ISSN: 2226-8012
Volume 12, Number 2, 2025
Journal of International, Educational Research and Development

EFFICACY OF COGNITIVE BEHAVIOURAL TASK ANALYSIS TRAINING ON ACHIEVEMENT IN MATHEMATICS-RELATED CHEMISTRY TOPICS AMONG STUDENTS IN RIVERS STATE, NIGERIA.

Zudonu, Onisoman Chuks
School of Sciences, Federal College of Education (Technical), Omoko, Rivers State, Nigeria
Email:onisoman.zudonu@fcetomoku.edu.ng
https://orcid.org/0000-0002-0892-7877

https://doi.org/10.60787/JIERD.VOL12NO2.3368

ABSTRACT

Task analysis process in problem-solving is rarely used in teaching. This has contributed to students' poor achievement in chemistry, linked to their background knowledge in mathematics. As such, Cognitive Behavioural Task Analysis Training (CBTAT) was used to train students to solve Mathematics-related Chemistry topics. The researcher adopted a randomized pretest-posttest control group design. The sample of 105 senior secondary school II students from Rivers State, Nigeria, participated in the study. The instrument for data collection was Mathematics-related Chemistry Essay Test (MCET) developed by the researcher. Inter-rater reliability was done and Kendell coefficient of concordance was obtained as 0.88. Data analysis was done with SPSS version 26 and the test statistic was analysis of covariance. It was found that Cognitive Behavioural Task Analysis Training had a more significant effect on students' achievement in Mathematics-related Chemistry topics. The researcher concluded that Cognitive Behavioural Task Analysis Training enhanced students' achievement in Mathematics-related Chemistry topics.

Keywords: Cognitive-Behavioural Training, Task Analysis, Mathematics, Chemistry.

INTRODUCTION

Mathematics is an important tool for the sciences. It provides students with the quantitative background that they need to succeed in their science courses. However, there is no gainsaying that there exists a relationship between mathematics and chemistry. Nadrian (2018) noted that mathematical confidence and problem-solving ability are probably the most important factors in predicting the success of students in a first-year course in general chemistry. Jonathan (2016) is of the view that knowledge and skills in the areas of basic mathematics, calculus, and 3-dimensional geometry can be useful as a prerequisite or co-requisite to general chemistry. Sheryl (2018) identified the following areas of chemistry where mathematics is applied; single and multivariable calculus (used in physical chemistry), linear algebra (used in physical chemistry), differential equations with modelling (used in chemical kinetics and thermodynamics), applied statistics (used in almost all areas of chemistry), analysis, advanced calculus, or Fourier analysis (used in physical chemistry and quantum mechanics), abstract algebra or group theory (used in inorganic chemistry and crystallography), probability theory (used in biophysical chemistry and Monte Carlo simulations), partial differential equations (used in chemical reaction kinetics, mass transport and thermodynamics), numerical analysis (used in computational chemistry). It is therefore unlikely that a student will excel in general chemistry without a solid understanding of at least basic mathematics concepts (Robinson, 2018).

Chemistry is the basis of all environmental sciences. All science students must offer and pass it at the credit level before they can proceed to study any science course at the university level (Kolawole et al, 2011). However, despite the vital role played by chemistry in the study of science in general, a lot of research has shown that students still perform poorly in chemistry. Experiential evidence also shows that only a few students are exceptional in their chemistry achievement whereas many appear to know little in the subjects. These large numbers of students with little

knowledge often obtain low scores during internal and external examinations, which in turn affect the average marks of their groups in the subject. This unsatisfactory state of students' achievement in chemistry has been documented (Abu & Fabunmi, 2005; Adesoji and Olatunbosun, 2008; Njoku, 2013; West African Examination Council Chief Examiner's Report 2014-2017-WAEC, 2017; Ibezim, 2018) among others. Concerted efforts are being made by parents, teachers, government, private organizations among other to stem the tide of failure in chemistry or below average achievement in chemistry but the situation still remain the same.

Some factors identified by (Adeyemi, 2011), as causes of students' academic failure in chemistry are: lack of personal confidence, emotional instability and a temperamental tendency towards extroversion. Al-methen and Wilkinson (1992) argued that students' failures are due to academic problems arising from personal inadequacies like low ability, negative self-concept, anxiety, peer influence, poor classroom conditions and lack of home support. This poor achievement of students recorded in chemistry may also be linked to their background knowledge in mathematics. Adesoji and Ibraheem (2009) were of the view that the mathematical abilities of students were tied to their success in chemistry. They reiterated that the ability to manipulate symbols (geometry) and the ability to use and manoeuvre algebraic symbols to solve problems were necessary for success in chemistry. The authors went on to say that students with intellectual abilities had a greater chance of success in chemistry than those without intellectual abilities.

