

Meta-Analysis of Four Modes Application Technique on the Academic Achievement of Students in Science

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Abstract

The study investigated Meta-analytical review of studies conducted on the effects of 4MAT teaching strategy on students' achievement in science carried from 2008-2018. The aim of the study was to determine the extent to which 4MAT improves students' performance, whether sample size (small or large) and science subject type has effect on the outcomes of 4MAT with respect to students' achievement in science. Twenty seven (27) primary studies were obtained out of which only Fifteen (15) studies were used based on inclusion criteria set in the study. Comprehensive Meta Analysis Software version 3 (CMS, V3) was used for data analysis. Three research questions were answered using Meta analytical analysis output of the selected studies. The results of the study revealed that the effect sizes of these studies are highly heterogeneous ($Q > \chi^2$, $P < 0.05$, $I^2 = 94.858\%$) suggesting for the use of Random model effect. It was found that 4MAT significantly improves science students' academic achievement with effect size (d) of 1.582 corresponding to distribution overlap (U3) of 94.5% ($d=1.582$, $U3=94.5\%$), science students' academic achievement did not show significant difference on exposure to 4MAT with respect to sample size and Subjects type. Based on the results, it was recommended that 4MAT should be used in teaching and learning of Science, Technology and Mathematics.

Keywords: 4MAT Model, Meta analysis, Science, and Students' academic achievement

Introduction

Scientific knowledge is applicable in many aspect of life, for example, it can be applied in industries, medicine, construction of bridges, modeling for disease control, security printing, and biological warfare among others. Despite the application of science and its ability for proffering solution to problems, students' academic achievement in science subjects has been poor (West African Examination Council, WAEC, 2014-2017; Lucy, 2015). Studies conducted by Sabel and Sabiha, 2016 reported that science should be taught in such a way that can address individual differences existing among the learners in order to solve problem of students' academic achievement . Among students each individual is different from other in terms of physiological and psychological variables as a result of genetic makeup and past experience (Tezcan & Güvenç, 2017).

Learning styles is preferred way whereby individual use to perceive and process new concepts (Fayambo, 2015). Nicoll and Joan (2009) defined learning style as the favorite of the person in using his/her ability in recognizing and processing the new information. Fayombo (2015) reported that considering every learner's learning style in class while teaching could improve their achievement and retention. Hermann-Nehdi (2009) is of the view that individual's learning styles results from the differences in the parts of brain that is frequently used. Studies have proven that teaching according to learning styles is related to the relationship between the brain, its structure and learning should not rule out (Abdelsalam, 2017; Teczan & Guvenc, 2017; Nurman, 2016).

The consideration of individual learning styles in conjunction with the brain parts functions while delivering science learning activities is called Four Modes Application Technique (4MAT) and was developed by Bernice McCarthy in 1987. 4MAT considered 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, Fahad & Ayman, 2016). The model is of the view that there are four types of learners in normal class settings: Hamdan and Vedat (2015) reported that the 4 types of learners as: Type 1 (Imaginative), Type 2 (Analytic), Type 3 (common sense) and Type 4 (Dynamic) learners. The type one learners prefers concrete experience and abstract conceptualization and ask why? , Type 2 learners prefer abstract conceptualization and reflective observation and usually ask What? Type 3 learners prefer abstract conceptualization and active experimentation and ask How? And Type 4 learners prefer concrete experience and active experimentation and ask what if? (Teczan & Guvenc, 2017; Joan, 2012). The human brain is structurally divided into left and right parts which are physiologically different in terms of function. left brain is analytical, systematic, looks at part, rational while the right brain is intuitive, random, look at whole and creative(Humera, 2015; Geak, 2011). In 4MAT model the learning activities is delivered to the learners in a manner that addresses their individual styles coupled with function of left and right parts of brain.

