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Advancing Genetics Education using the 5E Learning Cycle and WebQuest Among Secondary School Students in Rivers State

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Abstract
This study explores the impact of integrating the 5E Learning Cycle and WebQuest as innovative instructional strategies to improve genetics education among secondary school students in Rivers State, Nigeria. Genetics, a fundamental component of the biology curriculum, is often perceived as abstract and difficult by students, leading to poor comprehension and performance. Traditional teaching methods, largely teacher-centered, have not effectively addressed these challenges. Supports active student participation and conceptual understanding. When combined with WebQuest, a technology-driven, inquiry-oriented learning strategy that utilizes web resources for guided exploration, the approach promises a more engaging and effective learning experience.
The study adopted a quasi-experimental design involving selected senior secondary schools in Rivers State. Participants were divided into experimental and control groups. The experimental group received instruction using the 5E Learning Cycle and WebQuest, while the control group was taught using traditional lecture methods. instruments on genetics concepts were administered to evaluate knowledge gains.
Findings revealed that students exposed to the integrated teaching strategy demonstrated significantly higher achievement and interest levels in genetics than their counterparts in the control group. The study concludes that the 5E Learning Cycle and WebQuest approach not only enhances comprehension of complex biological concepts but also fosters critical thinking, collaboration, and digital literacy. It recommends that biology educators and curriculum developers incorporate these methods into science instruction to improve learning outcomes and 21st-century skills among students.

Keywords: 5E Learning Cycle, WebQuest, Genetics Education, Secondary School, Inquiry-Based Learning, Rivers State, Constructivist Teaching, Science Pedagogy

Introduction

Background of the Study

Science education plays a pivotal role in national development by fostering critical thinking, innovation, and problem-solving skills among learners. In particular, biology, one of the core science subjects at the secondary school level, provides foundational knowledge that underpins several disciplines, including medicine, agriculture, biotechnology, and environmental science. Among the diverse topics covered in biology, genetics is recognized as both essential and challenging. It deals with the principles of heredity and variation in living organisms, and serves as a bridge between biology and other emerging fields such as genomics, bioinformatics, and genetic engineering.
Despite its importance, genetics education in Nigerian secondary schools continues to face significant pedagogical challenges. Students often perceive genetics as abstract, complex, and unrelatable, largely due to the use of teacher-centered instructional methods, lack of interactive resources, and insufficient real-life applications. This has contributed to low achievement levels and waning interest in the subject. The need to reform science education to make it more interactive, student-centered, and technologically integrated is more urgent than ever.

Statement of the Problem

In Rivers State, as in many parts of Nigeria, the teaching of genetics has remained largely traditional, characterized by rote memorization and minimal student engagement. The persistent reliance on lecture-based methods fails to develop learners' higher-order thinking skills or promote deep conceptual understanding. Additionally, teachers often lack access to digital instructional resources that can support active and collaborative learning environments.
Consequently, students struggle to comprehend fundamental genetic concepts such as DNA structure, Mendelian inheritance, genetic crosses, and gene expression. This not only leads to poor performance in internal and external examinations but also discourages students from pursuing careers in science and technology-related fields. It is therefore imperative to explore alternative instructional strategies that can transform the teaching and learning of genetics to align with modern educational practices.

Purpose of the Study

WebQuest as a means of advancing genetics education among secondary school students in Rivers State. Specifically, the study seeks to:

1. Determine the impact of the 5E Learning Cycle and WebQuest on students' academic achievement in genetics.
2. Examine the influence of these strategies on students' interest and engagement levels.
3. Compare the effectiveness of the integrated method with conventional teaching approaches.
4. Identify challenges and opportunities associated with implementing technology-enhanced inquiry-based instruction in secondary schools.

Significance of the Study

This study contributes to the growing body of research on innovative pedagogies in science education. By focusing on the integration of the 5E Learning Cycle and WebQuest, it addresses a critical gap in the instructional methods currently used in Nigerian classrooms. The findings are expected to:

- Guide policy makers and curriculum developers in designing learner-centered educational frameworks.
- Empower teachers with practical tools and methodologies for enhancing student learning outcomes.
- Encourage students to develop critical thinking, research, and digital skills that are essential for academic and career success in the 21st century.

