

## Effects of ChatGPT-Based Instruction Using VARK Model on Academic Performance in Cellular Respiration among Secondary School Students in Zamfara State, Nigeria

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### Abstract

*The study investigated the effects of ChatGPT-based instruction using VARK model on academic performance in cellular respiration among secondary school students in Zamfara state, Nigeria. 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), Cellular Respiration Performance Test (CRPT) 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, CRPT and BSPCII using Cronbach's Alpha, Pearson's r and Cohen's Kappa correlations which yielded reliability indices of 0.81, 0.82 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 academic performance 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' academic performance 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, Academic Performance Cellular Respiration

### 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 losing its might in academic performance of students in post-primary institutions (Ekinah 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 the three main stages of cellular respiration: glycolysis, the citric acid cycle, and oxidative



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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 FADH<sub>2</sub> as byproducts. Oxidative phosphorylation refers to the process by which electrons from NADH and FADH<sub>2</sub> 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, read/write learners prefer written texts, while kinesthetic learners prefer hands-on activities. Academic performance is defined as the extent by which learners perform in the lesson taught or examination result. It is affected by many factors such as retention, student ability, the quality of secondary education received and teaching method (Gachi, 2024). Some studies (Oladehinde, 2023) have demonstrated that student's academic performance in senior secondary school certificate biology and other science subjects' examinations since eighties had remained poor. Adding that, a lot has been done to improve teaching of biology in secondary schools in Nigeria such as using different innovative teaching strategies, training and retraining of biology teachers, provision of laboratory equipment among others. In spite of all these, students continue to perform poorly in biology. This situation has created the need for more effective method. It then becomes necessary to explore the efficacy of alternative method of redressing this situation (Oladehinde, 2023). This is among the main reasons for carrying out the present study among secondary school students in Zamfara state. The prevailing poor outcomes of students' performance in biology every year in Senior School Certificate Examination (SSCE) is attributed to the instructional strategies employed by teachers being inappropriate (Segun & Akanbi, 2023). Predictive analytics, a

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prominent application of AI in modern science education, empowers educators and institutions to anticipate students' success, identify areas of improvement and intervene proactively to enhance learning outcomes (Johnson, 2021).

### **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 academic performance 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' academic performance in cellular respiration; and
2. determine students' perceptions on the use of ChatGPT tool in learning cellular respiration.

### **Research Questions**

1. Is there mean difference in academic performance scores of students taught cellular respiration concept with CBIVM and those exposed to conventional demonstration method in Zamfara state?
2. How does senior secondary biology students perceive the use of ChatGPT tool in teaching cellular respiration concept in Zamfara state?

### **Null Hypothesis**

There is no statistically significant mean difference between academic performance scores of students taught cellular respiration concept with CBIVM and those exposed to conventional demonstration method in Zamfara state.

### **Research Methodology**

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 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.

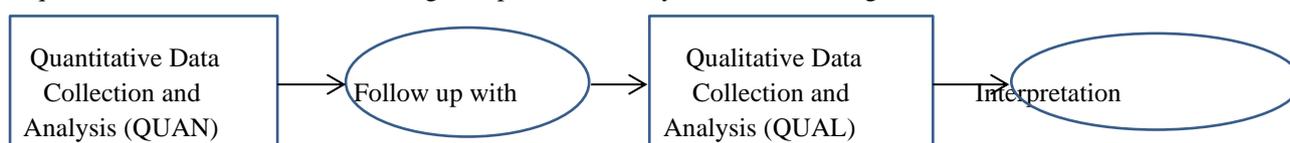


Figure 1: Illustration of the Explanatory Sequential Mixed Method Research Design Adopted in the Study

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.



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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. Cellular Respiration Performance Test (CRPT)

In the qualitative phase, data were collected through follow-up structured interviews using the 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 (CDM)) 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 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 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



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and/or groups. IBM Statistical Package for Social Sciences (SPSS) Statistics Version 25.0 Software was used for the analysis. The qualitative data 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).

## Presentation of Results

### Research Question One

Is there mean difference in academic performance scores of students taught cellular respiration concept with CBIVM and those exposed to conventional demonstration method in Zamfara state? To answer this research question, the students' posttest CRPT scores in the two different groups were analysed and the result is presented in Table 1.

