a fractional or a decimal component. • Integers are a set of whole numbers that include the following: -3, -2, -1, 0, 1, 2, 3. • They are positive whole numbers, negative whole numbers, and zero. • The name derives from the Latin *integer,* meaning literally "untouched", hence "whole".	What do you understand by the term integers?

Development: (30 minutes) **Activity II (5mins)** **Characteristics of the term** Class discussion of the facts or characteristics about the term, and fill in the area "facts and characteristics." Give "examples and non-examples."	**Characteristics of the term** • Integers include the whole numbers and their additive inverses. • Form a subset of the rational numbers. • Represents the difference between two objects in a set • Successive integers differ by one	What are the Characteristics of the term integers?
Activity II (6mins) Log into http://http://www.amathsdictionary.com. Provision of the students' mathematics Vocabulary Dictionary (SMVD)	**Examples of the word** -30, -4/2, 0,1 **Non-examples of the word** -3.75, - 2/3, 0.6, 3 ½ , $\sqrt{2}$	What are some examples of the word?
Activity III (5mins) **Students complete the Frayer Model**	**The Frayer model** Examples: -30, -4/2, 0,1,3 — Definition: They are positive whole numbers, negative whole number and zero Non- Examples: -3.75, - 2/3 , 0.6, 3 ½ — Characteristics: Include the whole numbers and their additive inverses	What are some non-examples of the word? How can the word be represented in a Frayer Model diagram?
Activity IV (10mins) a) Students create a foldable about the definition of the term b) They will complete each section of the foldable in class with a step-by-step procedure **Activity V (5mins)** Harmonization of the results from the various groups.	**Foldable** Integers: -3,-2,-1, 0,1,2,3 Whole number Positive or natural 1, 2,3,4…… Term Zero • Representation of integers on the number line (number line -5 to 5) • Integers are usually represented on a number line at equal intervals	How can one represent integers in a foldable? How can integers be represented in a number line? Classify the following as integers:- -20,-6,0.8,10,0,0.67, ½ , 2/3, 7/8 , 2.75
Conclusion (5mins) -Cognitive closure	Review of the meaning, word, characteristics, examples, and non-examples.	

Results

The findings showed that an effective model lesson plan based on the Frayer model for teaching vocabulary should adhere to the following procedure:

i) The teacher guided the learners in the introduction and definition of the concept.

ii) The teacher or facilitator then explains the Frayer model graphical organizer.

iii) The facilitator divided the class into small group cooperative learning groups and distributed the worksheets.

iv) The teacher/ facilitator guides the learners to fill out the diagrams. The learners use technology to look for definitions. A website such as http://www.amathsdictionaryforkids.com by Eather can be used to see the illustrations for the definition of the terminology.

v) The students practice the assigned vocabulary for some time.

vi) The students then write the foldable.

vii) Once the diagram is complete, they share their work with other students.

viii) The teacher/facilitator should harmonize the results and help the learners' conclusions.

The pretest students' mathematics test (PRESMAT) was administered in Week 1 of the study, while the post-test students' Mathematics Achievement Test, POSMAT, was administered in Week 11. The results are presented in Table 1.

Table 1.
Results for PRESMAT and POSMAT for Control and Experimental groups

Groups	N	PRESMAT		POSMAT		Cohen d Within groups	Effect size	Cohen d Between groups	Effect size
		Mean	SD	Mean	SD				
Control	108	5.79	2.64	5.90	2.61	.04	Negligible	-	-
Experimental	108	5.74	2.17	9.13	4.73	.92	large	.85	Large

Table 1 revealed that the experimental group (*M = 9.13, SD=4.73*) outperformed the control group (*M 5.90, SD=2.61*) in the Post-Test Students' Mathematics Achievement Test, POSMAT. The results showed that structured vocabulary instruction significantly improved conceptual understanding and student achievement in mathematics outcomes. The prototype lesson plan integrating the Frayer Model, ICT, and learner-centered strat-

egies that were developed and piloted demonstrated potential for deepening students' conceptual understanding of mathematical vocabulary and eventually enhancing students' achievement in mathematics. The findings in Table 2 also indicate that within-group changes from pre-test (PRESMAT) to post-test (POSTMAT) were minimal (*M= 5.79, SD= 2.64* to *M = 5.90, SD =2.61*), with a *negligible effect size* (*Cohen's d = .004*). On the other hand, the experimental group, which received the treatment, structured vocabulary instruction based on Frayel Model, showed a remarkable improvement from re-test (*M = 5.74, SD =2.71*) to post-test (*M =9.13, SD =4.73*), with a large *within-group effect size* (*Cohen's d =0.92*). In addition, the between-group comparison of post-test scores shows a large effect size (*Cohen's d =.0.85*). This demonstrates that the experimental group significantly outperformed the control group. These findings suggest that structured vocabulary instruction using the Frayer model effectively enhances students' conceptual understanding and mathematical achievement compared to traditional definition-only approaches.

Further analysis was carried out using the independent samples t-test. The findings are presented in Table 2.