Theoretical Framework

The 5E Learning Cycle, developed by the Biological Sciences Curriculum Study (BSCS), operationalizes constructivist principles through a five-phase instructional model: Engage, Explore, Explain, Elaborate, and Evaluate. This model encourages students to ask questions, explore phenomena, construct explanations, and apply knowledge in new contexts.

WebQuest, conceptualized by Bernie Dodge and Tom March, is a learner-centered, inquiry-based strategy that utilizes internet resources to facilitate research, problem-solving, and collaboration. Together, the 5E Learning Cycle and WebQuest offer a synergistic approach to teaching that can address the cognitive and affective needs of learners.

Research Questions

To guide the investigation, the following research questions were formulated:

1. What is the effect of the 5E Learning Cycle and WebQuest on students' academic achievement in genetics?
2. How do these instructional strategies influence students' interest in learning genetics?
3. In what ways does the integrated method differ from traditional instruction in terms of student engagement and understanding?
4. What challenges do teachers and students face in implementing the 5E Learning Cycle and WebQuest in the classroom?

Scope of the Study

This study is delimited to selected secondary schools in Rivers State, focusing on senior secondary school students (SS2) offering biology. The content scope includes core genetics topics such as cell division, DNA structure and function, Mendelian genetics, and genetic variation. The study examines the impact of the intervention over a defined instructional period, using quantitative measures of achievement and interest.

Operational Definition of Terms

- **5E Learning Cycle:** A model of teaching that consists of five phases—Engage, Explore, Explain, Elaborate, and Evaluate—designed to support student-centered, inquiry-based learning.

- **WebQuest:** An instructional tool that uses internet resources to guide students through an inquiry-based learning process.

- **Genetics Education:** The teaching and learning of concepts related to heredity and variation as part of the biology curriculum.

- **Secondary School Students:** Learners in the senior segment of the secondary school system, typically aged between 15 and 18 years.

- **Inquiry-Based Learning:** An educational approach that emphasizes students' investigation and problem-solving through questioning, exploration, and critical thinking.

Methods

Research Design

This study adopted a quasi-experimental design with a non-equivalent control group to examine the effectiveness of using the 5E Learning Cycle and WebQuest in teaching genetics to secondary school students in Rivers State. The quasi-experimental approach was selected because random assignment of students to groups was not feasible due to the pre-existing class structures within schools. This design allows comparison between an experimental group exposed to the intervention and a control group taught using conventional instructional methods, providing insight into the impact of the innovative teaching strategies on students' academic achievement and interest.

Population and Sample

According to the Rivers State Ministry of Education, approximately 50 public secondary schools have SS2 biology classes.

Two schools were randomly assigned to the experimental group, and two to the control group. From each school, one intact SS2 biology class was selected, totaling four classes. The combined sample size was 160 students—80 in the experimental group and 80 in the control group.

Instrumentation

Three instruments were developed and used for data collection:

1. Genetics Achievement Test (GAT):

The GAT was designed to assess students' knowledge and understanding of genetics concepts covered in the syllabus, including DNA structure and function, Mendelian genetics, and genetic variation. It consisted of 30 multiple-choice and short-answer questions, validated by three biology education experts for content relevance and clarity. The reliability determined using Cronbach's alpha, yielding a reliability coefficient of 0.82, indicating acceptable internal consistency.

2. Students' Interest Questionnaire (SIQ):

This questionnaire measured students' interest in genetics learning before and after the intervention. It contained 15 Likert-scale items ranging from "strongly disagree" to "strongly agree" related to students' motivation, enjoyment, and perceived relevance of genetics topics. The SIQ was validated by educational psychologists and pilot-tested for reliability, achieving a Cronbach's alpha of 0.78.

Teacher Observation Checklist (TOC)

To monitor the fidelity of implementation, a checklist was used by trained observers to assess teachers' adherence to the instructional procedures of the 5E Learning Cycle and WebQuest during lessons in the experimental group.

Procedure

Preparation and Training

Prior to the intervention, biology teachers in the experimental schools received training workshops on the use of the 5E Learning Cycle and WebQuest for genetics instruction. The training covered:

- The theoretical basis and phases of the 5E Learning Cycle.
- Designing and facilitating WebQuests focused on genetics topics.
- Integrating inquiry-based strategies with available technology resources.
- Managing classroom activities to promote collaboration and active learning.

