

Effects of Four Mode Application Technique (4-MAT) and Merrill's Instructional Models on Students' Self-Regulation and Academic Achievement in Algebra

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Abstract

The study investigated the effects of 4-MAT and Merrill's instructional model on students' self-regulation and achievement in algebra in Isi – Uzo Local Government Area, Enugu State. Two research questions were posed and two null hypotheses were formulated for the study. Quasi-experimental design, specifically, the pretest - posttest non-equivalent groups research design was used. The population of the study comprised 495 SSI students in Isi – Uzo Local Government Area. A total of 163 SSI students from four intact classes were selected from four co-educational secondary schools using multistage sampling procedure. The instruments for data collection for the study were Algebra self-regulation Scale (ASRS), Algebra Effort to learn Scale (AELS) and Algebra Achievement Test (AAT). The instruments were validated by five experts from University of Nigeria, Nsukka. The reliability of the instruments were determined using Kuder-Richardson 20 (K-R₂₀) for AAT and Cronbach Alpha for ASRS and their indices were 0.79 and 0.79 respectively. The data collected were analyzed with SPSS version 20 to find the mean and standard deviations used for answering the research questions and ANCOVA which was used for testing the null hypotheses at 0.05 level of significance. The findings from the analysis indicated that 4-MAT and Merrill's instructional model had positive effect on students' self-regulation and achievement in algebra and students taught algebra using 4-MAT model had better mean self-regulation score than the students taught using Merrill's model while students taught algebra using Merrill's model had higher mean achievement score than the students taught using 4-MAT model. Based on the findings of the study, it was recommended among others that mathematics teachers should be encouraged to adopt 4-MAT and Merrill's instructional model in the teaching of mathematics to improve students' self-regulation and achievement.

Keywords: *Four Mode Application Technique (4-MAT), Merrill's Instructional Model, Self-Regulation, Achievement, Algebra.*

INTRODUCTION

Mathematics is an integral part of life because it is needed by everyone for everyday activities and interactions. Mathematics is a systematic treatment of magnitude, relationship between figures and forms and relationship between quantities that are expressed symbolically (Barboianu, 2021). It has also been viewed as an indispensable subject needed by all for daily living. Mathematics is a science of number which systematically digs out patterns, rules, principles and theories to explain events (Brown, 2020; Genç, 2023). Mathematics is a means of communication, a tool for solving problems in a wide range context and providing ways in real situations (Ekwueme, 2013). It also helps in developing reasoning and analytical thinking skills in individuals. Mathematics quickens the mind, generate practicality and can also be

applied in the day to day activities (Odo & Ugwuda, 2014). Mathematics is widely recognized as an indispensable tool for achieving the developmental goals of any society. These definitions show that Mathematics is of great importance to mankind.

In Nigeria, the federal government is quite aware of the important role of mathematical knowledge in other school subjects, hence, Mathematics is made a mandatory at the basic and post-basic level of education (Federal Republic of Nigeria (FRN, 2014). Admission into any tertiary institutions to study any course is based on a requirement for a pass at credit level in mathematics at Senior Secondary School Examinations (SSSCE) of West African Examination Council (WAEC) or National Examination Council (NECO). As a subject, Mathematics content is divided into many interrelated parts. According to the national education research and development council (NERDC, 2009), Mathematics contents at the senior school level in Nigeria is divided into the following: number and numeration, algebra, geometry, statistics and probability and introductory calculus. In this, algebra was chosen because it is the foundation area of the subject Mathematics hence, algebra is the language through which most of the Mathematics is communicated. It is expected that Algebra should provide each child that is learning it with basic skills like critical thinking that is necessary for survival. Therefore, it is necessary to have a good foundation in Algebra.

