



Impact of Process-Based Instruction on Performance of Students with Different Memory Capacity in Qualitative- Analysis of Secondary School Chemistry

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Abstract

Impact of Process-Based Instruction (PBI) on Performance of Secondary School Students with Different Memory Capacity was studied using quasi-experimental design. A sample of 96 students was used for the study. Qualitative Inorganic Analysis Performance and Memory Capacity Questionnaire with reliability coefficients of 0.86 and 0.76 were obtained using Pearson Product Moment Correlation were used for data collection. Data were analyzed using means, standard deviations and ANCOVA at 0.05 α -level. Findings showed significant difference in performance between students experimental and control group ($F(2, 93) = 56.45, P = 0.00$). No significant difference between male and female students taught qualitative analysis using PBI, ($F(2, 14) = 6.66, P = 0.22$) and significant difference in performance between high memory capacity and low memory capacity students taught qualitative analysis using PBI, ($F(2, 46) = 96.63, P = 0.00$). Thus, PBI was recommended for the teaching of chemistry in senior secondary school.

Keywords: Process based, Memory Capacity, Performance, Gender, Qualitative Analysis

Introduction

The long-term goal of Science Education has been that students learn science concepts in a meaningful way and apply them to solving problems. Science concepts (including Physics, Biology and Chemistry) can only be meaningful if students understood the processes involved in generating them. Teachers cannot teach science effectively without employing the process of science, neither can students learn science effectively without the process of science (Al-Rabaani 2014). That why National Policy on Education (Federal Republic of Nigeria - FRN, 2013) in one of its goals, is to equip students to live effectively in modern age of science and technology. However, Adanyi (2019) observed that students are still not involved in the act of science but are predominantly made to learn science (Chemistry inclusive) by copying and memorizing learning materials provided by the teachers. Samuel, Libata and Sabitu (2018) add that students' find some chemistry concepts as complex and difficult to understand. Such concepts include: Stoichiometry; Mole Concept; Metals and their compounds; Qualitative analysis of inorganic salts, among others. The difficulty according to them, is as a result of the frequent use of lecture method in teaching Chemistry at the Senior Secondary School.

Science is a great enterprise which nations depend on for technological advancement. Science therefore, has much emphasis in education because of its significance and relevance to the society. The emphasis placed on

science alongside with the important role it plays towards national development makes it pertinent and practically necessary for science to be taught in an organized and well-structured pattern involving activities for students. Hence, Jadrich and Bruxvoort (2011) identified process skills: observing, inferencing, measuring, communication, classification, prediction, etc. which characterises Process-Based Instruction (PBI) strategy to harness students' performance and different memory capacity.

Process-Based Instruction Strategy (PBI) is a procedural skill used to produce and use scientific information to perform scientific research to solve problems. Process-Based Instruction improves knowledge of content among junior and senior secondary students. The use of Process-Based Instruction helps the students to develop responsibility in their own learning and increased permanency of learning as well as teach them to investigate scientifically widening their reasoning horizon (Abdulrauf, Abdulrasul, Mansor & Lyndo, 2013). Science Process Skills such as observation, use of numbers and classification are the foundation for the acquisition of Science Process Skills. Therefore, PBI is important in scientific investigation such as conducting and carrying out experiments.

Using Process-based instruction to teach Chemistry (qualitative analysis inclusive), the learner, according to

AI-Rabaani (2014), need to engage in scientific investigation so as to acquire scientific knowledge and skills. Science process skills are activities oriented and when PBI is used in teaching and learning, the male and female students are able to become competent and experience in its application to solving problems or observing the desired end results as scientists. Science process skills enable students experience hands-on-activities with science materials when solving problems using meaningful activities. The emphasis on process-based instruction in science lessons cannot be doubted, as this is clearly evident in the objectives and instructional programmes in science subjects at the secondary school. The proponents of process-based instruction strategy uphold the teaching of process-skills and advocate for the skills to be developed through experimentation enhancing academic performance and different memory capacity. Empirically, Adanyi (2019) found that Process-Based Instruction (PBI) improved science skills acquisition, performance and retention among Basic Science students in Zaria Educational Zone, Kaduna. Ayefite (2019) found that Science Process - Based Approach (SPBA) improved Creativity, Process Skill acquisition and Performance among Secondary School Biology Students with Varied Ability in Zaria. Cowan (2008) examined whether different classes of working memory tasks measure the same general construct of working memory capacity, but did not include the difference between low or high working memory capacities. Therefore, the need to study effect of process-based instruction on academic performance in qualitative-analysis of high and low memory capacity students.

