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EFFECTS OF CHATGPT-BASED INSTRUCTION USING VARK MODEL ON SCIENCE-PROCESS-SKILLS IN CELLULAR RESPIRATION AMONG SECONDARY SCHOOL STUDENTS IN ZAMFARA STATE

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ABSTRACT

The study investigated the effects of ChatGPT-based instruction using VARK model on science-process-skills (SPS) in cellular respiration among secondary school students in Zamfara state. Two objectives, two research questions and one hypothesis guided the study using explanatory sequential mixed method research design. The population was all the 98,417 senior secondary school students for the 2024/2025 academic session in the state. Sample was 93 students for both the quantitative and qualitative phases. Three validated instruments: Visual, Aural, Read/write and Kinesthetic Questionnaire (VARKQ), Science-Process-Skills Questionnaire (SPSQ) and Biology Students' Perceptions on ChatGPT-based Instruction Interview (BSPCII) were used for data collection. Test-retest method was adopted in establishing the reliability of the VARKQ, SPSQ and BSPCII using Cronbach's Alpha, Pearson's r and Cohen's Kappa correlations which yielded reliability indices of 0.81, 0.87 and 0.79 respectively. Quantitative data were analyzed using mean and standard deviation to answer the research questions and One Way ANCOVA to test the hypothesis at $p \leq .05$ significance level while the qualitative data were analyzed thematically. Findings revealed that: the mean SPS score of the experimental group was greater than that of the control group and secondary school biology students' perceptions on the use of ChatGPT in learning were positive. The study concluded that ChatGPT-Based Instruction using VARK Model (CBIVM) significantly enhances students' SPS and was perceived positively by the students. It was recommended that biology teachers should adopt the CBIVM and senior secondary school students should be encouraged to make better utilization of ChatGPT for personalized learning.

Keywords: ChatGPT, Model, Instruction, Science-Process-Skills, Cellular Respiration

1.0 INTRODUCTION

Biological knowledge offers multifaceted and highly significant roles that impact the universe and all living matters existing on earth from time immemorial to the future. It has contributed tremendously to financial, physical and aesthetic benefits of mankind and to nation-building (Adekali, 2023). However, despite the importance of biology, statistics of grades obtained by biology candidates in the West African Examinations Council (WAEC) examination in recent years have not been encouraging (Nwagbo, 2019; WAEC Chief Examiner's Reports, 2021-2023). That is why biology is loosing its might in academic performance of students in post-primary institutions (Ekineh and Otuturu, 2024). Biology is a very vast branch of science with diversified branches and topics like botany, zoology, microbiology, anatomy, physiology, genetics, biochemistry, biotechnology, cytology and cellular respiration.

Cellular respiration is one of the most important topics in biology and that students learning biology without a basic understanding of cellular respiration will find it difficult to study other topics in biology. According to Dam et. al. (2019), respiration is the process by which complex food substances are broken down, in a stepwise series of reactions, in cells, to produce energy with carbon dioxide and water as waste products. Dam et. al. (2019) explained

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the three main stages of cellular respiration: glycolysis, the citric acid cycle, and oxidative phosphorylation. Glycolysis is a process by which glucose is broken down into pyruvate in the cytosol, producing a small amount of ATP and NADH. Citric acid cycle (Krebs cycle) is the process by which pyruvate is converted into acetyl-CoA, which enters the citric acid cycle. This stage produces more ATP, NADH, and FADH2 as byproducts. Oxidative phosphorylation refers to the process by which electrons from NADH and FADH2 are passed through the electron transport chain, generating a proton gradient. This gradient is used to produce ATP through the process of chemiosmosis. Cellular processes and genetics are complex concepts that can prove difficult to grasp solely through traditional teaching methods. Cellular respiration is also identified among the perceived difficult topics in senior secondary school biology curriculum in Zamfara state (Isma'il and Matazu, 2024). It is so wide with varied abstract contents or ideas that could best be taught using student-centered instructions like the CBIVM in which the instructional tool is mainly ChatGPT.