Algebra is one of the branches of mathematics that deals with generalization of arithmetic in which letters are used to represent numbers or letters and numbers combined according to the rules. Algebra according to Usman and Musa (2015) is an aspect of mathematics which involves the use of letters and numbers. It is the most important aspect of school Mathematics. When students do not master topics in algebra very well, they may not do well in the other branches of Mathematics because it serves as foundation for proper learning of these other branches of Mathematics. According to Arbor (2015), algebra is known as a “gateway” to other branches of mathematics learned by senior secondary school students. Algebra develops students’ problem- solving abilities, critical thinking skills, communication and reasoning that are necessary in human daily living. According to Asekun (2023) and Lourens (2022), algebraic competence promotes the habit of accuracy, logical, systematic and orderly arrangement of facts in the learner. This has to do with the learner having the skill of critical thinking. Despite the critical role algebra plays, students’ achievement in mathematics examination has not reached the expectation of the stakeholders in education.

Academic achievement is act of achieving a certain educational goal. It is a person’s competence with regards to a field of knowledge (King 2016). It is also the outcomes that reflect the extent to which learners or students have achieved specific goals that were the focus of classroom instruction (Steinmayr et al., 2015). The students’ poor achievement in mathematics has become a source of concern in mathematics education. The clear view of students’ poor achievement in Mathematics may not be far from the poor achievement in algebra as summarized by WAEC Chief Examiner’s report of 2016 to 2023. The weaknesses of Nigeria candidates in algebra in the years are as follows: interpretation/ solution to word problem (2016 report); translating word/ story problems in mathematical problems (2017 report); difficulty in translating word problem in mathematical statement (2018 report); difficulty in translating word problem in mathematical statement (2019 report); inability to draw quadratic graph (2020 report); difficulty in translating word problem in mathematical equation (2021 report); poor interpretation of questions and inability to apply mathematical principles correctly (2022 report); inability to draw and read quadratic graph (2023 report). These results show that students’ poor academic achievement may be as a result of their

inability to have the fundamental skill of solving algebraic problems. In other words, improving students' ability to solve algebraic problem could result in improving or enhancing students' academic achievement in mathematics. Most importantly, Mathematics internal examination results from some secondary schools in Isi-Uzo Local Government Area (LGA) has shown poor achievement in Mathematics. The results show that many of the students failed Mathematics on regular basis in the (LGA).

Researchers identified many factors that attributed to this poor achievement. Some of the factors include; poor instructional method, poor students' background, lack of motivation, (Bridget, Julius & Metropolitan, 2024), large class size, poor evaluation, lack of students' interest (Khan, 2021), unqualified teachers, poor syllabus coverage (Maganga, 2016) among others. Another important reason why students have poor achievement in mathematics especially in algebra is due to the abstract nature of it. Teachers find it difficult to teach and students also find it difficult to learn (understand) (Gambari, Falode & Adegbenro, 2014). A lot has been done to reduce the abstract nature of mathematics especially in algebra which has great negative effect on students' achievement but the poor achievement persists.

Scholars and researchers believe that academic attainment may be enhanced if certain aspects of psychological variable like self-regulation was addressed properly. This is so because, achievement is so essential in people's life and activities. It becomes imperative to look into the challenges that surround it and figure out how to effectively address the students' poor academic achievement in mathematics especially in algebra. It is therefore appropriate to use models that generate and sustain psychological variables like self-regulation for high academic achievement in mathematics. Exploring this psychological variable might improve students' academic achievement in mathematics by closing the gap between the ideal and real.

Self-regulation is essential for learning mathematics. Self - regulation is the control that students have over their cognition, behaviour, emotions and motivation through the use of personal strategies to achieve the goals they have established (Agbenyegah, 2022; Alzahrani & Alnufaie, 2024). Zimmerman as cited in Agbo (2024) defines self-regulation as self-generated thoughts, feelings and actions that are planned and cyclically adapted to the attainment of personal goals. A self –regulated learner gets actively involved in the learning process, focuses attention on the presented information and organizes information in a meaningful way. Through self-regulation, the learner constructs a new model of understanding and refinement of conceptual understanding. Students' self – regulation skill could be generated and sustained for high achievement through effective teaching models like 4MAT model and Merrills' principle model which have ability of enaging students and their capacity of handling the issue of learning styles of different students.