Chemistry as an experimental subject that involves the study of processes and interaction that create gases, liquid and solid substances that constitute the physical world. It is therefore on this basis that a good knowledge of qualitative analysis in Chemistry is needed for one to become professional in any science and technology related discipline. The importance of Chemistry to mankind, technology development, and its central role in other sciences can be seen in almost every human endeavour (Ojokuku 2019). Therefore, teaching the concept of qualitative analysis in chemistry at senior secondary school, process-based instructional approach has to be employed (i.e., use of five sense organs such as sight, touch, hearing, smelling and tasting). Ugwuanyi and Nwafor (2021) add that, qualitative analysis involved colour change test, flame test, distillation, extraction and precipitation. It is used to

investigate the composition of substances or the absence of certain substances or the mechanism of reactions. The Process-Based Instruction in teaching of Qualitative Analysis in chemistry at secondary school is necessary because it improves male and female students' understanding and enables them to use the five senses effectively for building memory capacity and performance if taught using process-based instruction.

Memory capacity, according to Baddeley (2003), consists of several specialized components of cognition that enable humans to comprehend and mentally represent their immediate environment, retain information about their recent past experiences, aid in the acquisition of new knowledge, solve problems, formulate, relate, and act on current goals (Usman, 2021). Memory capacity has been defined as the ability to mentally construct relationships between elements or grasp relationships in given knowledge, according to scholars (Conway & Engle, 2011). Students' memory capacity has been linked to their ability to complete complicated cognitive activities including process skills and problem-solving (Chuderski & Jastrzebski, 2018).

Male and female students' academic performance in Senior Secondary Certificate Examination (SSCE) Chemistry over the years has been reported to be consistently poor. Students result in Chemistry in the SSCE is usually below average as reported by Omwirhiren, (2015), Omokaadejo, (2015) and Oyinloye, (2020). The poor performance of students in Chemistry becomes more evident, looking at the records of the West African Examination Council (WAEC) in Chemistry. The consistent poor performances in chemistry have become a major concern to science educators, parents and other stake holders in science education. The Report of the Chief Examiners (WAEC, 2018 - 2022) indicated reasons for the inconsistency in male and female students' performance and low memory capacity in Chemistry with particular reference to qualitative analysis questions which are poorly attempted or not even attempted at all by many male and female students. The West Africa Examination Council (WAEC) (2019) Chief Examiner's report attributed the poor attempt of Chemistry questions among others to include: poor knowledge of qualitative analysis concepts, poor understanding of the demands of questions on qualitative analysis, poor representations of test inference and observation and poor teaching method used in teaching chemistry.

Bang and Baker (2013) reporting data collected from the Assessment of Performance Unit (APU) in the United Kingdom (UK) who indicated that female show superior performance in observational skill at all ages tested (11, 13 and 15 years). Adebayo (2014) on gender and practical skill performance on science indicated that there is no gender difference in observation, reporting, or planning skill, and there was no differential performance in the use of scientific language. It is against this background that, the purpose of the study sought to investigate the impact of process-based instruction on performance of secondary school students with different memory capacity in Katsina State, Nigeria. Specifically, the objectives are listed under.

1. Determine the academic performance in qualitative-analysis of students taught using process-based instruction and those taught using lecture methods.
2. Find out the effect of process-based instruction on academic performance in qualitative-analysis of male and female students.
3. Find out the effect of process-based instruction on academic performance in qualitative-analysis of high and low memory capacity students.

The following research questions were posed in line with the purpose to guide the study:

1. What is the difference in the mean academic performance between students taught qualitative-analysis using process-based instruction and those taught using lecture method?
2. What is the difference in the mean academic performance between male and female students taught qualitative-analysis using process-based instruction?
3. What is the difference in the mean academic performance between high and low memory capacity students taught qualitative-analysis using process-based instruction?

In line with the research questions, the following null hypotheses were formulated and tested at $p \leq 0.05$ level of significance:

H_{O1} : There is no significant difference in the mean academic performance score between students taught qualitative-analysis using process-based instruction and those taught using lecture methods.

H_{O2} : There is no significant difference in the mean academic performance score between male and female students taught qualitative-analysis using process-based instruction.

H_{O3} : There is no significant difference in the mean academic performance score between high and low memory capacity students taught qualitative-analysis using process-based instruction.