Table 2.

Independent samples t-test for the Post-test between the experimental and control groups

| Groups | n | POSMAT | | *t-test* | df | p-value | *Cohen d* Between groups | Effect size |
		Mean	SD					
Control	108	5.90	2.61	-	-	-	-	-
Experimental	108	9.13	4.73	6.21	214	< .001	.85	Large

Table 3.0 shows that a statistically significant mean difference between the experimental group and the Control group in the post-test, t (214) = 6.21, ρ = <.001, at $\propto$ = .05. Thus, the null hypothesis (H_{01}) was rejected, and the alternative hypothesis (H_{A1}) was accepted. These findings show that *structured vocabulary instruction using the Frayer Model significantly improves students' conceptual understanding and mathematics performance compared to traditional definition-only approaches.* The effect size for this difference was high, with Cohen's d equal to 0.85

The findings compare to those by [12] and [16]. [13] found a strong link between mathematical vocabulary knowledge and students' performance in Mathematics, while [16] showed that the Frayer Model significantly improved learners' acquisition of mathematical concepts. In addition, the findings also agree with a study by [26] that demonstrated that the Frayer Model enhanced students' vocabulary retention and conceptual understanding of English words.

Discussions

The research objective design and evaluate the effectiveness of a prototype lesson plan for Mathematics vocabulary-based instruction. The ASEI-PDSI approach using the graphical organizer based on the Frayer model with ICT integration was developed. According to [24], ASEI is relevant in ICT integration. The teaching approach is activities, student-centered teaching, Experiments, and improvisation (ASEI), and cyclic instructional processes of Plan-Do-See-Improve (PDSI) are critical aspects of engaging learners meaningfully in instruction [23.

According to [6] and [13], there are several benefits to the students associated with the Frayer model. The students can (1) develop an understanding of key concepts and vocabulary, (2) draw on prior knowledge to make connections among concepts, (3) compare attributes and examples, (4) think critically to find relationships between concepts and to develop a deeper understanding, and (5) make visual connections and personal associations. Informed by the benefits, the study recommends the adoption of the Frayer Model for Mathematics Vocabulary-based instruction. The definition-only traditional strategy is shallow and leads to surface or instrumental learning only. In contrast, the Frayer model supports deep learning through multiple perspectives on a concept. It goes beyond simple definitions and requires that the student analyse the characteristics, give examples and non-examples, and relate the terminology or concept to their existing knowledge. This multifaceted approach promotes a profound understanding of the word's meaning, retention, and usage. Perhaps this explains why the experimental group outperformed the control group.

Conclusions

1. Vocabulary instruction using the Frayer Model, especially when integrated with ICT resources, significantly enhances students' understanding of mathematical concepts by promoting relational learning and active engagement. It is therefore recommended that the Frayer Model be adopted in secondary school mathematics instruction to improve academic outcomes.

2. The observed improvement in learners' performance confirms that explicit teaching of mathematical vocabulary addresses language-related barriers in mathematics comprehension. Mathematics teachers should incorporate structured vocabulary strategies into regular lessons to support concept mastery.

3. The study's prototype lesson plan provides a practical and scalable framework for implementing vocabulary-based instruction aligned with the Competency-Based Curriculum (CBC). The Ministry of Education and curriculum developers should adopt and adapt this model in official teaching guides and syllabi.

4. Teachers reported the approach to be practical, engaging, and relevant to classroom realities, suggesting strong potential for widespread application. In-service teacher training programs should be updated to include modules on mathematical language and graphic organizer-based instruction.

5. The use of ICT-supported vocabulary tools (e.g., www.amathsdictionaryforkids.com) enhances learner autonomy and resource access, fostering 21st-century competencies. Policymakers and school administrators should invest in digital infrastructure and internet access to support such blended learning environments.

6. The strong relationship between vocabulary mastery and improved mathematics performance highlights the need for curriculum developers and textbook writers to include graphic organizers and word-study activities in instructional materials.

Ethics committee conclusion. The study was conducted following the set ethical guidelines and regulations of the National Commission for Science, Technology and Innovation (NACOSTI), Kenya. Approval

was obtained from NACOSTI and Kenyatta University before data collection. Informed consent was secured from all participants, and confidentiality was strictly maintained.

Informed consent. Informed consent was obtained from all respondents who participated in the study. Participation was entirely voluntary, and respondents were assured of anonymity, confidentiality, and the right to withdraw at any stage without any penalty.

References

1. Amadalo, M. (2013). *Mathematics teachers' perception of the effectiveness of the SMASSE in-service training programme in Kenya* (Master's thesis, unpublished). *Educator*, 25(1), 24–28.
2. Chamot, A. U., & O'Malley, J. M. (1994). *The CALLA handbook: Implementing the cognitive academic language learning approach*. Addison-Wesley.
3. Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education* (8th ed.). Routledge.
4. Cuevas, G. J. (1984). Mathematics learning in English as a second language. *Journal for Research in Mathematics Education*, 15(2), 134–144. https://doi.org/10.2307/748889
5. Doty, D. E., Cameron, G. N., & Barton, M. L. (2003). *Teaching reading in social studies, science, and math*. Carson-Dellosa.
6. Frayer, D. A., Fredrick, W. C., & Klausmeier, H. J. (1969). *A schema for testing the level of concept mastery* (Working Paper No. 16). University of Wisconsin.