4-MAT is an instructional model designed to take care of diverse learning styles and preferences of students. It recognizes that students come to the classroom with unique cognitive processes and learning patterns. 4-MAT sees learning process as a journey by asking four simple questions. Why? What? How? and If? 'Why' question seeks a reason or motivation for learning; 'What' question seeks for information and knowledge; 'How' question seeks to find a way of applying the knowledge or information gained and 'If' question develops extensions for the students to bring out new experiences from the learned materials (Osama et al., 2016). In 4-MAT model, the learning activities is delivered to the learners in a manner that addresses their individual styles coupled with function of the left and right parts of the brain. 4-MAT model segments the learning and instructional process into four distinct quadrants, each addressing a different aspect of the learning cycle: experiencing, conceptualizing, applying,

and refining. In experiencing students' interest are captured by starting with real – world scenario and answers the question “why is this important?” In conceptualizing (what) teacher as a facilitator move on to present theoretical concepts and information related to the experience and provides opportunity for learners to explore and understand the key concepts through activities, discussions and examples. Applying (how) provides opportunity for learners to apply their knowledge through problem solving, exercise or real-world applications. In refining (if) students reflect on and consolidate their understanding, making connection to real-life situations or future application. By incorporating all four quadrants, 4-MAT seeks to holistically engage learners and facilitate a deeper understanding of the subject matter. This process has proven effective in improving achievement in mathematics (Okoro et al., 2020; Aliustaoğlu & Tuna, 2018; Tezcan & Güvenç, 2017). 4-MAT instructional model is also useful in generating and sustaining self-regulation skill (Aktas & Bilgin; 2015)

Merrill's Principles of Instruction model which is a systematic approach to teaching that is guided by five fundamental principles: task-centered, activation, demonstration, application, and integration. In task/problem centered; students learn more when the instruction is centered on relevant real world task or problem, including series of tasks or problems that progress from simple to complex. In activation: students learn more when they are directed to recall prior knowledge, or recall a structure for organizing that knowledge or are given a structure for organizing new knowledge. Demonstration: students learn more when new knowledge is demonstrated to them in the content of real-world tasks or problems. Application: students learn more when they perform real-world tasks or solve real-world problems and receive feedback and appropriate guidance during that application. Integration: students learn more when they are encouraged to integrate their new knowledge into their life through reflection, discussion, debate and or presentation of new knowledge. Teachers needs to show the learner what is going to be learned rather than telling them about it; they also must be given a chance to do and practice what they have learned through a variety of assessment and activities. Merrill's model is rooted in the idea that learning is most effective when learners are actively involved in the process, and when instruction is sequenced logically to guide them through a progressive series of cognitive activities. It is a series of very effective problem-based teaching methodologies. Merrill's instruction model has been shown to impact students' achievement, self-regulation, and self-efficacy in mathematics (Lee & Koszalka, 2016; Yorganci, 2020), as well as students' effort in learning mathematics (Lo & Hew, 2020; Xiao & Hew, 2023).

However, from the description of both 4-MAT instructional model and Merrill's principle instruction model, it is evident that these instructional models might be a way forward to improving the students' self-regulation and academic achievement. The reason for choosing the two instructional models is due to their interactive nature and application to the contents of the study. Self- regulation skill may be psychological factor that might contribute to students' academic achievement in algebra.