ChatGPT stands for chat Generative Pre-trained Transformer (GPT). It is an AI chatbot that was developed by OpenAI and was initially released on 30th November, 2022 based on GPT-3.5 and updated on 14th March, 2023 based on GPT-4. It is considered as the most powerful AI tool ever created (Rudolph et. al., 2023). It is able to comprehend and respond to a variety of prompts with a high level of expertise and carry on a continuous dialogue with the user. This is among the reasons why it was selected and used in this study. Humans and machines can collaborate and work together like in the ChatGPT scenario (Longo et. al., 2020). It has amazed the world with its extraordinary ability to perform extremely complex tasks (Baidoo-Anu and Owusu-Ansah, 2023). The strength of ChatGPT lies in its ability to interact through natural conversation, including a series of questions from the user and feedback from the application (Rospigliosi, 2023). Teaching and learning practices are never left behind by the ChatGPT effects in many aspects and levels of education. However, the emergence of ChatGPT has aroused diverse views among educators because its potential applications could revolutionize existing educational approaches (Tlili et. al., 2023). While some educators have expressed concerns about integrating ChatGPT into educational settings, many others present strong arguments in favor of its incorporation (Halaweh, 2023). The use of ChatGPT, with its positive and negative impacts on education, is still in its infancy and that implies the need for more empirical researches. ChatGPT could best be utilized in education using appropriate models like the Visual, Aural, Read/Write and Kinesthetic (VARK).

VARK.model is a teaching model which mainly focuses on students' learning styles advocating that individuals learn best when taught based on their preferred styles of acquiring and assimilating knowledge. Learning styles refer to the different ways in which individuals prefer to acquire, process and retain information (Matazu and Ismail, 2023). One of the popular learning style models is the VARK model, which suggests that learners have different preferences in knowledge acquisition (Padmalatha and Shamanewadi, 2022). The concept of VAK learning styles was first coined by Neil Fleming in the late 1987 which was later modified to VARK in 2006. The model classifies students/learners into four, according to their sensory modalities on how they choose to have information submitted to them (Ismail and Haniff, 2020). For those who do not know which type/class they belong, they can answer the VARK questionnaire which consists of sixteen questions and the result represents which type among the four styles they truly belong to. Agu et. al. (2021) visual learners prefer visual aids such as diagrams and illustrations, auditory learners prefer verbal communication like lectures and podcasts,

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read/write learners prefer written texts, while kinesthetic learners prefer hands-on activities.

Science-Process Skills (SPS) are cognitive and psychomotor skills which scientists employ in problem identification, objective inquiry, data gathering, transformation, interpretation and communication of scientific facts and discoveries. They are special skills that learners and teachers use in carrying out mental operations and physical activities in the field of science (Segun and Akanbi, 2023). SPS include: observing, measuring, classifying, predicting, inferring, hypothesizing, testing/experimenting, interpreting and communicating. Abuh et. al. (2023) observed that the type of teaching that has persisted in Science, Technology, Engineering and Mathematics (STEM) education over the years is mainly the memorization of facts handed down by the teacher. They added that this type of teaching is contrary to modem way of teaching STEM and does not significantly improve students' motivation, performance and science-process-skills. Of all the factors that could be responsible for the situation, the teacher and method of teaching are the major ones (Abuh, 2021). Therefore, better student-centered teaching methods (like CBIVM) need to be explored especially in Zamfara state. The significance of the SPS has led to the expansion of the goals of science education to include an understanding and development in the students of these process skills (Flavia et. al., 2022). Consequent upon the above issues raised and discussed, it would be interesting to explore how the collaboration between the AI machine (as a teaching tool) and the human teacher (that operates the tool) could impact on senior secondary school students' SPS and overall leaning outcomes especially in learning abstract and intricate topics like cellular respiration.

1.2 Aim and Objectives of the Study

The main aim of this study was to investigate the effect of ChatGPT-Based Instruction using VARK Model on science-process-skills in cellular respiration among secondary school students in Zamfara state. However, the specific objectives of the study were to:

1. investigate if CBIVM has relative effect on students' science process skills in cellular respiration; and
2. determine students' perceptions on the use of ChatGPT tool in learning cellular respiration.

1.3 Research Questions

1. Is there mean difference in level of science process skills of students taught cellular respiration using CBIVM and those exposed to demonstration method in Zamfara state?
2. What are the perceptions of students on the use of ChatGPT tool in learning cellular respiration in Zamfara state?

1.4 Research Hypothesis

There is no statistically significant difference between science process skills level of students taught cellular respiration using CBIVM and those exposed to demonstration method in Zamfara state.

2.0 MATERIALS AND METHODS

To have a nuanced and comprehensive insight of the effect of ChatGPT's integration, the study adopted the Mixed Method research design of the Explanatory Sequential type (Olatunde-Aiyedun, 2024) which triangulates (Alneyadi and Wardat, 2023) and blends quantitative and qualitative research methods in a particular study. The design entails using quantitative method first followed by the qualitative method to explain the findings for deeper insights, comprehensive understanding, validity and reliability of the study. The design was appropriate for the study due to the fact that it allows for the collection and analysis of both numerical (quantitative) and observational or textual (qualitative) data to validate the findings and increase reliability of the study. It is also appropriate owing to the

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fact that each of the quantitative and qualitative approaches has both strengths and limitations (Cresswell, 2014) so the study could combine the strengths to develop a stronger understanding of the research problem and, as well, overcome the limitations of each approach. The explanatory sequential mixed method research design adopted in the study is illustrated in figure 1.