Achievement in Mathematics is a fundamental indicator of the performance of a school system of any country (Reddy, 2005). Moreover, it is a key subject for countries with emerging economies, since Mathematics enables learners to enroll for careers in the fields of engineering, the natural sciences, accountancy, and many others crucial to support economic development (Makgato & Mji, 2006). Mathematics has been identified as the foundation science subject for the other science subjects like Chemistry, Physics and Biology (Akinsila & Ogunleye, 2003). It is therefore logical to think that students who perform highly in Mathematics are more opportune to perform better in Chemistry and other subjects with mathematics-related concepts than their counterparts who are low achievers in Mathematics.

Many studies have however recorded a global poor academic achievement of students in Mathematics over the years. Researchers have indicated that Mathematics education in South Africa is in crisis (Hlalele, 2012; Reddy, Winnaar, Visser, Feza-Piyose, Arends, Prinsloo, Mthethwa, Juan & Rogers, 2013; Siyepu, 2013; Pournara, Hodgen, Adler & Pillay, 2015). The well-known Trends in International Mathematics and Science Study (TIMSS), conducted in 2011, found that South African learners' Mathematics achievement was poor (Reddy et al., 2013). Chhinh and Tabata (2003) in their study also found a poor academic achievement of students in Mathematics. The global outcry of poor academic achievement in Mathematics is equally experienced by students from Nigeria. Several studies conducted in Nigeria show that there is a poor academic achievement of students in Mathematics (Jegede, 2010; Oloyede; 2010; Daso, 2013).

This poor performance in Mathematics seems to be caused by teachers who lack the knowledge and skills to explain concepts clearly or appreciate the individual differences existing among learners (Siyepu, 2013). It is also caused by teachers who do not understand mathematical cognition in learners (Henning, 2013); It is equally caused by the fact that most students are learning English second language, so they struggle to learn Mathematics through English as medium of instruction (Botes & Miji, 2010; Howie, 2003; Setati, 2008).

Task analysis is the process of breaking an assignment down into smaller, more manageable components (Szidon & Franzone, 2009). Task analysis according to Sam and Afirmt (2015) is a method of identifying the hierarchical order of all essential components in a task. Anderson, Taras and Cannon (1996) see task analysis as the delineation of a complex task into smaller, more manageable steps. It is the analysis of how a task is accomplished, including a detailed description of both manual and mental activities, task and element durations, task frequency, task allocation, task complexity, environmental conditions, necessary clothing and equipment, and any other unique factors involved in or required for one or more people to perform a given task (Yılmaz, Konukman,

Birkan, Ozen, Yanardagù, & Camursoy, 2010). It is a foundational practice used to teach target skills and increase desired behaviour (Wong, 2014).

It could be deduced that task analysis is simply a list of logically ordered component behaviours in any given task or goal. The list can provide teachers and students with a good starting point to determine which particular steps are more complex and need to be learned and which can be learned more easily or are already in the student's repertoire. If task analysis is carefully organized and follows the proper steps, it can be used to solve many mathematical problems, not because of some inherent magic, but because of the detailed, careful, integrated analysis involved (Carlisle, 2013).

Task analysis can be used by a variety of professionals, including teachers, special educators, therapists, paraprofessionals, and early interventionists in educational and community-based environments (Wong, 2014). In the teaching-learning environment, there have been questions as to why some students learn and perform better than other students under the same conditions. Researchers have explored the effect of the task analysis process in enhancing problem-solving skills. Stein, Smith, Henningen and Silver (2010) found that task analysis is an important tool that can be used as a mathematics problem-solving procedure. Catrambone (2010) indicated that the task analysis process is useful in identifying the knowledge for learning materials, and is particularly useful for revealing procedural and conceptual knowledge that a learner needs to know. In a similar study, Carlisle (2013) observed that task analysis is an effective technique which facilitates a learning procedure. In the application of the elaborative theory's procedure for designing mathematical instructions, Reigeluth and Darwazah (2016) found that task analysis is an effective means of teaching mathematics. The researchers also added that task analysis helps in engaging the students in solving and discussing mathematical tasks in the most logical pattern.

Despite the seemingly overwhelming empirical evidence about the benefits of the task analysis process in problem-solving, it is rarely used in teaching students, especially integrating it with Cognitive Behavioural Therapy (CBT). This may have contributed to students' academic achievement in Mathematics and chemistry topics remaining below the threshold of what could be considered an average mark. This in turn may be responsible for students' challenges in Mathematics-related Chemistry topics. The question therefore is: How could this problem of students' poor academic achievement in Mathematics-related chemistry be resolved? It is on this premise that using Cognitive Behavioural Task Analysis Training (CBTAT) to remedy students' poor academic achievement in Mathematics-related chemistry topics for students enrolled in Chemistry becomes pertinent. Cognitive Behavioural Task Analysis Training is a modified Cognitive Behaviour Therapy procedure that integrates task analysis with psychotherapy. The aim is to help students challenge and overcome the beliefs that Mathematics-related chemistry topics are abstract and difficult to understand.