Many studies (Umate, 2018; Abdelsalam, 2017; Nurman, 2015; Osama, Fahad & Fahad, 2016; Sabiha & Sabila, 2016 Aktas & Bilgin,2015; Okoyefi, 2014; Serap & Sengul, 2013; Ovez, 2012; Protootong,2011) carried on the effects of 4MAT on the students' academic achievements and other dependent variables such as retention, motivation, attitude and misconception in different science subjects: biology, chemistry, physics and mathematics. The findings of these studies revealed that 4MAT has significantly improved science students' academic achievement and recommended it for the teaching of science subjects but these studies di not specified the extent to which 4MAT improves students' achievement

Kanadi (2016) carried out a Meta analytical study on the effects of learning style instructional models on the students' achievement, retention and attitude. The study revealed that leaning instructional models improved students achievement ($d=1.029$), retention ($d=1.290$) and attitude ($d=1.113$) . The study also used course types, types of learning styles models and experimental design as moderators and found that learning style instructional model significantly improved students' achievement independent of course type and learning style model used. The present study estimated the effect sizes of studies carried out only on the effects of 4MAT on students' achievement unlike the reviewed study which estimated effect size of all learning styles models on the students' achievement. Lovelace (2005) held a Meta analytical study on the effect Dunn and Dunn learning style model on academic achievement and attitude of students. The effect size calculated for the achievement and attitude were 0.87 and 0.85. As a result it was concluded that Dunn and Dunn learning model had a very strong effect on students' academic achievement and attitude. Slemmer (2002) conducted a Meta analytical study on the effect of learning styles on academic achievement in technology enhanced learning environment. The study used 48 experimental studies and the effect size was calculated as 0.13 a small effect size.

Though 4MAT has significantly improved science students academic achievement but to what extend in terms of effect sizes and subject types of these studies has not been explained. Thus this study aims at synthesizing individual effect size of individual study and come up with overall effect size that can be used to explain the extent to which 4MAT has significantly improved science students' performance in terms of small, or large effect size and subject types in science.

Objectives of the study

The objectives of this study are:

1. To determine the extent to which 4MAT improves students' performance across the selected studies.
2. To determine whether sample size (small or large) has effect on the outcome of 4MAT with respect to students' achievement in science across the selected studies.
3. To find out if there is significant difference in subject type when exposed to 4MAT across the selected studies.

Research Question

1. What is the extent to which 4MAT improves students' performance across the selected studies?
2. Is there any significant difference in the outcome of 4MAT based on sample size (small or large) across the selected studies?
3. Does 4MAT show significant difference on science students' academic achievement according to subject type across the selected studies?

Methodology

The Meta analysis research design was employed in this study. Meta-analysis is the analysis of analyses and it involves aggregating and combining the results of comparable studies into a coherent account to discover main effects (Cohen, 2007). The standardized mean difference (Cohn, d) was used as effect size. Sample size and science subject types were used as moderators in this study. The studies with sample size of 10-45 were considered as small sampled size while studies with sample size of 46-upward were considered as large sampled size studies in this study. The various studies were organized under biology, chemistry, physics and mathematics. While studies conducted in General science and other related science subjects such as engineering course were coded as others.

Study inclusion and Exclusion criteria

The specified criteria for inclusion of study are: (i) It must have sample size (ii) It must employed quasi-experimental research design, (iii) It must has experimental and control group; the experimental group must exposed to 4MAT model while control group must exposed to traditional method of teaching. (iv) It must have mean and standard deviations (v) the study must employed parametric statistics: T-test, ANOVA, ANCOVA or MANOVA. (vi) It must be carried out in biology, chemistry, physics, Mathematics or applied sciences or science related subjects and within the range of 2008-2018 in English, Arabic or language that is translatable by Google translator. In this study, 27 related studies were obtained but only 15 studies posses all the listed criteria and were coded ranging from A to O. And each study has two groups: experimental and Control groups. The experimental groups were coded A while control groups were coded B in each study.

Data Analysis Procedure

Meta-analysis involves combining effects sizes of individual studies and come up with single effect size which is used for drawing conclusion. The combination of these effect sizes is conducted based on two models: Fixed effect or Random effect models. To decide which model is to use in combining effect sizes, a test of heterogeneity among the study was performed first to examine the observed variance in the effect sizes of individual studies is significantly different from expected variance as a result of sampling error (Copper, 2010). The Cochran (Q)-value or significant level is used in testing heterogeneity If p-values is significant ($p < .05$) or the Q-value is bigger than the χ^2 -value in the table corresponding to the degree of freedom the studies are said to be heterogeneous; and if p-value is not significant ($p > .05$) or the Q-value is smaller than the table χ^2 -value then the studies are homogeneous (Dinçer, 2014).