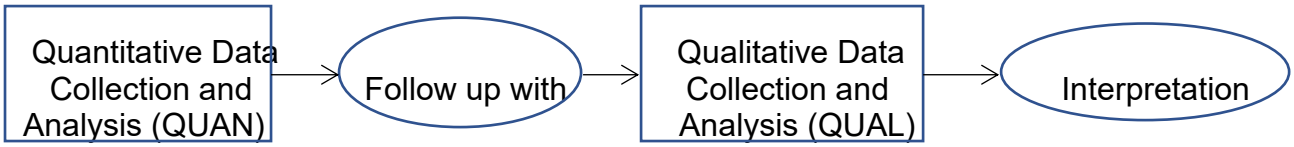

Figure 1: Illustration of the Explanatory Sequential Mixed Method Research Design Adopted in the Study
Source: Creswell (2014)

A. Quantitative Phase

Quasi-Experimental of the pretest-posttest non-equivalent control group design was adopted in this phase. The design is suitable for the study because: it is not possible for the researcher to conduct true experimental study due to lack of randomization of the participants/groups; intact classes (supported by the central limit theorem as noted by Turney, 2022) were used; and to avoid disruptions of the students' natural classroom settings in their respective schools. The design employs two distinct groups of participants (experimental and control). The pretest was used to establish equivalence and identify initial difference among the two groups and to control selection bias which may be a threat to the internal validity.

B. Qualitative Phase

Follow-up interviews were adopted in this phase. This is appropriate because qualitative data were harnessed from the sample in order to deeply explore, validate and explain the initial findings of the quantitative phase. It is also suitable as the qualitative data collection builds directly on the quantitative results obtained. Hence, the qualitative follow-up interview used the quantitative sample (experimental group exposed to CBI) where the qualitative data were collected through structured interview and analyzed thematically.

The total population of the study was all the 98,417 (61,784 male; 36,633 female) senior secondary school students for the 2024/2025 academic session in all the 339 senior secondary schools (both public and private) in Zamfara state while the target population was only the 30,805 (19,541 males; 11,260 females) SS2 students in the schools (National Association of Proprietors of Private Schools (NAPPS) Zamfara State Chapter, 2024; ZSMEST, 2024). As there were no public coeducational senior secondary school in the study area, Public-Private Partnership (PPP) coeducational senior secondary schools which share common characteristics with the public schools in the state were used to serve the purpose better.

Multi-stage sampling procedure was used in selecting the study's sample in which cluster sampling was initially used in selecting two (2) out of the four (4) educational zones in the state. One (1) local government area (from each of the two selected educational zones) was randomly selected by balloting. Thereafter, purposive sampling (due to the need for mix-schools) was used in selecting one (1) PPP coeducational senior secondary school from each of the two (2) local government areas selected (these schools were coded as schools: "A" and "B" and were assigned as experimental group one and two respectively using simple random sampling

by tossing coin. An intact class from each of the schools was finally selected using simple random sampling by balloting as the sample of the study. The two (2) intact classes with a population of 83 students and the 10 selected students for the interview formed the study's sample size of 93 students.

Multi-stage sampling procedure was used because it was difficult for the researcher to carry out the study throughout the state and to avoid selection bias. Simple random sampling technique was appropriate due to the facts that it is scientific/probabilistic in which any school/student has equal chances of either being selected or deselected as part of the study's sample. The purposive sampling technique was suitable as the study involved gender as one of its variables which required the use of coeducational schools. For the qualitative phase of the study, simple random sampling by balloting was used in selecting ten (10) students (5 males and 5 females) from the experimental group exposed to CBIVM during the quantitative phase for the follow-up interview.

In the quantitative phase, two validated instruments were used for data collection as follows.

1. Visual, Aural, Read/Write and Kinesthetic Questionnaire (VARKQ)
2. Science Process Skills Questionnaire (SPSQ)

In the qualitative phase, data were collected through follow-up structured interviews using an instrument called Biology Students' Perceptions on ChatGPT-Based Instruction Interview (BSPCII).