Therefore, the researcher is of the view that CBTAT could enhance the achievement of students in mathematics-related Chemistry topics. The training makes it possible to restructure the students' psychology in terms of their task analysis process which in turn enhance their problem-solving abilities. However, there is no empirical evidence on the efficacy of cognitive behavioural task analysis training on students' achievement in mathematics-related Chemistry topics among students enrolled in Chemistry available to the researcher at present to prove or disprove the researchers' claim. Thus, this study determined the efficacy of cognitive behavioural task analysis training on students' achievement in mathematics-related Chemistry topics.

Based on empirical evidence available to the researcher in similar situations, Cognitive Behaviour Therapy CBT has been shown in other fields to help individuals challenge their patterns and beliefs and replace "errors in thinking such as self-defeating behaviour". The researcher is however of the belief that the condition of poor academic achievement of students in chemistry and mathematics could be arrested by the use of Cognitive Behaviour Therapy (CBT) on the students, to restructure their cognition which could enhance their learning styles and improve their task analysis process in solving problems relating to chemistry and mathematics. The objective of this

study however was to determine the efficacy of cognitive behavioural therapy on task analysis process and achievement in mathematics-related Chemistry topics among students enrolled in Chemistry education. Based on the objective, it was hypothesized that cognitive behavioural therapy (CBT) will significantly improve the task analysis process and achievement in mathematics-related Chemistry topics in Nigeria.

METHODS AND MATERIALS

Ethical considerations of participants

The researcher adhered to the established Ethical Principles and Code of Conduct of the American Psychological Association and also complied with the Declaration of Helsinki. The participants completed writing informed consent form designed by the researcher. The participants were assured of their confidentiality concerning any information given either in filling out the demographic section or responding to all the items in the Mathematics-related Chemistry Essay Test (MCET). The following inclusion criteria were used: 1) Senior Secondary (SS) II students in Rivers State, Nigeria, 2) Students who are offering Chemistry, 3) Students who are willing to participate in the experiment, and 4) Students in schools with Chemistry Teachers. The following exclusion criteria were used: 1) Students who are not in regular Chemistry classes, 2) Students who are already participating in another study, 3) on medication due to health challenges, and 4) those who did not meet the inclusion criterion. The participants for the study were 108 SS II students in Nigeria. The justification for using this sample size is anchored on Gpower software statistical analysis conducted, and the result showed that the sample size was adequate for the study.

Design

The study employed a randomized pretest-posttest control group design. This is an experimental design which uses one independent variable with two levels in a single experiment and the effect of each of the level of the independent variable is measured using different group of participants. The researcher manipulated one level of an independent variable of the study (Cognitive Behavioural Task Analysis Training-CBTAT) whereas the waitlisted or control group (WCG) was not manipulated. Subjects were randomized into experimental and control groups.

Measure

Mathematics-related Chemistry Essay Test (MCET) was developed by the researcher. The essay test has 10 questions. Questions 1, 2, 3 and 10 are from atoms, moles formulae and equations while questions 4, 5, 6, 7, 8 and 9 are from stoichemistry; mole ratio, mass relationship and reaction involving volumes. MCET was validated by three experts, two of the experts are in Chemistry education and one in Measurement and Evaluation from the University of Nigeria, Nsukka. Inter-rater reliability was done and a coefficient of 0.88 was obtained. Based on the validity and reliability information of MCET, it was considered a valid and reliable instrument to be used by the researcher.

Training guide

Cognitive Behavioural Task Analysis Training (CBTAT) guide developed by the researcher was used to train the research assistants who are classroom teachers of Chemistry. CBTAT direct both the research assistants and participants on how to analyze test items to solve them correctly. It indicates the basic principles, steps and skills involved in solving test questions. The training lasted for 16 sessions (Eight weeks of two sessions per week with a time frame of 2hours for each session). Supportive materials for Mathematics-related chemistry were provided and the trainers adhered to the directives of the researcher in implementing the guide.

Research assistants

Four research assistants administered this intervention. The four research assistants were two males and two females with age range of 30-50 years and a minimum of 10 years of practice.

The research assistants are experts in Chemistry Education. They hold master's degrees in Chemistry Education and are licensed teachers. The skills to teach Mathematics-related Chemistry topics have been acquired already, and are currently teaching in various senior secondary schools.

The researcher conducted a four-session briefing for the research assistants. Each session lasted for 2 hours per day, and the briefing lasted for four days. Session 1: Research assistants established rapport with colleagues and were briefed on the intention of the study. The research assistants were told to mention some techniques they could use in teaching students the task analysis of Mathematics-related Chemistry topics. Hands-on activities, Jigsaw, Think-pair-share and Brainstorming techniques were emphasized by research assistants. All the research assistants agreed to hands-on activities and Think-pair-shared techniques for the implementation of the study for the following reasons: i) All the research assistants can effectively and efficiently employ the technique. ii) The technique requires them to form teams, iii) Know how to make members from each team in a class meet as a group to learn a task together, iv) When the team understands the task, they return to their whole class and teach what they have learned.

