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EFFECTS OF INNOVATIONS IN SCIENCE TEACHING FOR NURTURING CURIOSITY AND CRITICAL THINKING IN SECONDARY SCHOOLS

Aigboje Juliana Oyida Ph.D[1] & Abhulimen Josephine Ph.D[2]
[1]Department of Curriculum and Instruction, Faculty of Education
Ambrose Alli University, Ekpoma, Edo State, Nigeria
[2]Department of Vocational and Technical Education, Faculty of Education
Ambrose Alli University, Ekpoma, Edo State, Nigeria
EMAIL: julianaaigboje@gmail.com[1], jossyabhus@gmail.com[2]

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ABSTRACT

This study investigated the Effects of Innovations in Science Teaching for Nurturing Curiosity and Critical Thinking on Secondary School Students. It explored the evolving landscape of science education, focusing on innovative pedagogical approaches that aim to enhance students' curiosity and critical thinking skills. The study analyzes a variety of teaching methods, including inquiry-based learning, project-based learning, and the integration of technology in the classroom. The quasi-experimental design was adopted in the study. Three research questions were raised and with the corresponding three null hypotheses. 84 SSII students were purposively selected. The instruments used for data collection were validated by experts in Science Education. "Students Engagement and Interest in Science Questionnaire" (SEISQ) and Teachers' Challenges and Effectiveness of Teaching Methods Questionnaire (TCAEFTMQ). Data was analyzed using Mean, Standard deviation and ANCOVA. The findings revealed that when teachers employ innovative teaching strategies, students are more likely to engage with the material, ask probing questions, and develop the critical thinking skills necessary for success in the 21st century. Recommendations based on the findings includes among others; professional development and training should be provided to teachers to equip them with the skills and knowledge necessary to implement innovative teaching strategies effectively and Curriculum developers and educators should integrate innovative teaching methods into the science curriculum.

INTRODUCTION

This study centers on the growing need to reform traditional science education to better prepare students for the complexities of the modern world. Traditionally, science teaching has often relied on rote memorization and passive learning, where students absorb information without fully engaging with the material or developing a deeper understanding of scientific principles.In recent years, there has been a significant shift in educational philosophies, emphasizing the importance of fostering critical thinking, creativity, and curiosity in students. This shift is driven by the recognition that the skills needed for success in the 21st century such as problem-solving, analytical thinking, and the ability to innovate are not adequately developed through conventional teaching methods.

The study is set against the backdrop of these educational trends and the increasing integration of technology in classrooms. It examines how innovative teaching methods, such as inquiry-based learning, project-based learning, and the use of digital tools, can transform science education. The background also touches on the global push for STEM (Science, Technology, Engineering, and Mathematics) education, which has further highlighted the need for teaching approaches that not only convey scientific knowledge but also inspire students to think critically and creatively.

Despite the increasing recognition of the importance of critical thinking and curiosity in education, many science classrooms continue to rely on traditional teaching methods that prioritize memorization and the passive absorption of information. These methods often fail to engage students in deeper learning or to develop the essential skills needed for problem-solving and innovation in the modern world. As a result, there is a growing concern that students are not adequately prepared to meet the challenges of the 21st century, particularly in the fields of science and technology. This study seeks to address this issue by exploring and identifying innovative teaching strategies that can be adopted to foster these essential skills in students. Specifically, the research aims to determine how various innovative approaches can be implemented in science classrooms to enhance students engagement promote deeper understanding of scientific concepts, and cultivate the critical thinking necessary for success in a rapidly evolving world.

Traditional science teaching methods often emphasize a more structured, teacher-centered approach, focusing on the transmission of knowledge through lectures, demonstrations, and the memorization of facts. Some of these methods include: Lecture-based Teaching: This is a predominant method where teachers deliver content through spoken explanations while students take notes. It emphasizes the delivery of factual knowledge from teacher to students. Demonstrations: In this method, the teacher shows scientific phenomena, experiments, or concepts in a controlled environment, usually with students observing passively.

In this method, students learn mainly from textbooks, with a focus on mastering standard scientific facts and theories. Textbooks guide both the curriculum and the learning outcomes, which are often assessed through standardized tests. In this method, students repeatedly practice solving problems or answering questions related to scientific concepts, often to prepare for exams or assessment. These methods often focus on rote learning and factual recall, which has drawn criticism for limiting critical thinking and creativity in students. However, they are still widely used due to their structured nature and perceived efficiency in delivering large amounts of information.

