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The effect of hands-on activity and problem-based learning on achievement of biology students in Enugu state

Amaka Loretta Nwankwo, Ugwu Theresa Ukamaka, Geoffrey Ukala*, Ozichi Okwukwe Benson

University of Nigeria, Nsukka, Nigeria

*Corresponding author, email: geoffrey.ukala@unn.edu.ng

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Abstract: The research researched the impact of problem-based learning and hands-on activity on the students' academic performance in biology. The study implemented a quasi-experimental design, specifically a non-equivalent control group design with a pre-and post-test design. The study's population consisted of 2691 students from 32 public secondary schools in the Nsukka. We used a multi-stage sampling procedure to sample 85 SS II students from two intact classes. The researchers developed the "Biology Achievement Test (BAT)" as an instrument for data collection. We used the mean and standard deviation to answer the research question and used the ANCOVA to test the null hypotheses. The study's findings revealed that there is a significant difference in the mean achievement scores of secondary school students taught biology using the hand-on activity method and problem-based learning. According to the study, biology teachers should always use hands-on activities when teaching biology to students. Based on the findings, we recommend training biology teachers through workshops, orientation courses, and seminars on adopting hands-on activities in teaching to enhance students' academic achievement in biology. The study concluded that using hands-on activities in teaching biology is more effective in enhancing students' biology achievement.

Keywords: Biology achievement, hands-on, problem-based learning, STEM

Abstrak: Studi ini menguji pengaruh aktivitas hands-on dan pembelajaran berbasis masalah terhadap prestasi belajar biologi siswa. Penelitian ini menggunakan desain eksperimen semu, khususnya desain kelompok kontrol non-ekuivalen pre-test dan post-test. Populasi penelitian terdiri dari 2691 siswa dari 32 sekolah menengah negeri di daerah Nsukka. Kami menggunakan prosedur pengambilan sampel multi-tahap untuk mengambil sampel 85 siswa SS II dari dua kelas utuh. Peneliti mengembangkan "Tes Prestasi Biologi (BAT)" sebagai instrumen pengumpulan data. Kami menggunakan mean dan deviasi standar untuk menjawab pertanyaan penelitian dan menggunakan ANCOVA untuk menguji hipotesis nol. Temuan penelitian menunjukkan bahwa terdapat perbedaan yang signifikan dalam nilai rata-rata prestasi sekolah menengah siswa yang diajarkan biologi menggunakan metode aktivitas hands-on dan pembelajaran berbasis masalah. Menurut penelitian, guru biologi hendaknya selalu menggunakan aktivitas langsung saat mengajarkan biologi kepada siswa. Berdasarkan temuan ini, kami merekomendasikan pelatihan guru biologi melalui lokakarya, kursus orientasi, dan seminar tentang penerapan aktivitas hands-on dalam pengajaran untuk meningkatkan prestasi akademik siswa di bidang biologi. Penelitian ini menyimpulkan bahwa penggunaan kegiatan hands-on dalam pembelajaran biologi lebih efektif dalam meningkatkan prestasi belajar biologi siswa.

Kata kunci: Prestasi biologi, aktivitas hands-on, pembelajaran berbasis masalah, STEM

INTRODUCTION

STEM, which stands for science, technology, engineering, and mathematics, intertwines four subject areas to form a modern form known as science education. Science education plays a crucial role in national development by equipping future scientists and educators with the necessary knowledge and skills to effectively communicate science's principles, pedagogy, and applications to learners (Nasir et al., 2023; Ukala & Ugwu, 2019). Ukala (2018) and FutureLearn (2021) report that Nigerian secondary schools teach science as a basic science in junior secondary and separate it into biology, chemistry, and physics in senior secondary. Apparently, concerns about advancing STEM education have become a global issue in recent years. Apart from educators, other stakeholders, such as policymakers, non-government organizations, businesses, industries and organizations, are emphasizing the necessity of improving STEM skills to satisfy this century's present and future social, economic, and technological needs (Sutaphan & Yuenyong, 2019).

STEM educators face the challenge of enhancing their creativity in the classroom and implementing innovative instructional strategies to maximize their students' potential (Maharani et al., 2024). In STEM teaching, especially biology, teachers do not only strive to impart knowledge and correct pupils when they make errors; instead, they provide cognitive tasks and versatile ways of engaging students during teaching and learning for present and future development (Inyama, 2017). This can be achieved through the use of innovative teaching methods (Benson, 2023; Ugwu, 2023).

STEM-related disciplines are taught and learned through a variety of innovative instructional methods. These methods allow teachers to explore various techniques to arouse the learners' interest and consequently enhance their academic achievement. For instance, studies have shown that students respond much better to practical activities than written exercises, which makes learning more meaningful (Gonibala et al., 2024). Altmeyer et al. (2020), Belser et al. (2017), and Hansen and Gonzalez (2014) also observed that these methods make the acquisition of knowledge, retention, and achievement easy, as well as facilitate the transfer of learning. In another study, Zhu (2020) revealed that some teaching approaches found to be effective in STEM teaching and learning include, but are not limited to, those that encourage active learning, personalized instruction, engaging learning, and building learning communities. Therefore, STEM education, especially biology education, should focus on the processes that allow students to participate actively in teaching and learning.

Biology is a science branch that studies life and living organisms (Akhmadkulovna, 2024; Nasir et al., 2020). The field of biology encompasses the study of both living and non-living organisms in the ecosystem. According to Ugwu (2023), and Benson (2023), Biology is part of natural science that is concerned with the living universe. The authors defined biology as the structure, function, development, and existence of biological organisms and their relationship to the environment in which they exist. Ukala (2018) defined biology as a

natural science that looks into the structure, function, growth, evolution, origin, identification, distribution, interrelationship, and taxonomy of living organisms. The study of biology is an excellent foundation for a variety of professions, including engineering and fundamental science (Peter, 2015). The objectives of biology education, as outlined in the biology curriculum, were derived from the National Policy on Education (Federal Ministry of Education, FME 2014).