Session 2: The researcher reviewed ideas about atoms, moles formulae and equations. Session 3: Research assistants worked stoichiometry; mole ratio, mass relationship and reaction involving volumes. Session 4: All the research assistants and the researcher met for rehearsal on implementation of the experiment using CBTAT by research assistants. The reason for organizing the briefing sessions was to control the errors which may arise as a result of research assistants' differences that were used for the study. The briefing helped to establish a common instructional standard among the research assistants and monitored them to ensure that they adhere strictly to the specifications of the guide.

Procedure

The researcher visited the schools in December 2024 to become accustomed to the students. Prior to the commencement of the treatment, MCET was administered as pretests (Time 1) to the students in their groups by the researcher assistants by March 2025. The aim was to determine the baseline MCET scores of the students (N=108). Of all the 108 students, 105 who met our inclusion criterion were used as participants in this study, whereas 3 students were excluded. The recruited participants were assigned to Cognitive Behavioral Task Analysis Training (CBTAT) group (n=54) and the control group (n=51). Simple random allocation software (Saghaei, 2004) facilitated students' allocation by the researcher. The process adopted during the distribution was use of a box containing slips of papers tagged "CBTAT" and "CG". Students who picked "CBTAT" slip was assigned to Cognitive Behavioral Task Analysis Training group whereas those who picked "CG" were assigned to the control group. The recruitment exercise lasted for three weeks, that is, from 6th March 2025 to 27th March 2025. Students in CBTAT group were exposed to Cognitive Behavioural Task Analysis Training for MCET. However, those in the comparison group (control group) were attended to by their regular classroom teachers. The CBTAT group comprised 28 males (51.85%) and 26 (48.15%) females; the waitlist control group comprised 26 males (50.98%) and 25 (49.02%) females.

The intervention was a 16-sessions training that lasted for eight weeks (April to June 2025). The training was implemented by four research assistants. The CBTAT group was partitioned into 11 sub-groups. Each sub-group was made up of about 5 students and handled by two research assistants. Each sub-group of 5 students sat on a laboratory table, and all 11 sub-groups were trained in two halls. Six groups were in one hall and five groups were in the second hall. The control group (CG) students received training on Mathematics-related chemistry topics using lecture method. The control group (CG) students were partitioned into two subgroups. One group, made up of 26 students, was taught in a hall, and the second group, made up of 25 students, was taught in another hall. The students were chosen for this study because they appear to show limited skills in Mathematics-related chemistry topics.

Week one was the first and second sessions. The first session focused on introduction of students and research assistants, as well as the rules and regulations that guided the process. The time and limits of confidentiality were established. In the 2nd session, the research assistant administered pretest and introduced the participants to: Mathematics-related chemistry topics.

Week two was used in handling the third and fourth sessions. The 3rd session was used to expose students to task analysis specific involving contents in Mathematics-related chemistry topics. The 4th session was used to make students identify Mathematics-related chemistry topics from their scheme of work, textbooks and past examination question papers. Week three was used for the fifth and sixth sessions. In the 5th and 6th sessions, students were engaged in Hand-on-activities and Think-pair-shared techniques with task analysis skills earlier learnt to solve problems involving Mathematics-related Chemistry topics. Week four was used for the seventh and eighth sessions. The 7th and 8th sessions were used for further training of students on Mathematics-related Chemistry topics.

In week five, the ninth and tenth sessions were handled. Each group presents the problems involving Mathematics-related Chemistry topics they have solved with all the groups. Week six was used for the eleventh and twelfth sessions. In the 11th and 12th sessions, students were exposed to many problems in Mathematics-related Chemistry topics. Week seven was used for the thirteenth and fourteenth sessions. The 13th and 14th sessions were used by individual students in solving exercises on Mathematics-related Chemistry topics. Students were engaged in sub-group discussion and criticism of individual work. Week eight was for the 15th and 16th sessions, and the training was terminated. MCET was administered again on CBTAT and Control groups as a Posttest.

There was no risk arising from the experiment; rather, it was anticipated that students' achievement in Mathematics-related Chemistry topics improved due to the use of Cognitive Behavioural Task Analysis Training (CBTAT). Monetary compensation was not paid to students, and schools used for the study. The researcher blinded the students in both groups and data analyst. This is to ensure that possible bias is eliminated and concealment is maintained in the study. To ensure a high level of compliance from the students in CBTAT, CG and research assistants, the researchers provided snacks and transportation fare for the research assistants.

Data Analysis

The data of the pretest and posttest were subjected to statistical analysis using SPSS version 26. Specifically, Analysis of covariance (ANCOVA) was used as a method of data analysis. ANCOVA was used to determine the main effect due to treatment, as well as control for factors or characteristics like gender, which cannot be randomized. The demographic characteristics of the students were not taken into consideration.