7. Hussey, I., O'Donovan, B., & Smith, J. (2020). An aberrant abundance of Cronbach's alpha values at 0.70: Implications for reliability interpretation. *Assessment & Evaluation in Higher Education*. Advance online publication. https://doi.org/10.1080/02602938.2020.1778379

8. Kenya Literature Bureau (KLB). (2003). *Secondary mathematics students' book one* (pp. 28–35). Nairobi: Kenya Literature Bureau.

9. Kenya National Bureau of Statistics. (2023). *Statistical abstract*. Kenya National Bureau of Statistics. https://www.knbs.or.ke/reports/2023-statistical-abstract

10. Kenya National Bureau of Statistics. (2024). *Statistical abstract*. KNBS. https://www.knbs.or.ke/reports/2024-statistical-abstract

11. Kenya National Examinations Council (KNEC). (2018–2023). *KCSE annual reports*. Nairobi: Kenya National Examinations Council.

12. Madzore, E. (2023). *The impact of learning mathematical vocabulary of functions using the Frayer model on conceptual understanding and mathematical performance of Grade 11 learners* (Doctoral dissertation, University of the Witwatersrand, Johannesburg). WIReDSpace. https://hdl.handle.net/10539/40990

13. Marzano, R. J. (2004). *Building background knowledge for academic achievement: Research on what works in schools*. ASCD.

14. McGhan, B. (1995). *MEAP: Mathematics and the reading connection*. http://comnet.org/cspt/essays/mathread.htm

15. Miheso, M. C. (2012). *Factors affecting mathematics performance among secondary school students in Nairobi Province, Kenya* (Doctoral dissertation). Kenyatta University.

16. Mohammed, M. J. (2019). *The impact of using the Frayer teaching model on 3rd-grade learners' acquisition of mathematical concepts* (Master's thesis). Qatar University, Doha, Qatar. https://qspace.qu.edu.qa/handle/10576/11652

17. Monroe, E. E., & Orme, M. P. (2002). Integrating vocabulary instruction into mathematics classrooms. *Reading Psychology*, 23(2), 113–131.

18. Monroe, E. E., & Pendergrass, M. R. (1997). Effects of mathematical vocabulary instruction on fourth-grade students. *Reading Improvement*, 34(3), 120–132.

19. Mugenda, O. M., & Mugenda, A. G. (2019). *Research methods: Quantitative, qualitative, and mixed methods approaches* (3rd ed.). Nairobi, Kenya: ACTS Press.

20. Mutunga, P., & Breakwell, J. (1992). *Mathematics education*. Nairobi: EARP.

21. Neyland, J. (1994). *Mathematics education: A handbook for teachers*. Wellington College Press.

22. Njoroge, B. (2003). *The role of mathematical language in students' performance in mathematics* (Master's thesis, unpublished). Kenyatta University.

23. Njuguna, E. (1999). *Quality education and the role of science teachers in the implementation of the ASEI-PDSI approach*. Nairobi: SMASSE Project.

24. Onchong'a, R. A. (2013). ICT integration in teaching and learning: A case for ASEI-PDSI pedagogy in the SMASSE project. *International Journal of Education and Research*, 1(3), 1–10.

25. Pimm, D. (1987). *Speaking mathematically: Communication in mathematics classrooms*. Routledge.

26. Privitera, G. J. (2014). *Research methods for the behavioral sciences*. Sage Publications, Inc.

27. Riksadianti, D. (2021). Enhancing vocabulary through Frayer model. *English Education and Applied Linguistics Journal (EEAL Journal)*, 4(1), 48–57. https://doi.org/10.31980/eealjournal.v4i1.1106. EDN: https://elibrary.ru/UCIAYI

28. Russell, M., Waters, L., & Turner, R. (2013). *Developing conceptual understanding using the Frayer Model*. Learning Sciences International.

29. Stahl, S. A., & Fairbanks, M. M. (1986). The effects of vocabulary instruction: A model-based meta-analysis. *Review of Educational Research*, 56(1), 72–110. https://doi.org/10.3102/00346543056001072. EDN: https://elibrary.ru/JTSQYD

30. Vacca, R. T., & Vacca, J. L. (1996). *Content area reading* (5th ed.). HarperCollins College Publishers.

31. Wiersma, W., & Jurs, S. G. (2005). *Research methods in education: An introduction* (8th ed.). Boston, MA: Pearson.

DATA ABOUT THE AUTHOR
Benson N. Wanjiru, PhD, Dr., Dean, School of Education
Mount Kenya University
P.O. Box 342, 01000, Thika, Kenya
bnjoroge@mku.ac.ke
ORCID: https://orcid.org/0009-0003-4607-2317