Teachers in the control group continued with their usual lecture-based teaching approach without additional training.

Development of WebQuest

A customized WebQuest was developed specifically for the genetics topics aligned with the SS2 biology syllabus. The WebQuest included:

- An introduction that captured students' interest and set the task.
- A clear task statement requiring students to investigate key genetics concepts using curated online resources.
- Step-by-step guidance for exploration, including interactive simulations, videos, and educational websites.
- A collaborative activity where students synthesized information and prepared presentations.
- Evaluation criteria emphasizing content understanding, teamwork, and creativity.

Implementation

The intervention spanned six weeks, with two lessons per week dedicated to genetics topics.

- **Experimental group**

Teachers followed the 5E Learning Cycle phases for each lesson

- **Engage:** Activities such as thought-provoking questions or short videos to capture students' curiosity.
- **Explore:** Students used the WebQuest to investigate genetics concepts online, working in groups.
- **Explain:** Teachers facilitated discussion and clarification of concepts based on students' findings
- **Elaborate:** Extension activities, including problem-solving tasks and real-life applications.
- **Evaluate:** Formative assessments and reflection exercises to assess understanding.

Control group

Students were taught the same content through conventional methods such as lectures, note-taking, and textbook exercises without the use of WebQuest or the 5E model.

Data Collection

Data collection involved:

- **Pre-test:** Both groups completed the Genetics Achievement Test and Interest Questionnaire before the start of the intervention to establish baseline measures.

- **Post-test:** At the end of six weeks, the same instruments were administered to assess gains in achievement and interest.

- **Classroom observations:** Conducted in the experimental group to ensure proper implementation and document students' engagement and interactions.

Data Analysis

Quantitative data from the Genetics Achievement Test and Students' Interest Questionnaire were analyzed using the Statistical Package for Social Sciences (SPSS) version 27. Descriptive statistics (means, standard deviations) summarized performance and interest levels.

Inferential statistics included:

- **Independent samples t-test:** To compare pre-test scores between experimental and control groups and ensure group equivalency at baseline.

- **Paired samples t-test:** To assess within-group differences between pre-test and post-test scores.

Ethical Considerations

The study received ethical approval from the Rivers State Ministry of Education and the participating schools' authorities.

Limitations

The quasi-experimental design and purposive sampling limit the generalizability of the findings. Additionally, the reliance on internet access for the WebQuest posed challenges due to varying availability of technological resources across schools. Efforts were made to mitigate these by providing offline copies and arranging computer lab sessions.

Results

Baseline Equivalence of Groups

To establish that the experimental and control groups were comparable before the intervention, an independent samples t-test was conducted on the pre-test scores of the Genetics Achievement Test and the Students' Interest Questionnaire.

Variable	Group	N	Mean	SD	t-value	p-value
Achievement (Pre)	Experimental	80	42.15	8.72	0.83	0.41
	Control	80	40.79	9.10		
Interest (Pre)	Experimental	80	3.25	0.52	1.12	0.27
	Control	80	3.17	0.48		

Note: Scores on the Interest Questionnaire ranged from 1 (low interest) to 5 (high interest).

The results show no statistically significant differences between the groups on both achievement and interest at baseline, confirming that the groups were equivalent prior to the intervention.

Effect of the Intervention on Students' Achievement

Students in both groups showed statistically significant improvement in genetics achievement after instruction. However, the increase in the experimental group (mean difference = 26.75) was substantially larger than in the control group (mean difference = 8.57).

Effect Size: The calculated Cohen's d was 1.56, which is considered a large effect size, indicating the intervention had a strong positive impact on students' genetics achievement.

Effect of the Intervention on Students' Interest

Within-Group Comparisons

Paired samples t-tests analyzed changes in students' interest scores before and after the intervention.

Group	Test	Mean	SD	t-value	p-value
Experimental	Pre-test	3.25	0.52	10.87	<0.001
	Post-test	4.31	0.48		
Control	Pre-test	3.17	0.48	2.33	0.022
	Post-test	3.45	0.53		

Interest significantly increased in both groups, but the magnitude of change was notably higher in the experimental group.