RESULTS

The result presented in Table 1 shows the pretest and posttest mean achievement score in Mathematics-related Chemistry topics of the students. The result showed that the CBTAT group had a pretest mean achievement score of ($\bar{x}$ = 41.11, SD = 2.77) and a posttest mean score of ($\bar{x}$ = 80.00, SD = 5.27). The mean difference was 38.89. The result also showed that the control group had a pretest mean achievement score of students in Mathematics-related Chemistry topics of ($\bar{x}$ = 42.29, SD = 2.84) and a posttest mean score of ($\bar{x}$ = 57.57, SD = 4.78) with a mean difference of 15.28. The result reveals that the CBTAT group had a higher mean gain in Mathematics-related Chemistry topics than their CG counterparts.

Table 1: **Mean and Standard deviation of CBTAT and CT groups at pretest and posttest**

Gender	N	Pretest $\bar{x}$	Pretest SD	Posttest $\bar{x}$	Posttest SD	Mean Difference
CBTAT Group	54	41.11	2.77	80.00	5.27	38.89
CT Group	51	42.29	2.84	57.57	4.78	15.28

CBTAT= Cognitive Behavioural Task Analysis Training; CT= Control group

The result in Table 2 main effect due to treatment was significant (F= 503.33, ρ = 0.00 and η_p^2 = 0. 834), the main effect due to gender was not significant (F= 1.393, ρ = 0.241 and η_p^2 = 0. 014) and the interaction effect for treatments and gender was equally not significant (F= 1.524, ρ = 0.220 and η_p^2 = 0.015). This implies that CBTAT and CT significantly enhanced the mean achievement score of students in Mathematics-related Chemistry topics. The partial eta square, η_p^2 (effect size) of 0.834 means that 83.4% of the increase in the mean achievement score of students in Mathematics-related Chemistry topics was due to the effect of training they received. The partial eta square, η_p^2 (effect size) due to gender and interaction effect were 1.4% and 1.5% respectively, indicating that the increase in achievement due to them was negligible.

Table 2: ANCOVA result on the difference in the mean conflict management values of participants in CBTAT and CT groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	13282.619[a]	4	3320.655	131.499	.000	.840
Intercept	1902.780	1	1902.780	75.351	.000	.430
Pretest	9.321	1	9.321	.369	.545	.004
Groups	12710.457	1	12710.457	503.339	.000	.834
Gender	35.170	1	35.170	1.393	.241	.014
Groups * Gender	38.489	1	38.489	1.524	.220	.015
Error	2525.229	100	25.252			
Total	517232.000	105				
Corrected Total	15807.848	104				

a. R Squared = .840 (Adjusted R Squared = .834)

Discussion of the Results

The findings of the study revealed that at the post-treatment measures, the efficacy of cognitive behaviour task analysis training on the improvement of achievement scores of students in Mathematics-related Chemistry topics was significant. This finding has shown the superior nature of the CBTAT over the conventional lecture approach in the improvement of students' achievement in Mathematics-related Chemistry topics. The students who were trained using CBTAT were optimally motivated during the intervention sessions, and that led to a radical increase in their Mathematics-related Chemistry topics scores after the intervention. Although this finding was based on achievement in Mathematics-related Chemistry topics, it is in line with that of (Kortering & Braziel, 2008) who found that students' engagement in school activities influences their psychological and academic outcomes encouragingly. The result was clear evidence that CBTAT was able to reduce the limitations students encountered in Mathematics-related Chemistry topics.

As one of the problems faced by students in their academic pursuit, CBTAT is a sure remedy for enhancing weakness in Mathematics-related Chemistry topics skills. CBTAT can be used in addressing the foundational practice of teaching target skills and increasing desired behaviour (Wong, 2014). Before the training commenced, students' cognitive structure for handling

Mathematics-related Chemistry topics was limited; as such, some students' achievement was poor. It was noticed that the students had challenges in Mathematics-related aspects of atoms, moles formulae and equations, stoichemistry; mole ratio, mass relationship and reactions involving volumes in Chemistry, among others. After the training, the post training outcome indicated that the pre-training challenges in Mathematics-related Chemistry by students were surmounted.

The result in Table 2 shows a significant change in Mathematics-related Chemistry topics due to the use of CBTAT. The training received by students now enables them to accurately solve problems in chemistry involving mathematical skills. This, in turn, enhances student learning outcomes as well as obtains objective and accurate information about students' academic achievement in school from teacher records. This finding affirmed (Carlisle, 2013; Reigeluth & Darwazah, 2016) assertion that task analysis is an effective technique for teaching mathematics, which facilitates a learning procedure, increases students' support and directly leads to increased student engagement. The engagement of students in task analysis activities further influences their achievement and academic progress delightfully. In cognitive behavioural task analysis training, students were instructed and given opportunities to carry out a lot of activities during the experiment, and this increased their achievement scores. Thus, CBTAT intrinsically motivated students' curiosity, and enhanced their intellectual competence in mathematics-related chemistry topics.