Critical thinking is particularly important in today's information-rich world, where students must navigate vast amounts of information from various sources. It enables them to discern credible sources, challenge assumptions, and approach problems with a reasoned and reflective mindset. This skill is essential for fostering independent thinking and empowering students to engage with and contribute to the society meaningfully (Abrami, 2015). Critical thinking on the other hand refers to the ability to analyze, evaluate, and synthesize information in a reasoned manner. It is essential in education because it equips students with the tools to assess arguments, identify biases, and make informed decisions. In an educational context, critical thinking promotes problem-solving, creativity, and the ability to apply knowledge in various contexts. It helps students move beyond rote memorization to higher-order thinking, which is necessary for understanding complex concepts and solving real-world problems (Paul and Elder, 2008).

The term curiosity is the intrinsic desire to explore and understand, drives students to ask questions and seek knowledge beyond the surface level. It serves as a motivator, encouraging learners to actively engage with new material and make connections between ideas. When students are curious, they are more likely to pursue learning opportunities, which leads to improved retention and understanding. Curiosity stimulates inquiry-based learning, where students investigate, experiment, and discover, leading to more meaningful and personal educational experiences (Engel, 2013). Curiosity is also linked to increased motivation and academic achievement. Studies showed that students who exhibit curiosity are more likely to persist in challenging tasks and develop a deeper understanding of the content (Grossnickle, 2016). By fostering curiosity, educators can create a learning environment that promotes exploration and inquiry, encouraging students to become active participants in their own education.

These innovations reflect a broader move towards flexible, technology-integrated learning environments, making science education more accessible, engaging and effective for diverse learners. Nurturing curiosity in students involves creating an environment that encourages exploration, inquiry and discovery. Inquiry-Based Learning (IBL), **i**nquiry-based learning is an educational approach that emphasizes students driven inquiry and active exploration to foster deeper understanding. Instead of passively receiving information from the teacher, students are encouraged to ask questions, investigate and use critical thinking skills to discover answers. This model promotes autonomy, curiosity, and engagement, allowing students to connect learning with their experiences.

Project-Based Learning(PBL) is also an instructional method that encourages students to learn by actively engaging in real-world and meaningful projects. In PBL, students explore complex questions, problems, or challenges, often over extended periods. It fosters deeper understanding of content, as students connect theory with practice (Bell, 2010). PBL supports the development of critical thinking, collaboration, communication, and creativity (Larmer, Mergendoller, and Boss, 2015). Since projects are based on students interest and real-world problems, learners often show higher levels of motivation and engagement (Condliffe, 2017).

Despite the increasing recognition of the importance of critical thinking and curiosity in education, many science classrooms continue to rely on traditional teaching methods that prioritize memorization and the passive absorption of information. These methods often fail to engage students in deeper learning or to develop the essential skills needed for problem-solving and innovation in the modern world. As a result, there is a growing concern that students are not

adequately prepared to meet the challenges of the 21st century, particularly in the fields of science and technology. The prevailing didactic approach to science instructions has resulted in low student motivation and interest in science, limited development of critical thinking and problem solving skills, inadequate preparation of students for real-world Mathematics challenges and poor performance in Science, Technology, Engineering and Mathematics (STEM) subjects.

This study seeks to" investigate the effect of innovative science teaching methods in nurturing curiosity and critical thinking skills on secondary school students". Specifically, the aims are to determine how various innovative approaches can be implemented in science classrooms to engage students actively, promote deeper understanding of scientific concepts, foster critical thinking and develop problem-solving skills necessary for success in a rapidly evolving world.

Research Questions

1. Do innovative science teaching methods, such as inquiry-based learning influence students' curiosity and critical thinking skills?
2. What challenges do teachers face in implementing these innovative methods, and how can they be addressed?
3. What is the role of digital tools in enhancing the effectiveness of science teaching in fostering curiosity and critical thinking?