The comprehensive Meta analysis Software (CMS) version 3 was used in conducting data analysis with reference to the means, standard deviations and sample sizes of the experimental and control groups and standardized mean differences (Cohen d) and it classification is given as Cohen's

d value between 0 to 0.3 is a small effect size, ranging from 0.3 and 0.6 is a moderate effect size, and an effect size bigger than 0.6 is a large effect size.’ (Aktas & Bilgin, 2015). The effect size can be expressed in terms of distribution overlap, known as U3 and it implies that 92% of the two groups will overlap and there is a 56% chance that a person picked at random from the treatment group will have a higher score than a person picked at random from the control group.

Results

RQ1. What is the extent to which 4MAT improves students’ performance across the selected studies?

To answer research question one Meta analytical output of related 15 empirical studies was used and is presented in Table 1

Table 1: Summary of Meta analysis of studies on effect of 4MAT on science students’ academic achievement

Model	N	Std. error	Heterogeneity			Effect sizes	95% confidence interval		
			Q	df	P		I ²	Lower limit	Upper limit
Fixed	15	0.062	272.270	14	0.000	94.858	1.304	1.183	1.426
Random	15	0.279					1.582	1.035	2.130

In Table 1, the result of heterogeneity is significant ($P < 0.05$), Q-value is calculated as 272.270 which greater table chi square (23.68) with $df=14$ and 95% confidence level. I^2 is 94.858% indicating that there is high amount of heterogeneity among the studies. These findings reveal that the studies do not share common effects sizes. Therefore Random effect model was chosen for the computation of effect sizes in this study. Based on Random effect model, the effect size (d) of 15 studies included in this study was calculated as 1.582 with standard error of 0.279 and confidence interval of 2.130 and 1.035. This effect size (d) is very large according to Cohen (1988), as cited in Kanadi (2016).

RQ2. Does 4MAT show significant difference on science students’ academic achievement according to subject type across the selected studies?

To answer research Question two the effect sizes calculated from Meta analysis software was used as presented Table 2.1

Table 2.1: Meta analysis results on the effects of 4MAT on students’ science achievement according to subject types.

Model Type		Heterogeneity			Effect size(total)	95% confidence interval	
		Q	df	P		Lower limit	Upper limit
Fixed	Within group	221.998	9	0.000	1.304	1.183	1.426
	Between groups	50.272	5	0.000			
Random	Between groups	33.973	5	0.000	0.956	0.749	1.162

In Table 2.1, the Q value is under fixed model is 50.272, $df=5$ and $p=0.000$. This indicate that heterogeneity among the studies according to subjects is significant and hence fixed effect model cannot be used instead Random effect model should be used.

Table 2.2: Effect sizes of 4MAT studies according to subject types under Random effect Model

Subject	Effect size (d)	Lower limit	Upper limit
Biology	1.231	0.868	1.593
Chemistry	1.651	1.651	2.142
Physics	0.646	0.193	1.099
Mathematics	1.752	0.911	2.593
Others	2.045	0.113	3.978

Table 2.2 displays effect sizes (Cohen's d) with their lower and upper limit at 95% confidence interval of various science subjects: biology 1.231 (0.868, 1.593), chemistry 1.651 (1.160, 2.142), mathematics 1.752 (0.911, 2.593), Physics 0.646 (0.193, 1.099) and others 2.045 (0.113, 3.978). Based on this result, the effect size of studies conducted science related disciplines ie others is largest 2.045 and effect size of studies conducted in physics is the smallest 0.646.

RQ3. Is there any difference in the outcome of 4MAT based on sample size (small or large) across the selected studies?

The summary of Meta-analytical result based on Random model effect was used to answer research question three.

Table 3: Effect sizes of 4MAT studies based on sample sizes based on Random model effect

Sample size	Effect size (d)	Lower limit	Upper limit
Large	1.231	0.035	0.185
Small	1.351	0.110	0.703

Table 3 displays effect sizes of selected 4MAT studies according to sample size of the studies. The effect size of large sampled size studies (1.231) is smaller compared to that of small sampled size studies (1.351).