It was also revealed that gender had no significant influence on students' mathematics-related chemistry topics. This finding buttressed that of (Ugwumaduka & Ogunyemi, 2021; Ajai and Imoko, 2015), who found that gender did not significantly influence students' achievement in Basic Science and Mathematics, respectively. The result of this study is probably due to the fact that CBTAT enable both male and female students to gain similar classroom experiences equally without bias. CBTAT did not favour any particular gender and was therefore appropriate in teaching mixed schools.

Strength of the Study

This study explored an area which addresses the contemporary problems among chemistry students in Nigerian schools. The intervention has improved the achievement of chemistry students in Mathematics-related Chemistry topics. The intervention is considered timely, given the potential impacts of students' weak achievement in Mathematics-related Chemistry topics on future endeavours in Nigeria. The intervention successfully validated the effectiveness of CBTAT in improving Mathematics-related Chemistry topics among students using a randomized pretest-posttest control group design.

Implication for practitioner

Given the cost-effectiveness of CBTAT in improving Mathematics-related Chemistry topics among Chemistry students, it is appropriate that practitioners in relevant fields, especially teachers of secondary schools, should employ the skills and procedures as noted in CBTAT in the courses of their professional practices. It was noted that the students engaged in CBTAT progressively improved in their test scores. Therefore, practitioners should incorporate CBTAT in their teaching and learning process. The researcher found that the participants' post-intervention measures indicated dependable improvement. This means they retained most of the materials taught, which indicates mastery of learning and acquisition of task analysis skills. Based on these findings, if teachers are not properly trained in CBTAT, students' test scores will continue to be poor. This in turn, may result in other education problems like students' inability to pursue further studies.

Limitations

Like other empirical-based studies, this present study has some limiting factors. The Mathematics-related Chemistry Essay Test (MCET) for data collection was prepared and used for the first time with Nigerian students only. The Mathematics-related topics in the school scheme of

work were not exhausted during the training and also made the essay test not too comprehensive. This appears to localize the result of the study. It was only the moderating influence of gender that was determined among several demographic variables of the students. The demographic variables like age, ethnicity, state of origin etcetera of the students were not determined. Thus, the demographic variables moderating the effectiveness of CBTAT on the improvement of students' achievement in Mathematics-related chemistry still need to be determined in successive studies. Therefore, further study should be carried out on a larger scale and Mathematics-related topics in the school scheme of work exhausted. The instrument for subsequent research should be more comprehensive by covering all aspects of mathematics-related chemistry topics. With these limitations, the generalization of these findings should be done with caution.

CONCLUSION

Based on the aforementioned findings of the study, the researcher concluded that CBTAT is efficacious in the improvement of students' achievement in Mathematics-related chemistry in Nigeria. Students' gender had no significant influence on students' achievement in Mathematics-related chemistry. This means that CBTAT will be effective in teaching both male and female chemistry students all Mathematics-related chemistry topics.

RECOMMENDATIONS

Thus, it was recommended that;

1. Students should use the skills acquired during CBTAT intervention to prepare for internal and external examinations.
2. Teachers should integrate CBTAT into teaching and learning for better academic achievements of students.

REFERENCES

Abu, P. B. & Fabunmi, M. (2005). The relationship among teacher variables and adult learners' academic performance. *International Journal of African American Studies* 4 (1), 12-20.

Adesoji, F. A. & Ibraheem, T. L. (2008). Effects of student team-achievement division strategy and mathematics knowledge on learning outcome in chemical kinetics. *Journal of International Social Research* 2(6), 57-61.

Adeyemi, T. O. (2011). A comparative study of students' academic performance in public examinations in secondary schools in Ondo and Ekiti States, Nigeria. *Current Research Journal of Economic Theory* 3(2), 36-42.

Ajai, J. T., & Imoko, B. I. (2017). Gender difference in mathematics achievement and retention scores: A case of problem-based learning method. *International Journal of research in education,* 1(1), 45-50.

Akinsola, M. K. & Ogunleye, B. O. (2003). Improving Mathematics Curriculum at the Implementation stage. In O.A. Bamisaiye, I.A. Nwazuoke & A. Okediran (Eds). Education This Millennium: Innovation in Theory and Practice Lagos: Macmillan Nigeria Publisher Limited, 211-218.

Alavi, S. & Toozandehjani, H. (2017). The relationship between learning styles and students' identity styles. *Open Journal of Psychiatry,* 7(1), 90-102.

Al-Methen, A. E. & Wilkinson, W. J. (1992). Perceived causes of failure among secondary school students. *Journal of Manchester University Research in Education* 48(1), 26-35.

Anderson, S. R., Taras, M. & Cannon, B. O. (1996). Teaching new skills to young children with autism. In C. Maurice, G. Green, & S. C. Luce (Eds.), *Behavioral intervention for young children with autism.* 181-194. Austin, TX: Pro-Ed.