Prior to the commencement of the study the researcher ensured that the study complied with the ethical guidelines. On reaching to the schools, formal introductions were made in which the purpose of the study was explained to the school authorities, the students and their parents/guardians where informed consent forms were issued to them for approvals. On the consent form, information and assurance on their: voluntary participation; confidentiality/privacy/anonymity of their personal information and their schools; and strict utilization of the data for the study's purpose only were clearly stated and explained. In addition, a request for the noting of the interviews with hidden identities during the presentation of the results was also included. Thereafter, the respondents were coded accordingly and the data were collected via the procedure of pretest, treatment, posttest and post-posttest administrations of the research instruments.

Students in the experimental and control groups were firstly subjected to a pretest of the instruments before the treatments. The researcher used the two distinct methods (CBIVM and Conventional Demonstration Method) respectively in teaching the two different groups the concept of cellular respiration for a period of seven (7) weeks as treatment and placebo for both the experimental and control groups respectively during the normal biology periods in all the sampled schools. Students in the experimental group were firstly categorized into four (4) using the VARKQ. Thereafter, they were taught concept of cellular respiration with CBIVM, adhering strictly to the steps specified in its lesson plans. All the subjects in the control group were taught the same concept using the demonstration method also for seven (7) weeks, adhering to the steps in its lesson plans. At the end of the treatment, posttests of the instruments were administered to the same groups to determine the effect of the treatment. The data were then recorded as per the experimental and control groups (with separate males and females) for analysis. A week after the posttest session, the qualitative phase set in with a follow-up interview using the BSPCII to harness qualitative data from the selected students in the experimental group exposed to CBIVM.

The quantitative data were analyzed using descriptive and inferential statistics. Specifically, all the research questions and the null hypotheses were restated whereby the research questions were answered using mean and standard deviation and all the

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hypotheses were tested using One-Way ANCOVA at $p \leq .05$ level of significance. ANCOVA was appropriate for the hypotheses testing due to the presence of covariate (the pretest) and to remediate lack of randomization of participants and/or groups. IBM Statistical Package for Social Sciences (SPSS) Statistics Version 25.0 Software was used for the analysis. The qualitative data collected during the qualitative phase were analyzed using thematic approach (for the relevant aspects of the interview). The approach was used because it allows for the extraction of key insights and the identification of recurring themes within the narratives provided by the participants (Olatunde-Aiyedun, 2024).

3.0 RESULTS AND DISCUSSION

Research Question One

Is there mean difference in level of science process skills of students taught cellular respiration using CBIVM and those exposed to demonstration method in Zamfara state? To answer this research question, the students' SPSQ scores in the two different groups were analysed and the result is presented in Table 1.

Table 1:
Summary of the Result of Students' SPSQ Responses Means and Standard Deviations in both Experimental and Control Groups

Group	N	Mean ($\bar{X}$)	S.D	MD	Remarks
Experimental	47	25.46	3.60		
Control	36	19.98	1.87	5.48	Difference Exists
Total	83				

Source: Researcher's Fieldwork (2025)

As shown in Table 1, the mean SPSQ response of the experimental group was 25.46 with a standard deviation of 3.60 while that of the control group was 19.98 with a standard deviation of 1.87. Thus, the mean difference between the two groups was 5.48 in favour of the experimental group. This shows that the students in experimental group were ahead of the control group in their acquisition and applicability of SPS while learning the concept of cellular respiration. However, in terms of their respective standard deviations, the SPSQ responses of the control group were more closely around the mean than those of the experimental group.

Hypothesis 1

There is no statistically significant difference between science process skills levels of students taught cellular respiration using CBIVM and those exposed to demonstration method in Zamfara.

The result of testing null hypothesis one is presented in Table 2.

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Table 2:
Summary of One-Way Analysis of Covariance (ANCOVA) of Students' SPSQ Responses in both Experimental and Control Groups

Source	Sum of Squares	DF	Mean Squares	F	Sig.	Decision
Corrected Model	9915.137	4	2478.784	150.470*	.000	
Intercept	837.579	1	837.579	50.844*	.000	
Pre-test	3949.749	1	3949.749	239.762*	.000	
Inst. Strategy	5963.554	1	5963.554	362.007*	.000	Sign.
Error	1861.516	113	16.474			
Total	144873.000	118				
Corrected Total	11776.653	117				

Source: Researcher's Fieldwork (2025) Sign. = Significant at $p \leq 0.05$

Table 2 revealed that the computed *F*-ratio for the effect of the CBIVM on students' SPS in the cellular respiration concepts taught was 362.007 which is significant at *p*-value of .000. Therefore, at a higher *p*-value of .05, the effect is also significant. This led to the rejection of the null hypothesis that: CBIVM has no statistically significant effect on students' science process skills in cellular respiration. (*F*-ratio = 2.103, df = 1 and $p = .150 > .05$). Hence, it could be observed that the students in the experimental group were by far, ahead of those in the control group in terms of their acquisition and applicability of SPS in learning the concept of cellular respiration and this was largely attributed to the CBIVM treatment given during the study.