The students' poor achievement in algebra and Mathematics in general has been as a result of teachers' consistent use of traditional teaching methods that do not involve students in the teaching and learning. The way Mathematics concepts are developed and taught would go a long way in helping students to improve on their understanding of both concepts and applications in life. Mathematics teachers are supposed to develop and present Mathematics contents in a way that would help students to think logically and critically and see relationships between Mathematics and their environment. Students' non-involvement in teaching and learning can invariably make them not to regulate themselves in learning algebra and would

likely result in poor achievement towards Mathematics in general. This has necessitated the exploration of effective instruction models; 4-MAT and Merrill's instructional models. These models aim to enhance students' self-regulation for high achievement in mathematics.

The purpose of this study was to investigate the effect of 4-MAT and Merrill's instructional models on students' self-regulation and achievement in algebra. Specifically, the following research questions were posed for the study.

- 1) What are the mean self-regulation scores of students taught algebra using 4-MAT model and those taught using Merrill's model?
- 2) What are the mean achievement scores of students taught algebra using 4-MAT model and those taught using Merrill's model?

METHODOLOGY

Research Design

The study employed quasi-experimental research design. Specifically, the pretest-posttest non-equivalent groups research design was used. This is because intact classes or pre-existing groups are used as experimental and control groups. In this case, random assignment of subjects to different experimental groups were not used.

Participant

The population of the study comprised of all the four hundred and five (495) senior secondary one (SSI) students of 12 Public Secondary Schools (PSS) in Isi-Uzo Local Government Area (LGA) Enugu state. The participants consisted of one hundred and sixty-three (163) SSI students from four (4) intact classes drawn from four (4) sampled co-educational schools using multistage sampling procedure. 85 students in group 1 taught using 4-MAT instructional model and 78 students in group 2 taught using Merrill's instructional model.

Instrument

Two instruments titled Algebra self-regulation Scale (ASRS) and Algebra Achievement Test (AAT) were used for data collection. The ASRS was adapted from Pintrich, David, Smith & Wilbert (1991) which was 30 items instrument on self-regulation learning strategies that has sub-scales, while AAT consists of 50 multiple choice items developed by the researcher based on SSI Algebra content in SSI Mathematics curriculum that covered the two sets of lesson plans on the instructional models. The researcher trained four research assistants which are the regular mathematics teachers of the selected schools, with a minimum qualification of First Degree (B.Ed.) or its equivalent in Mathematics with at least three years post qualification teaching experience. They were trained for one week and were given opportunity to demonstrate teaching of some topics in algebra using 4-MAT and Merrill's instructional models. The instruments were administered to the students that is the pre-test before the treatment. The actual teaching lasted for four weeks with three lesson periods per week making a total of twelve lessons period. The use of three lesson periods per week were due to the fact that there were at least three lesson periods per week on school timetables for Mathematics at the senior secondary school levels in Nigeria. The research assistants used the regular periods on the time table. After the treatment, the same instruments administered at pretest but the items of the instruments were reshuffled and then re-administered to the students as posttest. The data generated from the pretest and posttest were used for analysis.

Validation and Reliability Procedures

The instruments were validated by five specialists, two from Mathematics Education, one from Measurement and Evaluation both from Department of science Education and two from Department of Education Foundation, all from Faculty of Education, University of Nigeria Nsukka. The instruments, were determined after trial testing 30 copies of each of the two instruments on 30 SSI students from Model Secondary School Nsukka in Nsukka LGA, which share similar characteristic with the population of the study. The obtained from the instruments were used to establish their reliability indices. The coefficients of stability obtained for ASRS using the Cronbach Alpha and the internal consistency of the AAT was established using the Kuder-Richardson 20 (KR-20) were 0.79 and 0.78 respectively.

Data Analysis

The data generated from ASRS and AAT pre-test, post-test were analyzed using SPSS version 20. The mean and standard deviation were used to answer the research questions while ANCOVA was used to test all the null hypotheses at 0.05 level of significance. Because the pre-test scores were utilized as covariates to the post-test scores and the participants were not randomly assigned, ANCOVA was the appropriate statistical tool for the analysis.