Barman, A. Aziz, R., & Yusoff, Y. (2014). Learning style awareness and academic performance of students. *South East Asian Journal of Medical Educatio,n 8(1)*, 17-24.

Beck, A.T. & Rector, N. A. (2005) .Cognitive approaches to schizophrenia: Theory and therapy. *Annual Review in Clinical Psychology,* 2(1), 577-606.

Berg, C. A. R. (2005). Factors related to observed attitude change toward learning chemistry among university students. *Chemistry Education and Practice, 2005, 6(1)*, 1-18.

Botes, H. & Miji, A. (2010). Language diversity in the mathematics classroom: Does a learner companion make a difference? *South African Journal of Education 30(1)*, 123-138.

Breckler, J., Teoh, C. S. & Role, K. (2011). Academic performance and learning style self-predictions by second language students in an introductory biology course. *Journal of the Scholarship of Teaching and Learning 11(4)*, 26-43.

British Columbia Ministry of Health (2007). British Columbia Ministry of Health, *Primary Health Care Charter: A Collaborative Approach* (Victoria: Ministry of Health, 2007). Retrieved from www.health.gov.bc.ca/library/publications/year/2007/phc_charter.pdf.

Carlisle, K. E. (2013). The learning strategy of task analysis. *NSPI Journal 22(2)*, 19-27.

Catrambone, R. (2010). Task analysis by problem solving (TAPS): uncovering expert knowledge to develop high quality instructional materials and training. Paper presented at 2011 Learning and Technology Symposium, Columbus, G A.

Chhinh, S., & Tabata, Y. (2003). Teacher factors and mathematics achievement of Cambodian Urban primary school pupils. *Journal of International Development and Cooperation* 9(2), 29-41.

Dalmolin, A., Mackeivicz, G., Pochapski, M., Pilatti, G. & Santos, F. (2018). Learning styles preferences and e-learning experience of undergraduate dental students. *Revista de Odontologia da UNESP Journal 47(3)*, 175-182.

Daso P. O. (2013). Teacher variables and senior secondary students' achievement in mathematics in rivers state, Nigeria. *European Scientific Journal 19(10)*, 1857-7881.

Fatemeh, V. & Camellia, T. (2018). The effect of teaching based on dominant learning style on nursing students' academic achievement. *Nurse Education in Practice 28(1),* 103-108.

Ghaedi, Z. Jam, B. (2014). The relationship between Learning Styles and Motivation for Higher Education in EFL Students. *Theory and Practice in Language Studies Journal 4(6)*, 1232-1237.

Gilbert, P. (2007). *Overcoming depression: a self help guide using cognitive behavioural techniques.* New York: Guilford Press.

Hassett, A. L. & Gevirtz, R. N. (2009). Nonpharmacologic treatment for fibromyalgia: Patient education, cognitive behavioral therapy, relaxation techniques, and complementary and alternative medicine. *Journal of Rheumatic Diseases Clinics of North America 35(2)*, 393-407.

Hawk, T. F. & Shah, A. J. (2007). Using learning style instruments to enhance student learning. *Decision Sciences Journal of Innovative Education 5(1)*, 1-19.

Henning, E. (2013). Teachers' understanding of mathematical cognition in childhood: Towards a shift in pedagogical content knowledge. *Perspectives in Education*, *31(3)*, 139-154.

Hlalele, D. (2012). Exploring rural high school learners' experience of mathematics anxiety in academic settings. *South African Journal of Education*, 32(3), 267-278.

Howie, S. J. (2003). Language and other background factors affecting secondary pupils' performance in Mathematics in South Africa. *African Journal of Research in Mathematics, Science and Technology 7(1)*, 1-20.

Ibezim E. V. (2018). Factors affecting chemistry students' performance in secondary schools in Mbaitolu local Government in Imo state. *International Journal of Advanced Multidisciplinary Research*. 5(5), 1-7.

Jegede, S. A. (2010). Nigerian students perception of technical words in senior secondary school chemistry curriculum. *Pakistan Journal of Social Sciences 7(2)*, 109-111.

Jonathan, S. (2016). *Applying discrete mathematics to solve theoretical and practical problems of digital information transmission.* University of Iowa Press.

Kanter, J. W., Schildcrout, J. S. & Kohlenberg, R. J. (2005). In vivo processes in cognitive therapy for depression: Frequency and benefits. *Psychotherapy Research 15(1),* 366-373.

Knapp, P. & Beck, A. T. (2008) Cognitive therapy: foundations, conceptual models, applications and research. *Revista Brasileira de Psiquiatria 30*(2), 54-64.

Kolawole, E. B, Oginni,O. I & Fayomi, E. O (2011). An ordinary level as predictors of students' academic performance in chemistry in Nigerian universities. *Educational Research and Reviews 6(14)*, 824-827.

Leahy, R. (2001). *Overcoming resistance in cognitive therapy.* New York: Guilford Press.