**Table 1:**

**Summary of the Result of Students' Posttest Academic Performance Scores Means and Standard Deviations in both Experimental and Control Groups**

Group	N	Mean ( $\bar{X}$ )	SD	MD	Remarks
Experimental	47	17.26	3.72		
Control	36	11.17	1.98	6.09	Difference Exists
Total	83				

**Source:** Researcher's Fieldwork (2025)

Table 1 portrayed that the posttest academic performance scores mean and standard deviation of the experimental group were 17.26 and 3.72 respectively while those of the control group were 11.17 and 1.98 respectively. Hence, the mean difference between the groups was 6.09 and this result clearly indicated that the students taught using the CBIVM had higher mean academic performance score than those taught using the lecture method. That is, the experimental group performed better than the control group. However, by their respective standard deviations, the students' scores in the control group were more closely around the mean compared to those of the experimental group. Therefore, to determine whether the mean difference found was statistically significant or not, the corresponding null hypothesis one was tested.

### Null Hypothesis 1

There is no statistically significant mean difference between academic performance scores of students taught cellular respiration concept with CBIVM and those exposed to conventional demonstration method in Zamfara state. The result of testing null hypothesis one is presented in Table 2.

**Table 2:**

**Summary of One-Way Analysis of Covariance (ANCOVA) of SS 2 Students' Academic Performance Scores for both Experimental and Control Groups**

Source	Sum of Squares	DF	Mean Squares	F	Sig.	Decision
Corrected Model	15245.594	4	3811.398	30.777*	.000	
Intercept	45302.745	1	45302.745	365.815*	.000	
Pre-test	31.012	1	31.012	0.250	.618	Not Sign.
Inst. Strategy	14469.023	1	14469.023	116.836*	.000	Sign.
Error	13993.974	113	123.840			
Total	424685.000	118				
Corrected Total	29239.568	117				

**Source:** Researcher's Fieldwork (2025)

\* = Significant at  $p \leq 0.05$

Table 2 revealed that the instructional strategy (CBIVM) has significant effect on students' academic performance in the cellular respiration concepts studied. This is because as seen from the table, CBIVM is statistically significant at  $P$ -value of .000 and therefore it is also statistically significant at a higher  $P$ -value of .05. This led to the rejection of the null hypothesis that there is no significant difference between the mean academic achievement scores of secondary school



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students when taught cellular respiration using the multiple intelligence-based instructional strategy and those taught using the lecture method. Thus, there is a statistically significant difference between the mean academic performance scores of secondary school students taught cellular respiration concepts using CBIVM and those taught using conventional method of teaching in favour of the experimental group ( $F = 116.836^*$ ,  $df = 1$  and  $p = .000 < .05$ ). However, to specifically determine which of the four categories of learners (the VARK learners) under the experimental group had significantly higher academic performance among others, a pairwise comparison of Bonferroni's post-hoc test was further conducted and the analysis was presented in Table 3.

**Table 3:**

**Summary of Bonferroni Post-hoc Analysis of Academic Performance of SS 2 Students in the Experimental Group Categories (VARK Learners) and Control Group**

(I) Group	(J) Group	Mean Difference (I-J)	Sig. <sup>b</sup>	95% Confidence Interval for Difference <sup>b</sup>	
				Lower Bound	Upper Bound
V.L.	A.L.	8.33*	.000	6.58	11.95
	R.L.	7.42*	.000	-11.07	-4.26
	K.L.	5.19*	.000	-9.64	-7.83
	C.G.	12.45*	.000	8.46	14.44
A.L.	V.L.	-9.80*	.000	-12.35	-6.68
	R.L.	-4.17*	.000	-17.64	-12.07
	K.L.	-8.67	.000	-13.33	-10.81
	C.G.	6.55	.169	-.49	5.61
R.L.	V.L.	-7.56*	.000	5.20	10.27
	A.L.	6.68*	.000	14.04	19.25
	K.L.	-5.73	.000	7.99	8.79
	C.G.	8.01*	.000	15.69	21.73
K.L.	V.L.	-1.89*	.000	-11.35	-5.68
	A.L.	5.36*	.000	-16.64	-11.07
	R.L.	4.07	.000	-12.33	-11.81
	C.G.	10.11	.157	-.58	6.61
C.G.	V.L.	-12.45*	.000	-13.54	-7.62
	A.L.	-6.55	.158	-4.91	.52
	R.L.	-8.01	.000	-7.79	.48
	K.L.	-10.11*	.000	-15.73	-14.69