RESULTS

Table 1: Mean analysis of the self-regulation scores of students taught algebra using 4-MAT model and those taught using Merrill's model

Group	N	Pretest		Posttest		Adjusted Mean
		Mean	Std. Deviation	Mean	Std. Deviation	
4-MAT Model	85	69.89	18.38	70.81	6.42	70.56
Merrill Model	78	60.24	11.36	65.78	5.22	65.97

Table 1 indicates that the mean self-regulation scores of students taught algebra using 4-MAT instructional model are ($M = 69.89$, $SD = 18.38$) and ($M = 70.81$, $SD = 6.42$) at the pretest and posttest respectively, while the mean self-regulation scores of students taught algebra using Merrill's instructional model are ($M = 60.24$, $SD = 11.36$) and ($M = 65.78$, $SD = 5.22$) at the pretest and posttest respectively. The adjusted mean scores of 70.56 and 65.97 for the students taught algebra using 4-MAT model and those taught using Merrill's model respectively indicate that the students taught algebra using 4-MAT model had better mean self-regulation score than the students taught using Merrill's model.

Table 2: Analysis of covariance of the effect of 4-MAT and Merrill instructional models on students' self-regulation in Algebra

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1117.239 ^a	4	279.310	8.071	.000	.170
Intercept	37093.276	1	37093.276	1071.818	.000	.872
Pre-Self-Regulation	51.374	1	51.374	1.484	.225	.009
Group	769.406	1	769.406	22.232	.000	.123
Gender	26.902	1	26.902	.777	.379	.005
Group * Gender	10.905	1	10.905	.315	.575	.002
Error	5468.037	158	34.608			
Total	769300.000	163				
Corrected Total	6585.276	162				

a. R Squared = .170 (Adjusted R Squared = .149)

Table 2 reveals that there is a significant difference in the mean self-regulation scores of students taught algebra using 4-MAT model and those taught using Merrill's instructional model in favour of the students taught using 4-MAT model, $F(1, 158) = 22.232, p = .000$. Thus, the null hypothesis is rejected since the associated probability value of .000 is less than the 5% probability value (level of significance). Besides, the effect size of .123 indicates that 12.3% improvement in students' self-regulation in algebra is attributed to the effect of 4-MAT model. Hence, the conclusion drawn was that there is a significant difference in the mean self-regulation scores of students taught algebra using 4-MAT model and those taught using Merrill's instructional model in favour of the students taught using 4-MAT model.

Table 3: Mean analysis of the achievement scores of students taught algebra using 4-MAT model and those taught using Merrill's model

Group	N	Pretest		Posttest		Adjusted Mean
		Mean	Std. Deviation	Mean	Std. Deviation	
4-MAT Model	85	22.29	8.35	37.54	10.97	36.78
Merrill Model	78	19.71	7.17	43.08	5.04	43.78

Table 3 indicates that the mean achievement scores of students taught algebra using 4-MAT instructional model are ($M = 22.29, SD = 8.35$) and ($M = 37.54, SD = 10.97$) at the pretest and posttest respectively, while the mean achievement scores of students taught algebra using Merrill's instructional model are ($M = 19.71, SD = 7.17$) and ($M = 43.08, SD = 5.04$) at the pretest and posttest respectively. The adjusted mean scores of 36.78 and 43.78 for the students taught algebra using 4-MAT model and those taught using Merrill's model respectively indicate that the students taught algebra using Merrill's model had slightly higher mean achievement score than the students taught using 4-MAT model. Besides, the posttest standard deviations of 10.97 and 5.04 show that the individual achievement scores of the students taught algebra using 4-MAT model varied more widely from their group mean than those of the students taught using Merrill's model.