Magulod Jr, G. C. (2019). Learning Styles, study habits and academic performance of Filipino University Students in Applied Science Courses: Implications For Instruction . *Journal of Technology and Science Education 9(2)*, 184-198.

Makgato, M. & Mji, A. (2006). Factors associated with high school learners' poor performance: A spotlight on mathematics and physical science. *South African Journal of Education,* 26(2), 253-266.

Mazlini, A., Mohd, F. N., & Yeniq, Z. Z. (2013). Learning styles and mathematics achievement among high performance school students. *World Applied School Journal 28(3)*. 392-399.

Nadrian, S. (2018). *Advances in Polymer Sciences*. New York University press

Naik, B. (2013). Influence of culture on learning styles of business students. *International Journal of Education Research 8(1)*, 129-139.

National Alliance on Mental Illness (NAMI, 2015). Cognitive Behavioural Therapy: FACT SHEET. Retrieved from NAMI%2C+2015)%2C+CBT+&tpr on 12/05/2016.

Njoku, Z. C. (2003). *Essentials of educational management*. Owerri; Versatile Publishers.

Oloyede, O. I. (2010). Enhanced mastery learning strategy on students' achievement and self-concept in senior secondary school chemistry. *Humanity and Social Sciences Journal 5(1)*, 19-24.

Orhun, N. (2007). An investigation into the mathematics achievement and attitude towards mathematics with respect to learning style according to gender. *International Journal of Mathematical Education in Science and Technology 38(3)*, 321-333.

Pournara, C., Hodgen, J., Adler, J., & Pillay, V. (2015). Can improving teachers' knowledge of mathematics lead to gains in learners' attainment in Mathematics? *South African Journal of Education*, 35(3), 10-19.

Reddy, V. (2005). Cross-national achievement studies: Learning from South Africa's participation in the Trends in International Mathematics and Science Study (TIMSS). *Compare*, 35(1), 63-77.

Reddy, V., Winnaar, L., Visser, M., Feza-Piyose, N., Arends, F., Prinsloo, C. H., Mthethwa, M., Juan, A. & Rogers, S. (2013). *Highlights from TIMMS 2011: South Africa*. Available at http://www.hsrc.ac.za/en/research-outputs/view/6363. Accessed 18 November 2014.

Reigeluth, C. M. & Darwazah, A. (2016). The elaboration theory's procedure for designing mathematical instructions: a conceptual approach. *Journal of Instructional Development 5(3)*, 22-32.

Robinson, M. (2018). *Laboratories in Mathematical Experimentation: A Bridge to Higher Mathematics.* Mount Holyoke College Press.

Sam, A. & AFIRM Team. (2015). *Task analysis*. Chapel Hill, NC: National Professional Development Center on Autism Spectrum Disorder, FPG Child Development Center, University of North Carolina. Retrieved from http://afirm.fpg.unc.edu/task-analysis

Sara, S. S. (2010). Effects of learning styles on career preferences of senior secondary school students in Jigawa state, Nigeria. *Edo Journal of Counselling, 3(1)*, 7-13.

Setati, M. (2008). Access to mathematics versus access to the language of power: The struggle in multilingual mathematics classrooms. *South African Journal of Education*, *28(1)*, 103-116.

Siyepu, S. (2013). The zone of proximal development in the learning of mathematics. *South African Journal of Education*, 33(2), 13-25.

Stein, M. K., Smith, M. S., Henningen,M. A. & Silver, E. A. (2010). *Implementing standards-based mathematics instruction using task analysis procedure – A casebook for mathematics professionals development.* New York: Teachers College Press.

Szidon, K. & Franzone, E. (2009). *Task Analysis*. Madison, WI: National Professional Development Center on Autism Spectrum Disorders, Waisman Center, University of Wisconsin.

Ugwumaduka, E. B, & Ogunyemi, O. T. (2021). Formative assessment, feedback, remediation and students' academic achievement in Basic Science: A quasi experiment. *African Journal of Education, Science and Technology,* 6(3), 337-349.

West African Examination Council, (2017). May/June Senior School Certificate Examinations (WASSCE) Chief Examiners' reports. Lagos: WAEC Publishers.

Wong, C. (2014). *Evidence-based practices for children, youth, and young adults with autism spectrum disorder*. Chapel Hill: The University of North Carolina, Frank Porter Graham Child Development Institute, Autism Evidence-Based Practice Review Group.

Yeung. A., Read, J., & Schmid, S. (2005). Students' learning styles and academic performance in first year chemistry. The University of Sydney: UniServe Science Blended Learning Symposium Proceedings.

Yilmaz, I., Konukman, F., Birkan, B., Ozen, A., Yanardag, M., & Camursoy, I. (2010). Effects of constant time delay procedure on the Halliwick's method of swimming rotation skills for children with autism. *Education and Training in Autism and Developmental Disabilities 45*(1), 124-135.