**Source:** Researcher's Pair-Wise Comparison

\* = Significant at  $p \leq 0.05$

**Key:**

V.L.: Visual Learners Exposed to CBIVM

A.L.: Auditory Learners Exposed to CBIVM

R.L.: Read/Write Learners Exposed to CBIVM

K.L.: Kinesthetic Learners Exposed to CBIVM C.G.: Control Group

Students Taught with CDM

The Bonferroni post-hoc analysis of the post-test mean academic performance scores in Table 3 revealed significant differences among the categories/groups. Visual Learners significantly performed better than Auditory Learners (Mdif = 8.33,  $p < .05$ ), Read/Write Learners (Mdif = 7.42,  $p < .05$ ) and Kinesthetic/Tactile Learners (Mdif = 5.19,  $p < .05$ ). However, Kinesthetic/Tactile Learners outperformed both the Read/Write Learners (Mdif = 4.07,  $p < .05$ ) and Auditory Learners (Mdif = 5.36,  $p < .05$ ). The Control Group Students performed significantly lower than all the four experimental group categories: Visual Learners (Mdif = -12.45,  $p < .05$ ), Auditory Learners (Mdif = -6.55,  $p < .05$ ), Read/Write Learners (Mdif = -8.01,  $p < .05$ ) and Kinesthetic/Tactile Learners (Mdif = -10.11,  $p < .05$ ). Therefore, these showed that CBIVM was most effective for the Visual Learners, followed by the Kinesthetic/Tactile Learners among the other experimental group categories and the control group.

**Research Question Two**

How does senior secondary biology students perceive the use of ChatGPT tool in teaching cellular respiration concept in Zamfara state? To answer this research question, the experimental group students' interview responses in the BSPCII 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

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ChatGPT in their cellular respiration classes” in which there were seven (7) positive and three (3) negative responses as follows.

### **Recorded and Transcribed Students’ Interview Responses**

#### **Positive Views**

1. Student 1: "ChatGPT helped me very well. It simply explained cellular respiration for me to understand easily. The examples it gave me were good."
2. Student 2: "It was like my teacher. I asked questions and it immediately gave me answers which helped me understand complex processes like glycolysis."
3. Student 4: "I liked how ChatGPT broke down the steps of cellular respiration. That made it much simpler to learn and remember."
4. Student 6: "The practice questions and quizzes were very useful. They helped me test my knowledge and retain information better."
5. Student 7: "ChatGPT's explanations were clear and simple. The summaries at the end of each lesson were very interesting."
6. Student 8: "I enjoyed the real-life examples it gave and how they related to cellular respiration. That made me more involved in the lessons. "
7. Student 10: "I felt happy that I could learn individually with ChatGPT. Its responses were always detailed and helpful."

#### **Negative Views**

1. Student 3: "Sometimes the explanations look somehow and I do not quickly understand. My teacher explains better for me."
2. Student 5: "I didn't like relying on a phone or computer for learning. I am use to my teacher teaching me directly."
3. Student 9: "ChatGPT is sometimes confusing me. Its answers were not always clear and straightforward for me."

#### **Thematic Analysis**

The main analysis was conducted following six (6) steps as follows.

#### **Step 1: Familiarization**

The students’ responses clearly indicated a mixture of both positive and negative perceptions about using ChatGPT in learning cellular respiration. The ositive views highlighted its clarity, personalization, and effectiveness in understanding complex concepts, while the negative views pointed at preference for human interaction, impersonality and confusion.

#### **Step 2: Coding**

##### **Codes for Positive Views**

- a. Clarity and simplicity of explanations - 1
- b. Personalization and flexibility - 2
- c. Effectiveness in understanding complex concepts - 3
- d. Engagement through real-life examples - 4

##### **Codes for Negative Views**

- a. Impersonality - 5
- b. Confusion and lack of clarity - 6
- c. Preference for human interaction - 7

#### **Step 3: Theme Identification**

Four distinct themes emerged from the codes as follows.

- i. **Effectiveness in Learning:** this theme centered on ChatGPT’s clarity, simplicity and effectiveness in understanding complex concepts.
- ii. **Personalization and Flexibility:** this theme focused on the students’ ability to learn at one's own pace and personalized responses.
- iii. **Engagement:** this theme underscored ChatGPT’s use of real-life examples and interactive nature.
- iv. **Challenges and Preferences:** this theme capitalized on impersonality, confusion and preference for human interaction.