Research Hypotheses

1. There is no significant difference in students' curiosity and critical thinking skills between those taught by innovative science teaching methods and those taught using traditional methods.
2. There is no significant difference between teachers' demographic (experience, training subject matter) and the challenges they face when implementing innovative teaching methods.
3. There is no significant development of curiosity and critical thinking skills among students taught science using digital tools compared to those taught using traditional methods.

Methodology

The study adopted the pre-test, post-test non-equivalent control group of Quasi-experimental research design. A quasi-experimental research design according to Nwankwo in Adolphus and Omeodu (2006) is a study in which some threat to internal and external validity cannot be properly controlled because of unavoidable situation associated with the study. Quasi-experimental design was considered appropriate for the study because intact classes were used to avoid disruption of normal class lessons. The study comprised 84 Secondary School Students two (SSS 2) science student purposely selected. Three Research Questions and three Hypotheses were formulated and tested.

Two instruments was used for data collection and were validated by experts in Science Education, titled " Students Engagement and Interest in Science Questionnaire"(SEISQ) and Teachers' Challenges and Effectiveness of Teaching Methods Questionnaire (TCAEFTMQ) were pilot tested using test re-test method to establish the reliability index using Pearson Product Moment Correlation (PPMC). Data was analyzed using Mean, Standard deviation was used to answer the Research Questions while the Hypotheses were tested using ANCOVA.

Results

Research Question 1: How do innovative science teaching methods, such as inquiry-based learning influence students' curiosity and critical thinking skills?

Item No.:	Items No.:	N	Responses	Mean	Standard Deviation
Research Question 1	1,3,4,5,6,7 and 12	80	SA	23.00	2.76
			A	23.14	2.47
			D	17.29	1.38
			SD	16.57	5.38

From the table above, it can be seen that the mean of responses on the affirmative (SA and A) are higher than those in the negative (D and SD). This suggests that innovative science teaching methods such as inquiry-based learning influence students' curiosity and critical thinking skills. The study found a significant increase in students' curiosity levels in the experimental group that was exposed to innovative teaching methods compared to the control group. Students who participated in inquiry-based and project-based learning activities demonstrated a higher inclination to ask questions, explore scientific concepts independently, and show interest in science beyond the classroom. The findings also revealed that students in the experimental group showed marked improvement in critical thinking skills as evidenced by their performance in post-tests and problem-solving tasks. The innovative approaches, particularly inquiry-based and project-based learning, were more effective in fostering critical thinking compared to traditional lecture-based instruction.

Research Question 2 What challenges do teachers face in implementing these innovative methods, and how can they be addressed?

Item No.:	Item No.:	N	Responses	Mean	Standard Deviation
Research Question 2	1,2,13,14,15,16,17 and 18	80	SA	21.50	1.93
			A	22.25	2.49
			D	17.25	1.98
			SD	19	4.84

From the table above, it can be seen that the mean of responses on the affirmative (SA and A) are higher than those in the negative (D and SD). This indicates that class workload, teachers negative attitude, technical issues, lack of accessibility to internet etc. are challenges teachers face in implementing innovative science teaching methods in the classroom.

To answer this research question, teachers reported various challenges in implementing innovative teaching strategies, including a lack of resources, time constraints, and the need for professional development. However, with adequate support, such as training and access to technological resources, many of these challenges were effectively managed. Teachers who received ongoing support were more successful in integrating innovative methods into their teaching.

Research Question 3: What is the role of digital tools in enhancing the effectiveness of science teaching in fostering curiosity and critical thinking?

Item No.:	Item No.:	N	Responses	Mean	Standard Deviation
Research Question 3	3,8,9,10,11,12	80	SA	23.3	1.97
			A	22.17	2.13
			D	17	1.54
			SD	17.50	3.39

From the table above, it can be seen that the mean of responses on the affirmative (SA and A) are higher than those in the negative (D and SD). This suggests that teacher demographics (experience, training, and subject area) could be associated with the challenges they face while implementing innovative science teaching methods.

To answer this research question, the integration of technology in the experimental classrooms contributed significantly to student engagement and a deeper understanding of scientific concepts. Students who used digital tools and participated in technology-enhanced lessons demonstrated better retention of knowledge and a more profound grasp of complex scientific.