Theoretical Framework

The study is anchored on Piaget's (1952) theory of cognitive development which assumes that cognition is transform through an interaction between maturational mechanism and environment. Piaget's work is important because it describes the cognitive process that students go through when learning a new concept which undoubtedly relate to process-based instruction in enhancing performance and reasoning ability when taught quantitative analysis. Process-Based Instruction involves activities that engage male and female students and such activities create meaningful learning experience. Sani (2021), stated that activities have been found to enhance the quality and the extent of scientific understanding and process skills that are achieved by different memory capacity students. Process-Based Instruction is meant to foster inquiry, skills acquisitions in students and discourages rote learning meanwhile, enhancing performance of students with different memory capacity. The memory capacity or working memory capacity represents the amount of information students can activate or retained while solving a problem (Reid, 2009). Memory is the process in which information is encoded, stored and retrieved. Memory refers to the processes that are used to acquire, store, retain and later retrieved information. According to Schacter, Gilbert and Wegner (2010) there are three processes involved in memory: encoding, storage, and retrieval. Measures of working memory capacity are strongly related to performance in other complex cognitive tasks such as reading comprehension, problem solving and with any measure of the intelligent quotient (Jessen, 2003).

Method

Quasi-experimental design was adopted. Specifically, a pretest posttest non-equivalent control group research design was used for the study. After pretest administration, the experimental group was taught concept of qualitative analysis in chemistry using Process-Based Instruction; while the control group was taught the same concept using Lecture Method. The

treatment lasted for six weeks. Thereafter, the students in both groups were given posttest. A sample of 96 senior secondary school students were selected from two schools drawn from the target population of 925 out of which 606 were males and 319 were females distributed across seventeen (17) schools in the study area was used for the study. The sample was drawn using multistage sampling by dividing the target population into stratum based on the number of Local Government Areas, followed by simple random sampling to assigned the schools into experimental and control groups. The sample of at least 30 subjects, is adequate for the experimental study as recommended by Sambo (2008) central limit theorem. Qualitative Inorganic Analysis Performance Test (QUIAPT) has two sections: section A, students bio data and section B has 40 multiple choice (a-d) items and Memory Capacity Questionnaire (MCQ) adopted from Kosmic (2012). It is made of two sections: section A, students' bio data and section B has 40 multiple choice (a-d) items, both were used for students' data collection. QUIAPT was validated by five experts: two Senior Lecturers and one Reader from the Department of Chemistry, Federal University, Dutsin-Ma, Katsina State; two Chemistry Education lecturers at the Department of Science Education, Ahmadu Bello University, Zaria and One Chemistry Education Chief lecturer from the Department of Chemistry Federal College of Education, Zaria. Also, MCQ was validated by two experts: both from the the Department of Psychology and Guidance and Counselling, Ahmadu Bello University, Zaria. Their above inputs were used to improve the research quality. QUIAPT and MCQ were trial tested on 45 senior secondary II Chemistry

students comprising 28 males and 17 female other than the study's actual sample, though with similar characteristics. To determine the reliability coefficient of QUIAPT and GALT, a test-retest method was applied with interval of two weeks as recommended by Tuckman (1975) and Sambo (2008). The data collected were analyzed using Pearson Product Moment Correlation and yielded reliability coefficients of 0.86 and 0.76 respectively. The intervention was administered to the experimental group using process based instruction. This instruction involve grouping the class into small practical groups after teacher's demonstrations and asking them to engage in the scientific processes. The students in the control group were taught using traditional teaching method. To minimized threat to validity due to interaction effect, history and pretest. The two schools were located at different towns of distance, both schools were under the same education zone and the post test questions were reshuffled to avoid pretest effect. Both pre-test and post-test were administered under standard examination conditions. Means and standard deviations were used to answer research questions. While research hypotheses were tested using ANCOVA at 0.05 levels of significance because of the normality of the distribution, homogeneity of variance, randomness of selection, measured based on an interval scale and independence of samples.

Results

To test the hypothesis, the scores of the students were subjected to Analyses of Covariant (ANCOVA) the result is resented in table 1

Table 1: ANOVA analysis of the Mean Scores for Experimental and control group

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1728.913 ^a	2	864.457	28.191	.000
Intercept	431.336	1	431.336	14.067	.000
PREMETHOD	.002	1	.002	.000	.994
GROUP1	1727.789	1	1727.789	56.346	.000
Error	2851.743	93	30.664		
Total	79007.000	96			
Corrected Total	4580.656	95			

a. R Squared = .377 (Adjusted R Squared = .364
Table 1 revealed that the F value computed was 56.35 and the p-value of 0.000 was observed. Since the obtained p-value of 0.000 is less than the alpha value of

0.05, the study rejected the null hypothesis that says there is no significant difference in the mean academic performance score between students taught qualitative-analysis using process-based instruction and those

taught using lecture method. This implies that, there is a significant difference in the mean academic performance score between students taught qualitative-analysis using process-based instruction and those taught using lecture method. This indicates that the students of experimental group performed significantly better than control group, this is as result of exposure to

process-based instruction. It can be stated that treatment has significant effect on students' performance in qualitative-analysis ($F(2, 93) = 56.45, P = 0.00$).