Table 4: Analysis of covariance of the effect of 4-MAT and Merrill instructional models on students' achievement in Algebra

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3658.894 ^a	4	914.723	14.983	.000	.275
Intercept	17299.974	1	17299.974	283.365	.000	.642
Pre-Achievement	2335.788	1	2335.788	38.259	.000	.195
Group	1915.217	1	1915.217	31.370	.000	.166
Gender	73.445	1	73.445	1.203	.274	.008
Group * Gender	21.713	1	21.713	.356	.552	.002
Error	9646.211	158	61.052			
Total	276591.000	163				
Corrected Total	13305.104	162				

a. R Squared = .275 (Adjusted R Squared = .257)

Table 4 reveals that there is a significant difference in the mean achievement scores of students taught algebra using 4-MAT model and those taught using Merrill's instructional model, $F(1, 158) = 31.370, p = .000$. Thus, the null hypothesis is rejected since the associated probability value of .000 is less than the 5% probability value. The effect size of .166 implies that 16.6% improvement in students' achievement in algebra is attribute to the effect of Merrill's model. The inference drawn is that Merrill's models of instruction improved students' achievement in algebra than 4-MAT model.

DISCUSSION

The findings of the study indicated that students taught algebra using 4-MAT had better mean self-regulation score in algebra than those taught using Merrill's instructional model. However, variation in the individual self-regulation ratings of students exposed to algebra with 4-MAT instructional model from their group mean is higher than those of the students taught using Merrill's instructional model. This showed that those in 4-MAT instructional model group had outlier in the achievement. Those in 4-MAT instructional model group have higher self-regulation ratings than those in Merrill's instructional model group. Further analysis of the results revealed significant difference in the mean self-regulation ratings in favour of the students taught using 4-MAT instructional model. This might be due to the exploration that the students were engaged with during their learning with 4-MAT instructional model that generated and sustained their self-regulation in the algebra. The instructional model was so interactive that the students were actively involved in the teaching and learning process. This may have made the students not to feel that the lessons were boring. The findings agreed with Wattananualsakul (2022)'s report that 4-MAT instructional model enhances students' self-regulation in teaching and learning process. It also corresponds with Handam and Vedat (2015)'s opinion that 4-MAT instructional model had a positive effect on students' self-regulation and learning. This means that the self-regulation of both fast and slow learners are enhanced and sustained when 4-MAT instructional model is employed in teaching algebra. This indicated significant higher self-regulation rating than the other. The implication of this is that 4-MAT instructional model enhances and sustains students' self-regulation in algebra and therefore use of the 4-MAT instructional model need to be encouraged. Hence, 4-MAT instructional model is effective in sustaining students' self-regulation in algebra.

The findings of this study showed that both 4-MAT and Merrill's instructional models have positive effects on students' achievement in algebra. This is so because from the findings of this study showed that students taught algebra using 4-MAT instructional model and students taught algebra using Merrill's instructional model improved in their mean academic achievement. It also indicated that those exposed to Merrill's instructional model had higher mean achievement score than those taught using 4-MAT instructional model. It also indicated that those exposed to Merrill's instructional model had higher variation in individual achievement score than those exposed to 4-MAT instructional model. To buttress this, further analysis revealed that a significant difference exists in the mean achievement scores of students exposed to 4-MAT instructional model and those exposed to Merrill's instructional model in favour of the students taught using Merrill's instructional model. This indicates that Merrill's instructional model are useful for improvement of students' achievement in algebra than 4-MAT instructional model. The reason for the difference in mean achievement of the two groups may be due to differences in the teachers involved in the teaching.

The positive effects of Merrill's instructional model in improvement of students' achievement in algebra may be from the fact that the instructional model has interactive tools that permit students to actively participate in teaching and learning process, hence from the process investigate and discover facts and the principles by themselves. Thus, they may have gained knowledge during the process to draw valid conclusion on any algebraic problem by themselves. The finding of this study validates McClelland (1961) theory that students at any level can learn through real life experience and improve their achievement if exposed to the processes involved. On using this model, the teacher as well as students who learned faster may have guided those that did not learn fast to discover the facts by themselves also. This finding

is in agreement with Odo, Agwagah, Ugwuanyi, Shiaki, Nwoye, Emeji, & Ugwuanyi, (2021) who found that Merrill's instructional model had significant effect on students' achievement in Number and Numeration. The finding is also in accordance with Bataineh, Al- Hamad, & Al- jamal (2018) and Mohammed & Shraikh (2020)'s finding that employment of instructional model improves students' achievement.