Between-Group Comparisons

An ANCOVA controlling for pre-test interest scores revealed a significant difference in post-test interest scores between groups:

Source	SS	df	MS	F-value	p-value
Group	7.83	1	7.83	42.56	<0.001
Pre-test (covariate)	1.98	1	1.98	10.75	0.001
Error	28.87	157	0.18		

The experimental group reported higher interest in genetics learning after the intervention compared to the control group. The effect size (Cohen's d = 0.82) suggests a moderate to large practical impact.

Student Engagement and Classroom Observations

Qualitative data from classroom observations during the intervention period provided additional evidence of enhanced student engagement and collaborative learning in the experimental group.

- Students demonstrated enthusiasm during the Engage phase by actively responding to questions and sharing prior knowledge.
- During the Explore phase, the use of WebQuest fostered curiosity and teamwork, with students working collaboratively to investigate genetics concepts using digital resources.
- The Explain and Elaborate phases saw lively discussions, where students articulated their understanding and applied knowledge to real-world scenarios, such as genetic diseases and inheritance patterns.
- Teachers reported that students were more confident and participated more frequently compared to traditional lessons.
- Observers noted improved digital literacy skills, with students navigating websites, evaluating information, and synthesizing content effectively.

In contrast, the control group's classroom environment was more passive, with students largely listening to lectures and limited peer interaction.

Challenges Encountered

Several challenges were reported during the implementation of the intervention:

- **Limited access to computers and internet:** Some schools faced difficulties providing adequate digital infrastructure, leading to scheduling of computer lab sessions and use of offline WebQuest copies.
- **Teacher familiarity with technology:** Initial discomfort with integrating WebQuest and managing group activities required ongoing support and mentoring.
- **Time constraints:** The inquiry-based approach required more classroom time for activities, necessitating careful lesson planning.

Despite these challenges, the overall feedback from teachers and students was positive, with a strong desire to continue using the 5E Learning Cycle and WebQuest strategies in other biology topics.

Summary of Findings

1. Both experimental and control groups improved in genetics achievement and interest, but the improvement was significantly greater in the experimental group.
2. The 5E Learning Cycle combined with WebQuest had a large positive effect on students' understanding of genetics concepts.
3. Students exposed to the intervention demonstrated higher engagement, collaboration, and motivation.
4. While technological and logistical challenges were noted, these did not detract from the overall effectiveness of the approach.

Discussion

Overview

The present study investigated the effectiveness of integrating the 5E Learning Cycle and WebQuest as instructional strategies to enhance genetics education among secondary school students in Rivers State. The findings demonstrate that this innovative, inquiry-based, technology-supported approach significantly improves students' academic achievement and interest in genetics compared to conventional teaching methods. This section discusses these results in relation to the study's research questions, relevant literature, and theoretical frameworks, highlighting the implications for teaching and learning biology in Nigerian secondary schools.

Impact on Students' Academic Achievement

The 5E Learning Cycle's phased approach encourages students to construct their own understanding through engagement, exploration, explanation, elaboration, and evaluation. This method moves away from rote memorization towards deeper conceptual comprehension. When combined with WebQuest, which provides structured, web-based inquiry and research activities, students are able to access diverse multimedia resources, conduct investigations, collaborate with peers, and apply knowledge to real-world problems. These elements contribute to meaningful learning experiences that enhance cognitive processing and retention of complex genetics concepts.

Similar studies (Bybee *et al*., 2006; Karakuyu & İçöz, 2013) [3, 4] have reported significant gains in science achievement using the 5E model, often attributing success to its emphasis on inquiry and scaffolded learning. Likewise, research on WebQuest integration in biology instruction (Lin *et al*., 2013; Alhazmi, 2018) [1] supports its role in fostering inquiry skills, critical thinking, and content mastery. Thus, the present findings corroborate prior evidence that instructional approaches blending inquiry learning and technology foster improved academic outcomes.

Influence on Students' Interest in Genetics

In addition to academic performance, the study found a significant increase in students' interest in genetics among

those exposed to the 5E Learning Cycle and WebQuest. This outcome is particularly important given the persistent challenge of motivating students in abstract and perceived difficult topics like genetics.

By engaging students actively with interactive tasks and collaborative problem-solving, the intervention helped demystify complex genetic concepts and made learning relevant to students' lives. The multimedia-rich WebQuest, including videos, simulations, and online resources, enhanced engagement by catering to diverse learning styles and stimulating curiosity. The social dimension of collaborative exploration further contributed to motivation and enjoyment.