Discussion of Results

The heterogeneity test was applied across the selected studies and it was found that the effect sizes of individual studies varies significantly from one another, hence were heterogeneous at high level ($p < 0.05$, $I^2 = 94.856$). As a result, Random model effect was used in combining effect sizes of the studies on the effects of 4MAT on the science students' academic achievement and the effect size of 1.582 was obtained. This effect size is very large and is associated to U_3 value of 94.5%. This implies that average student received learning activities based on 4MAT Model scored higher on academic achievement test than 94.5% of students receiving the same instruction using traditional methods of teaching. This findings is in agreement with Meta analytical studies conducted by (Kanadi, 2016; Lovelace, 2005; Slemmer, 2002). This study is also in accordance with the individual studies conducted on effects of 4MAT on the students' achievement by (Serap & Sengul, 2013; Okoyefi, 2014; Aktas & Bilgin, 2015; Abdelsalam, 2017). The reason for this finding might have result from the fact that 4MAT model provides opportunity for active involvement of the learners in teaching and learning as well as concretize the learning experiences so that students can manipulate them.

It was observed from the findings of this study that learning experiences designed in line with 4MAT teaching strategy improves students academic achievement irrespective of the subject type. this is in accordance with the findings of Kanadi (2016) who reported learning material prepared based on learning style models increase students academic achievement independent of course type. The emergence of the finding might stem from the fact that 4MAT model considers prior knowledge of learners and then concretize learning materials based on it and then give them opportunity to manipulate these materials.

The findings of this study revealed that there is no significant difference in students' academic achievement exposed to 4MAT with large sample size and those exposed to 4MAT with small sample size. This observation might have result from fact that in 4MAT model whether sample size is large or small, each student is given preference to him/her as regard to individual difference and ability level and then participate in the lesson actively. This mean everybody must participate actively in the lesson using prepared concrete materials and this may give chance to each student either in large sample size or small sample size.

Conclusion

In this study, the findings of 15 experimental studies conducted on the effects of 4MAT teaching strategy on science students' achievements and retention for the years 2008-2018 were combined through meta-analytical review method. The study was set to specify the extent to which 4MAT improves science students' academic achievement and retention and also to find out the impact of differences in sample size and science subjects on the results of 4MAT studies. Since only few studies are known in the literature with respect to the extent to which 4MAT improves science students' academic achievement and retention and the impact of smallness and largeness of sample across science subjects on the 4MAT studies. The results of the study revealed that the effect sizes of these studies are highly heterogeneous ($Q > \chi^2$, $P < 0.05$, $I^2 = 94.858\%$) suggesting for the use of Random model effect. The study revealed learning activities prepared and delivered using 4MAT model significant improved science students' academic achievement ($d = 1.582$, $U_3 = 94.5\%$), enhances students' achievement irrespective of subject type (biology $d = 1.231$, chemistry $d = 1.651$, mathematics $d = 1.752$, physics $d = 0.646$ and others $d = 2.045$) and that sample size has no significant effects on the students' academic achievement when exposed to 4MAT ($p < 0.05$). The evidences from this study suggest that 4MAT teaching strategy improves students' academic achievement and retention irrespective of science subjects involved and sample size.

Recommendation

The result of this study will be available to science teachers through workshops, seminars, conferences and publications through which they could be aware of the merit of 4MAT teaching method in teaching and learning of science subjects for the purpose of improving students' achievement.

References

- Abdelsalam, M. A. (2017). The effect of teaching science using McCarthy model on the 8th grade students' retention of learning in Jordan. *Journal of Education and Psychological Studies*, 11(1), 191-206.
- Aktas, I., & Bilgin, I. (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 Technology Education*, 33(1), 1-21.
- Anita, C. A. (2014). Effects of two instructional delivery approaches on senior secondary schools students' achievement and retention in biology. M.Ed Thesis, University of Nigeria, Nsukka, Nigeria
- Borenstein, M. (2011). *Comprehensive meta-analysis subgroups* [Video File]. Retrieved from <https://www.youtube.com/watch?v=Y7X5ZbfJgDI>
- Dinçer, S. (2014). *Eğitim bilimlerinde uygulamalı meta-analiz* [Practical meta-analysis in educational science]. Ankara, Turkey: Pegem Akademi.
- Fayombo, G. (2015). Learning styles, teaching strategies and academic achievement among some psychology undergraduates in barbados. *Caribbean Educational Research Journal*, 3(2), 46-61.