To test the hypothesis, the scores of the students were subjected to Analyses of Covariant (ANCOVA) the result is resented in table 2

Table 2: ANOVA analysis of the Mean Scores for Male and Female students

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	17.929 ^a	2	8.964	3.391	.063
Intercept	106.416	1	106.416	40.252	.000
PREGEND	.016	1	.016	.006	.939
GROUP2	17.602	1	17.602	6.658	.22
Error	37.012	14	2.644		
Total	18634.000	17			
Corrected Total	54.941	16			

a. R Squared = .326 (Adjusted R Squared = .230)
Table 2 revealed that the F value computed was 6.65 and the p-value of 0.22 was observed. Since the obtained p-value of 0.22 is greater than the alpha value of 0.05, the study retained the null hypothesis that says there is no significant difference in the mean academic performance score between male and female students taught qualitative-analysis using process-based instruction. This indicates that the students of male and

female students performed significantly similar after exposure to process-based instruction. It can be stated that treatment has no significant effect on students' performance in qualitative-analysis with gender ($F(2, 14) = 6.66, P = 0.22$)

To test the hypothesis, the scores of the students were subjected to Analyses of Covariant (ANCOVA) the result is resented in table 3

Table 3: ANOVA analysis of the Mean Scores for High and Low Memory Capacity Students

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	807.777 ^a	2	403.889	48.339	.000
Intercept	283.967	1	283.967	33.986	.000
PREMEM	.429	1	.429	.051	.822
GROUP3	807.349	1	807.349	96.627	.000
Error	384.345	46	8.355		
Total	43982.000	49			
Corrected Total	1192.122	48			

a. R Squared = .678 (Adjusted R Squared = .664)
Table 3 revealed that the F value computed was 96.63 and the p-value of 0.000 was observed. Since the obtained p-value of 0.000 is less than the alpha value of 0.05, the study rejected the null hypothesis that says there is no significant difference in the mean academic performance score between high and low memory capacity students taught qualitative-analysis using process-based instruction. This implies that, there is a significant difference in the mean academic

performance score between high and low memory capacity students taught qualitative-analysis using process-based instruction. This indicates that the students with high memory capacity performed significantly better than those with low memory capacity after exposure to process-based instruction. It can be stated that treatment has significant effect on students' performance in qualitative-analysis with memory capacity ($F(2, 46) = 96.63, P = 0.00$).

Discussion

On students' academic performance on teaching methods, it showed significant difference in the performance between students taught qualitative analysis using Process-Based Instruction and those taught using Lecture Method. Based on field experience, the finding is not odd because students in the Process-Based Instruction were highly involved, hence performance was fully developed. This shows that engagement of students in the Process-Based Instruction enhance their performance. Thus, the finding agrees with that of Adanyi (2019) who found that students taught by PBI performed better and retained Basic Science concept learnt than those taught by lecture method.

On students' academic performance on gender, it showed no significant difference in the performance between male and female students taught qualitative analysis using Process-Based Instruction. Based on field experience, the finding is not odd because students in the Process-Based Instruction were highly involved, hence performance was fully developed. This shows that engagement of students using Process-Based Instruction enhances performance in both male and female. Thus, the finding does not agree with that of Adanyi (2019) who found that there was significant difference in the academic performance and process skills acquired by male and female students exposed to PBI in favour of male. This could be due differences in time, location, content and ineffective classroom management by the facilitator. The study therefore, agrees with Ayefite (2019) who found that, there was no significant different in academic performance between male and female Students taught using SPBA. On students' academic performance on different memory capacity, it showed significant difference in the performance between high memory capacity and low memory capacity students taught qualitative analysis using Process-Based Instruction. Thus, the finding does not agree with that of Cowan (2008) who found that there were very strong relations of working memory capacity with secondary memory and fluid intelligence.

Conclusions

Based on the findings, it was concluded that process-based instruction strategy has significant effect on students' academic performance and it is gender friendly among senior secondary chemistry students in Katsina State, Nigeria.

Recommendations

On the basis of the outcome of the research findings, the following recommendations were made:

1. Chemistry teachers in public secondary schools should be encouraged through sponsorship to attend seminars, workshops and if possible, sponsored for further studies on how to effectively utilize process-based instruction and other teaching strategies that are students centered.
2. The State Quality Assurance should from time to time go round the secondary schools in the state to supervise and ensure that the use of conventional teaching method in teaching Chemistry concepts is minimized and used only when the topic to be treated calls for such

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