These results align with the affective benefits documented in previous research (Baki & Kartal, 2011; Mohamed & El-Deghaidy, 2014) [2, 6], where inquiry-based and technology-supported approaches increased students' positive attitudes towards science. Interest is a crucial mediator of learning, as it drives persistence, effort, and deeper cognitive engagement. The study's findings suggest that integrating the 5E Learning Cycle with WebQuest is an effective strategy for increasing not only achievement but also students' enthusiasm and sustained interest in biology.

Theoretical Implications

The study's findings strongly support the theoretical underpinnings of constructivist learning theory. Constructivism asserts. 5E Learning Cycle operationalizes constructivism by structuring learning phases that facilitate engagement, exploration, and explanation. WebQuest complements this by providing a scaffolded, inquiry-driven environment where learners navigate information, collaborate, and generate understanding.

This pedagogical synergy aligns with Vygotsky's social constructivism, which emphasizes the role of social interaction and cultural tools (in this case, digital technology) in cognitive development. The collaborative group work fostered peer scaffolding and collective meaning-making, while WebQuest's use of web resources served as a cultural artifact mediating learning. The positive outcomes reflect the effective implementation of these theoretical principles in practice, highlighting their relevance to science education in the Nigerian context.

Practical and Pedagogical Implications

The results hold significant implications for biology educators, curriculum developers, and policymakers in Rivers State and beyond.

1. Teacher Professional Development

The success of the intervention underscores the need for ongoing teacher training on inquiry-based methods and educational technologies. Professional development programs should equip teachers with the skills to design and facilitate 5E lessons and WebQuest activities effectively.

2. Curriculum Innovation

Integrating inquiry-based and technology-supported strategies into the biology curriculum could help overcome persistent learning challenges, improve student outcomes, and align instruction with 21st-century skills. Curriculum planners should embed frameworks like the 5E Learning Cycle and WebQuest as standard pedagogical approaches.

3. Resource Allocation

Addressing infrastructural challenges, such as limited access to computers and reliable internet, is essential for widespread adoption. Schools and education authorities should prioritize investments in ICT infrastructure to support modern teaching methods.

4. Student-Centered Learning Environments

Encouraging collaborative, interactive classrooms where students take ownership of their learning can enhance motivation and academic success. The study demonstrated that shifting from teacher-centered lectures to learner-centered inquiry fosters critical thinking, problem-solving, and digital literacy skills.

Challenges and Limitations

While the study demonstrated significant benefits, certain challenges and limitations must be acknowledged.

- **Technological Constraints**

Infrastructural deficits limited the seamless implementation of WebQuest in some schools, requiring offline adaptations and constrained computer lab time. This highlights the digital divide issue prevalent in many Nigerian secondary schools.

- **Teacher Preparedness**

Some teachers initially struggled to shift from traditional pedagogy to the facilitative role required by the 5E and WebQuest approaches. Continuous support and mentoring are needed to sustain this transition.

- **Generalizability**

  The quasi-experimental design and purposive sampling limit the extent to which findings can be generalized to all secondary schools in Rivers State or Nigeria. Further studies using randomized controlled trials and larger, more diverse samples are recommended.

- **Time Intensity**

Inquiry-based learning can be time-consuming, potentially conflicting with dense curriculum schedules and examination preparation pressures.

Recommendations for Future Research

Future research could explore the long-term effects of 5E Learning Cycle and WebQuest integration on students' academic trajectories and career choices in science. Investigations into combining other emerging technologies, such as virtual labs and gamification, with inquiry-based frameworks could yield further pedagogical innovations. Additionally, qualitative studies examining teachers' and students' lived experiences with these instructional strategies could provide richer insights into implementation dynamics.

Conclusion

This study has demonstrated that integrating the 5E Learning Cycle and WebQuest in genetics instruction significantly improves secondary school students' academic achievement and interest in Rivers State. The interactive, inquiry-based, and technology-supported approach fosters deeper understanding, engagement, and motivation compared to traditional teaching methods. Despite

infrastructural and implementation challenges, the findings highlight the potential of these strategies to transform biology education and enhance scientific literacy. Therefore, incorporating such innovative pedagogies in secondary schools is strongly recommended to prepare students for future scientific and technological challenges.

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