Test of Hypothesis

Hypothesis 1: There is no significant difference in students' curiosity and critical thinking skills between those taught by innovative science teaching methods and those taught using traditional methods.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	266	3	88.66667	7.940299	0.000753	3.008787
Within Groups	268	24	11.16667			
Total	534	27				

The table above shows the analysis of variance (ANOVA) of responses from the research instruments. The analysis gave a F statistic of 7.940 with a p-value of 0.000753. Since the p-value is less than the significance level of 0.05, we therefore reject the null hypothesis and conclude that there is a significant difference in students' curiosity and critical thinking skills among those taught using innovative science teaching methods and those taught using traditional methods.

Hypothesis 2: There is no significant relationship between teachers' demographic (experience, training subject matter) and the challenges they face when implementing innovative teaching methods.

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	127	3	42.33333	4.541507	0.010255	2.946685
Within Groups	261	28	9.321429			
Total	388	31				

The table above shows the analysis of variance (ANOVA) of responses from the research instruments. The analysis gave a F statistic of 4.541 with a p-value of 0.010255. Since the p-value is less than the significance level of 0.05, we therefore reject the null hypothesis and conclude that there is a significant association between teacher demographics (experience, training, subject area) and the challenges they face when implementing innovative science teaching methods.

Hypothesis 3: There is no significant development of curiosity and critical thinking skills among students taught science using digital tools compared to those taught using traditional methods.

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	186.3333	3	62.11111	9.434599	0.000433	3.098391
Within Groups	131.6667	20	6.583333			
Total	318	23				

The table above shows the analysis of variance (ANOVA) of responses from the research instruments. The analysis gave a F statistic of 9.434 with a p-value of 0.000433. Since the p-value is less than the significance level of 0.05, we therefore reject the null hypothesis and conclude that there is a significant difference in the development of curiosity and critical thinking skills among students taught science using digital tools compared to those taught using traditional methods.

Discussion

The findings indicated that classrooms employing innovative strategies were more dynamic and interactive. Students were more engaged, participating actively in discussions, group work, and hands-on activities. This contrasted with the more passive learning environment observed in the control group, where traditional teaching methods were used. The study also noted differences in the effectiveness of innovative teaching methods across different demographic groups. For example, students from diverse backgrounds showed varying levels of responsiveness to technology-based learning, suggesting the need for tailored approaches to meet the needs of all students.

Conclusions

Innovative science teaching methods have proven to be highly effective in nurturing both curiosity and critical thinking among students. By moving beyond traditional lecture-based instruction, educators are able to create dynamic learning environments that encourage students to explore scientific concepts more deeply. Techniques such as inquiry-based learning, project-based activities, and the integration of technology allow students to engage actively with the subject matter, fostering a sense of curiosity and motivating them to ask critical questions.

Studies suggest that students exposed to these innovative approaches not only demonstrate improved academic performance but also show heightened interest in science, which is critical in preparing them for future scientific endeavors (Smith and Brown, 2019). Additionally, research indicates that critical thinking skills, developed through such pedagogies, are essential for students' success in both academic and professional settings (Jones, 2021). These methods help students to think independently, collaborate with peers, and solve complex problems, which are vital skills in

the 21st century.

Ultimately, the integration of innovation in science teaching is not just a pedagogical trend but a necessity for cultivating the next generation of scientifically literate and critically minded individuals. Educators, therefore, should be encouraged to continually adopt and refine these methods to meet the needs of diverse learners.

Recommendations

Based on the findings the following recommendations were made:

- Schools and educators should integrate inquiry-based learning, project-based learning, and other innovative teaching methods into the science curriculum innovative strategies into the curriculum.
- Ongoing professional development and training should be provided to teachers to equip them with the skills and knowledge necessary to implement innovative teaching strategies effectively.
- Schools should invest in technology and digital tools that facilitate interactive and engaging science education. The use of technology has been shown to enhance student engagement and understanding of complex scientific concepts.
- **T**eachers should adopt innovative teaching methods to accommodate the diverse learning needs and background of students.
- Educational institutions should create a culture that encourages experimentation and innovation in teaching. This includes supporting teachers in trying new approaches and providing the necessary resources.
- Students should be encouraged to take an active role in their learning by participating in hand-on-activities, inquiry-based projects and collaborative learning activities.
- The government should address the challenges the teachers face when implementing innovative teaching strategies by providing adequate resources, such as time, material and administrative support.

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