- Geake, J. (2011). Position statement on motivations, methodologies, and practical implications of educational neuroscience research: studies of the neural correlates of creative intelligence. *Education Philosophy and Theory*, 43(1), 43-47.
- 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 school11. *Anadolu Journal of Educational Sciences International, Art Education Special Issue*, 242-265
- Herrmann-Nehdi, A. (2008). Whole brain design: engage and retain your learners. Retrieved from <http://www.elearningguild.com>
- Humera, S. (2015). A study of hemispheric dominance and mathematics achievement of the standard students of aurangabad city. *Scholarly Research Journal For Interdisciplinary Studies*, 2(16), 2753-2763
- Kanadli, S. (2016). A meta-analysis on the effect of instructional designs based on the learning styles models on academic achievement, attitude and retention. *Kuram ve Uygulamada Egitim Bilimleri*, 16(6), 2057–2086.
- Lovelace, M. K. (2005). Meta-analysis of experimental research based on the Dunn and Dunn Model. *The Journal of Educational Research*, 98(3), 176–183.
- Lucy, O. (2015). *Effect of inquiry method on academic performance of chemistry students in senior secondary schools in Kaduna state, Nigeria*. M.Ed Thesis Ahmadu Bello University, Zaria, Nigeria
- Nicoll-Senft, Joan M (2009). Assessing the Impact of the 4MAT Teaching Model Across Multiple Disciplines in Higher Education. *College Teach. J.* (58):19-27.
- Nurma, A., (2015). *Effect of 4 MAT Instruction on Learning Achievement, Retention and Instructional Satisfaction of Grade 12 Students*. Masters Degree Thesis, Prince of Songkla University, Thailand.
- Okoyefi, Q. O. (2014). *Effect of four mode application techniques on achievement, retention and multiple intelligences of students with different learning styles in biology*. PhD thesis. University Of Nigeria Nsukka, Nigeria
- 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.
- Ovez. D. F. (2012). The effect of the 4mat model on student’s algebra achievements and level of reaching attainments. *International Journal of Contemporary Mathematical Sciences* 7(45), 2197 – 2205.
- Oyenuga, A.O. (2010). *Effect of models on interest and academic achievement of auto-mechanics students in technical colleges in Lagos-state*. PhD Thesis University of Nigeria, Nsukka, Nigeria
- Pratoomtong, W. (2011). A development of science learning activities based on 4mat system and learning styles to promote multiple intelligences of sixth grade students. PhD thesis Srinakharinwirot University, Thailand.
- Ramida, C., & Boonyaras, S. (2017). Using the 4MAT Model to Promote Learning Achievement and Connection Skills on Chemical Reaction of the 10th Grade Students. *Research Journal Educational Studies*, 4(2), 24-31.
- Seker, B.,S., & Ovez, D., T., F. (2018).The Integration of the 4MAT Teaching Model with the Interdisciplinary Structure: A New Model Proposal and Test . *EURASIA Journal Math Science and Technical Education*, 14(5), 1767-1790
- Serap, T., & Demirel, M. (2009). The effect of brain based learning on achievement, retention, attitude and learning process. *Procedia Social and Behavioral Sciences*, 1, 1782–1791
- Sibel, C., & Sabiha. O. (2016). The effect of the 4mat learning style model on academic achievement and learning retention in teaching “ratio and proportions”. *Journal of Theory and Practice in Education*, 12(3), 568-589.

- Slemmer, D. L. (2002). *The effect of learning styles on student achievement in various hypertext, hypermedia and technology enhanced learning environments: A meta-analysis* (Doctoral dissertation). Available from ProQuest Dissertations and Theses database
- Tatar, E., & Dikici, R. (2009). The effect of the 4MAT method (learning styles and brain hemispheres) of instruction on achievement in mathematics. *International Journal of Mathematical Education in Science and Technology*, 40(8), 1027-1036.
- Teczan, G., & Guvenz, H. (2017) The Effects of 4MAT Teaching and Whole Brain Model on Academic Achievement in Science. *Education and Science*, 42(192), 303-325.
- Umate, B.A (2018). *Effects of Four Modes Application Technique on the Academic Achievement and Retention of Secondary School Chemistry students of Maiduguri Metropolitan Council Borno-Nigeria*. M.Sc.Ed Dissertation (Unpublished) Bayero University, Kano, Nigeria.
- Uyangor, S. M. (2012). The effectiveness of the 4MAT teaching model upon student achievement and attitude levels. *International Journal of Research Studies in Education*, 1(2), 43-53.
- West African Examination Council (WAEC), Annual Report, 2013- 2017