Research Question Two

What are the perceptions of students on the use of ChatGPT tool in learning cellular respiration? To answer this research question, the experimental group students' interview responses in the BSVCII were audio-recorded and transcribed, and the data were analysed thematically, allowing for the extraction of key insights and the identification of recurring themes within the narratives provided by the students. All the interviewees reported: "using ChatGPT in their cellular respiration classes." The following three (3) themes emerged from the data analysis of the students' responses to the twenty (20) items in the BSPCII.

Theme 1: ChatGPT's Effect on Science-Process Skills and Academic Performance

Most participants admitted that:

> "ChatGPT has improved their SPS acquisition and application as well as their academic performance in cellular respiration, even though some few of them reported that it was difficult to tell as they have not yet received grades or feedback."

They provided examples of how ChatGPT helped them understand complex equations, provided visual aids to explain concepts, and helped them solve homework problems.

Theme 2: Comfort and Friendliness with using ChatGPT

Generally, both male and female students reported:

> "feeling comfortable, ease of use and friendliness with using ChatGPT to learn cellular respiration, although a few expressed some hesitations or difficulties with the technology."

Most of them added that the technology was simple, user-friendly and impressive even at their own level as senior secondary school students.

Theme 3: Ability to use ChatGPT for Personalized Learning

Overall, all the interviewees admitted that:

> "they would be able to use ChatGPT on their own for personalized learning both in school or at home."

Almost all of them testified their capabilities to use it individually at their various paces, interests and learning styles in their educational practices.

4.0 DISCUSSION OF FINDINGS

The findings of the study revealed that there was statistically significant mean difference in students' SPS in learning cellular respiration between the students taught using the CBIVM and those taught using the demonstration method in favour of those taught using the CBIVM. This was observed in the mean SPS scores and the result of the one-way ANCOVA analysis on the SPSQ responses of the students exposed to the CBIVM in learning cellular respiration and those taught using the conventional method. This could be attributed to the interesting, supportive and enabling grounds provided by the strategy. This finding confirms that of Essel et. al. (2024) who found that incorporating ChatGPT influenced students' critical and creative thinking skills; and Olatunde-Aiyedun (2024) whose result demonstrated a tangible link between AI integration and science education; and Okunade (2024) whose results highlighted the role of AI in teaching science.

The findings of the second research question which was not subjected to hypothesis testing revealed that secondary school biology students' views on the use of ChatGPT tool in learning cellular respiration was positive. This was indicated by the thematic analysis result on the experimental group students' interview responses during the qualitative phase of the study which indicated that: the students perceived ChatGPT as a motivational teaching and learning tool (theme 1); it enhances their SPS and academic performance (theme 2); it was comfortable, simple and user-friendly (theme 3); it enhances personalized learning (theme 4); and it could be used in teaching students in other schools given its advantages (theme 5). These findings aligned with the prior research findings of: Betrancourt (2019b); Capinding and Dumayas (2024); Ismail and Lukman (2023) whose findings showed that students hold favourable perceptions concerning the utilization of online tools and resources in biology learning; and Lu et. al. (2020c) whose findings indicated that ChatGPT holds the potential to enhance both male and female students' learning outcomes through immediate feedbacks and personalized support; Szmyd and Mitera (2024) who revealed that AI-based tools are perceived by students as helpful in developing information analysis skills and constructing assignments. However, the findings contradicted those of Mayer (2014a) and Xu et. al. (2019a) who reported the need to enhance ChatGPT's capabilities to better comprehend students' inquiries and the significance of providing visual aids to support learning.

5.0 CONCLUSION

By the findings of the study, ChatGPT-based instruction proved significantly effective in enhancing senior secondary school students' SPS in learning cellular respiration in Zamfara state. This was because, significant improvements were observed in SPS acquisition and applicability levels of the experimental group students exposed to the ChatGPT-based instruction compared to those in the control group. Also, senior secondary school students' views on the use of chatGPT in learning were positive.

6.0 RECOMMENDATIONS

Based on the findings of the study, the following recommendations were made.

1. Biology teachers should adopt the CBIVM in their teaching.
2. Senior secondary school students should be encouraged to make better utilization of ChatGPT for personalized learning.

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