#### **Step 4: Theme Development**



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**Effectiveness in Learning:** Students found ChatGPT effective for understanding cellular respiration due to its clear and simple explanations. These included: Student 1: "ChatGPT helped me very well. It simply explained cellular respiration for me to understand easily. The examples it gave me were good." Student 4: "I liked how ChatGPT broke down the steps of cellular respiration. That made it much simpler to learn and remember." Student 7: "ChatGPT's explanations were clear and simple. The summaries at the end of each lesson were very interesting."

**Personalization and Flexibility:** The ability to learn at students' own pace and receive tailored responses was highly valued. These included: Student 10: "I felt happy that I could learn individually with ChatGPT. Its responses were always detailed and helpful." Student 2: "It was like my teacher. I asked questions and it immediately gave me answers which helped me understand complex processes like glycolysis." Student 6: "The practice questions and quizzes were very useful. They helped me test my knowledge and retain information better."

**Engagement:** Real-life examples and interactive nature of ChatGPT enhanced engagement. These included: Student 8: "I enjoyed the real-life examples it gave and how they related to cellular respiration. That made me more involved in the lessons." Student 1: "ChatGPT helped me very well. It simply explained cellular respiration for me to understand easily. The examples it gave me were good." Student 7: "ChatGPT's explanations were clear and simple. The summaries at the end of each lesson were very interesting."

**Challenges and Preferences:** Some students preferred human interaction and found certain aspects impersonal or confusing. These included: Student 3: "Sometimes the explanations look somehow and I do not quickly understand. My teacher explains better for me." Student 5: "I didn't like relying on a phone or computer for learning. I am use to my teacher teaching me directly." Student 9: "ChatGPT is sometimes confusing me. Its answers were not always clear and straightforward for me."

#### **Step 5: Data Analysis**

The analysis shows that while most students found ChatGPT beneficial for learning cellular respiration, some expressed concerns about its impersonality and clarity. This suggests the need for balancing the technology use (as a teaching resource or tool that complements human teaching) with human interaction so as to maximally leverage the technology's benefits while addressing its limitations.

#### **Step 6: Interpretation**

The findings indicated that ChatGPT can be a valuable tool for learning, offering personalized and engaging experiences. However, it is crucial to address the challenges and preferences for human interaction to ensure effective learning among senior secondary school students.

### **Discussion of Findings**

The findings of the null hypothesis disclosed that there was statistically significant difference between the mean academic performance of the students taught cellular respiration using the CBIVM and those exposed to CDM in favour of those exposed to the CBIVM. This was indicated by the groups' mean difference and the result of the one-way ANCOVA analysis on the SS 2 students' mean academic performance in learning cellular respiration. Thus, it implies that exposing students to the CBIVM as an instructional strategy helps students learn and comprehend even the erroneously misconceived cellular respiration concept more easily than using the conventional method. This finding confirms those of: Alneyadi and Wardat (2023) who reported that ChatGPT had a positive influence on students' achievement and perception of learning in the field of electronic magnetism; Eltahir and Babiker (2024) whose findings underscored the transformative potential of AI-powered personalized learning tools in improving students' learning outcome; Mina et al. (2023) who revealed that AI virtual assistant allowed students to explore their potentials and helped them achieve academic tasks that are generally difficult; Salami (2023) who found that virtual learning had a positive impact on the performance of students as compared to traditional learning; and Udosen and Udoh (2024) who found that students taught biology using ChatBot AI outperformed those taught with traditional expository method. However, it contradicted the findings of Fadzil and Mahmud (2020) who found that no significant difference in the mean post-achievement scores between the treatment group and the control group who were taught using the conventional method. The findings of the second research question which was not subjected to hypothesis testing revealed that secondary school biology students' perceptions 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 which indicated that: SS 2 students found ChatGPT effective for understanding and performing in cellular respiration due to its clear and simple explanations (theme 1); SS 2 students had the ability to learn



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at one's own pace and learning style (theme 2); SS 2 students found ChatGPT comfortable, simple and user-friendly tool which offers real-life examples in an interactive nature for enhanced engagement (theme 3); and some few SS 2 students who preferred human interaction found certain aspects of ChatGPT impersonal or confusing (theme 4). 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 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. On the negative side, the findings confirmed those of Xu et al. (2019a) and Mayer (2014a) who reported the need to enhance ChatGPT's capabilities to better comprehend students' inquiries and the significance of providing visual aids to support learning.

### **Conclusion**

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

### **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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