CONCLUSION

From the findings of this study, it was concluded that 4-MAT and Merrill's instructional model are very much effective in enhancing senior secondary one (SS1) students' self-regulation and improving their learning outcome in algebra. Students taught algebra using 4-MAT had better mean self-regulation score in algebra than those taught using Merrill's instructional model. It also showed that both 4-MAT and Merrill's instructional models have positive effects on students' achievement in algebra because students taught algebra using 4-MAT instructional model and students taught algebra using Merrill's instructional model improved in their mean academic achievement. Therefore, the researcher concluded that 4-MAT and Merrill's instructional model can be used to solve the problem of students' lack of self-regulation and poor achievement in mathematics.

References

- 1) Agbenyegah, K. B. (2022). *Primary school teachers' teaching strategies that develop and enhance self-regulated learning* (Doctoral dissertation, North-West University (South Africa)).
- 2) Aktas, I., & Bilgin, İ. (2015). The effect of the 4MAT learning model on the achievement and motivation of 7th grade students on the subject of particulate nature of matter and an examination of student opinions on the model. *Research in Science & Technological Education*, 33(1), 1-21.
- 3) Aliustaoğlu, F., & Tuna, A. (2018). The influence of 4-MAT model on academic achievement and retention of learning in transformation geometry. *International Journal on New Trends in Education and Their Implications*, 9(2), 16-32. Retrieved on January 12, 2023 from http://www.ijonte.org/FileUpload/ks63207/File/ijonte_2018.2_complete.pdf#page=23
- 4) Alzahrani, I. H., & Alnufaie, M. R. (2024). Deep Learning Self-Regulation Strategies in the Learning of English as a Foreign Language among Arab College Students. *TESL-EJ*, 28(2), n2.
- 5) Arbor, A. (2015). *The importance of learning Algebra in high school. News from Mathnasium of Ann Arbor. Mathnasium: The Math Learning Centre.*
- 6) Asekun, U. O. (2023). *Developing algebraic reasoning in the intermediate phase to encourage critical thinking: a case study of teachers* (Doctoral dissertation, Stellenbosch: Stellenbosch University).
- 7) Barboianu, C. (2021). *What is Mathematics: School Guide to Conceptual Understanding of Mathematics*. PhilScience Press.
- 8) Bridget, A., Julius, A., Metropolitan I. U. (2024). Teachers' motivation and students' academic performance secondary schools, mbarara city. *Metropolitan Journal of Social and Educational Research*, 3(4), 224-239.

- 9) Brown, T. (2020). *A contemporary theory of mathematics education research*. Springer.
- 10) Ekwueme, C.O. (2013). *Mathematics Teaching and Learning in Schools*: Calabar, Radiant Ventures Nig LTD
- 11) Gambari, A. I., Falode C. O. & Adegbenro D. A. (2014). Effectiveness of computer animation and geometrical instructional model on mathematics achievement and retention among junior secondary students. *European Journal of Science and Mathematics Education*, 2(2), 127-146
- 12) Genç, M. (2023). Identifying Mathematical Connections in Model-Eliciting Activities: A Case Study with Pre-service Mathematics Teachers as Designers. *Anadolu Üniversitesi Eğitim Fakültesi Dergisi*, 7(4), 1093-1118.
<https://doi.org/10.34056/aujef.1261714>
- 13) Handam, B., & Vedat O. (2015). Student views on the 4mat teaching model application in the two dimensional art studio classes in the fine arts high school. *Anadolu Journal of Educational Sciences International, Art Education Special Issue*, 242-265
<https://doi.org/10.21083/ajote.v2i2.2022>.
- 14) Khan, Z. (2021). Causes of Poor Performance in English at Secondary School Level in Pakistan. *University of Chitral Journal of Linguistics and Literature*, 5(I), 293-310.
- 15) King, R.B. (2016). Is a performance-avoidance achievement goal always maladaptive? Not necessarily for collectivists. *Personality and Individual Differences*, 99, 190-195
- 16) Lee, S., & Koszalka, T. A. (2016). Course-level implementation of first principles, goal orientations, and cognitive engagement: A multilevel mediation model. *Asia Pacific Education Review*, 17, 365-375.
- 17) Lo, C. K., & Hew, K. F. (2020). A comparison of flipped learning with gamification, traditional learning, and online independent study: the effects on students' mathematics achievement and cognitive engagement. *Interactive Learning Environments*, 28(4), 464-481.
- 18) Lourens, I. (2022). *A systematic analysis of the generalisation concept in early algebra for young learners—some ideas for the classroom* (Doctoral dissertation, Stellenbosch: Stellenbosch University).
- 19) Maganga, J. H. (2016). *Factors Affecting Students' Academic Performance: A Case of Public Secondary Schools in Ilala District, Dar es Salaam* (Doctoral dissertation, The Open University of Tanzania).
- 20) McClelland, D. C. (1961). *The achieving society*, Princeton, NJ: Van Norstrand Co.
- 21) Mohammed, A. T., & Shraikh, S. R. A. (2020). The impact of brain-based learning theory, Merrill model, and Vee-shaped diagram on the achievement and development of mind habits of kindergarten students in the curriculum of children's rights in Islam and their attitudes towards them. *Learning*, 29(11s), 2766-2784.
- 22) Odo, I., Agwagah, U. N., Ugwuanyi, C. C., Shiaki, O. B., Nwoye, M. N., Emeji, E. I., ... & Ugwuanyi, C. S. (2021). Effectiveness of First Principles of Instruction in Promoting high Achievement of students in Mathematics: Implications for physics teaching. *Journal of Critical Reviews*, 8(2), 119-128.

- 23) Odo, J. A. & Ugwuda, A. O. (2014). Effect of Mathematics Games on Students Achievement and Interest in Mathematics. Proceedings of Annual National Conference of Mathematics Association of Nigeria (M.A.N.), 151-157
- 24) Okoro, I.F., Unamba, E.C. & Ugochukwu, N.J. (2020). Effectiveness of 4mat instructional model on pupils Academic Achievement in mathematics (*Nigeria Journal of Business administration* 1(1), 237-245)
- 25) Osama, M.I., Fahad A. A., & Ayman, M.B. (2016). Effect of using 4MAT method on academic achievement and attitudes toward engineering economy for undergraduate students. *International Journal of Vocational and Technical Education*, 8(1), 1-11
- 26) Steinmayr, R., Meiner, A., Weideinger, A. F., & Wirthwein, L. (2014). *Academic achievement* (pp. 9780199756810-0108). Oxford, UK: Oxford University Press.
- 27) Tezcan, G., & Güvenç, H. (2017). The Effects of 4MAT Teaching Model and Whole Brain Model on Academic Achievement in Science. *Education & Science/EgitimveBilim*, 42(192).
- 28) Wattananualsakul, T. (2022). Development of Mathematics Instructional Model. *Educational Leadership*, 43, 45-48.
- 29) Xiao, Y., & Hew, K. F. T. (2023). Intangible rewards versus tangible rewards in gamified online learning: Which promotes student intrinsic motivation, behavioural engagement, cognitive engagement and learning performance? *British Journal of Educational Technology*.
- 30) Yorganci, S. (2020). Implementing flipped learning approach based on 'first principles of instruction' in mathematics courses. *Journal of Computer Assisted Learning*, 36(5), 763-779. <https://publons.com/publon/10.1111/jcal.12448>