The primary objectives of biology education are to cultivate the ability to apply scientific knowledge to everyday life in the context of personal and community agriculture and health, to acquire meaningful and relevant knowledge in biology, and to cultivate a reasonable and functional scientific mentality. Furthermore, it is anticipated that the students will acquire sufficient laboratory and field abilities in biology. Therefore, the more students strive to meet these biological objectives, the greater the potential for enhancing their biological achievement. The teacher's delivery of biology concepts greatly influences the students' understanding of the subject. Therefore, when teachers effectively teach biology using an innovative instructional approach, students will likely develop critical thinking, cognitive awareness, independent learning, digital literacy, collaboration, creativity, problem-solving, and self-reflection. According to Sutaphan and Yuenyong (2019), and Nunaki et al., (2019) instructional approaches that permit student active participation are problem-based learning strategies, project-based learning, inquiry-based learning, engineering design-based studies, and hands-on activity.

Hands-on activity is one of the most crucial teaching methods for teaching and learning science. This is due to the fact that scientists acquire knowledge by objectively observing phenomena. Therefore, Chukelu (2019) defined hands-on activities as a variety of activities, including the manipulation of apparatus, the classification of objects, the design of experiments, the formulation of hypotheses to draw conclusions, and the verification of results. It refers to any learning environment that actively entails students manipulating objects to acquire information or comprehend it (Haury & Rillero, 2014). Hands-on activity is an teaching approach that involves students' direct encounter with natural phenomena, as defined by these definitions. Engaging students in hands-on activities can stimulate their interest and curiosity while promoting long-term memory, a benefit that mere memorization cannot achieve (Kibga et al., 2021; Logar & Ferk-Savec). Hands-on activities have been demonstrated to improve student's performance compared to text-based and traditional learning (Bredderman, 1985 & Freedman, 1997), improve their comprehension, and overcome the misconceptions experienced with scientific concepts (Coştu et al., 2007; Ünal, 2008; Glasson, 1989), assist students in forming positive attitudes towards science (Adeyemi & Akhigbe, 2020), promote student independence, encourage their creativity in problem-solving, improve reading skills, communication, and arithmetic computation (Haury & Rillero, 2014; Staver & Small, 1990).

Problem-based teaching is another important STEM teaching method. Problem-based learning (PBL) focuses on students actively engaging in solving complex problems in a group setting instead of passively receiving information from a teacher. This type of instruction fosters the Enhancement of critical thinking and problem-solving abilities in students by encouraging them to assume responsibility for their learning (Damopolii & Kurniadi, 2019; Dischino et al., 2011). The PBL encourages students to learn skills and apply their knowledge by discovering and solving problems within a set of content (Damopolii et al., 2024; Iwan et al., 2020). In other words, the method presents students with a problem and allows them to examine and explore it, strategize and evaluate it, propose a solution, and present their findings (Zannah et al., 2022). The students dedicate an extended period to investigating and creating a solution to a problem or query. Among all the learning outcomes associated with teaching and learning science through problem-based learning is the learner's ability to develop self-awareness, self-direction, and critical and analytical skills (Nilson, 2010). The author added that learners' ability to achieve the abovementioned skills will facilitate their problem-solving ability across disciplines. The teacher's function is that of a facilitator, empowering students to assume complete responsibility for their initiatives from the outset. The study focuses on project-based learning and hands-on activity as alternative instruction delivery approaches for biology learning to enhance students' achievement in biology.

In any academic activity, students and schools look for achievement in any subject. According to Ugwu (2023), academic achievement is defined as a student's scholastic standing at a given condition, which expresses an individual's cognitive abilities, skills, and performance. Grades from examinations or continuous assessments can measure this achievement. It also involves determining the extent to which individuals have achieved specific learning tasks, courses, or programmes to which they have had sufficient exposure (Zheng & Mustapha, 2022). Therefore, students' performance in biology examinations determines their achievement in the subject. High school students' Academic accomplishments in teaching and learning biology concepts is very low (Njoku & Nwagbo, 2020).

It is noteworthy that the report of the West African Examination Council on the Senior Secondary School Certificate Examination on students' enrolment and performance in Nigeria by subject and grade revealed low academic achievement of students in biology at the senior school certificate examination (Benson, 2023; WAEC, 2013–2018). Research efforts to address the issue of inconsistent achievement in biology (Uwguadu, 2011; Amedu, 2014) have yielded little improvement (Bichi et al., 2019). Some major factors, including the mode of instructional delivery, poor use of activity-based instructional approaches such as hands-on activities, and problem-based learning approaches, may contribute to the poor achievement of students. Despite numerous efforts by educationists, biology achievement of

students in the Secondary Schools Certificate Examination (SSCE) in Nigeria has not improved over the years (Bichi et al., 2017; Bichi, et al., 2019).

Research question

The study was guided by a single research question. What are the mean score of achievement for students taught biology using hands-on activities and those taught using the problem-based learning?

Hypothesis

We formulated a null hypothesis to guide the study. H_0: There is no significant difference in the mean achievement scores of secondary school students taught biology using hand-on activity and problem-based learning methods.

METHOD

The study's design was quasi-experimental, specifically a pretest-posttest non-equivalent group design. Nworgu (2015) defined quasi-experimental design as a research design that reveals the cause and effect relationship between one or more independent and dependent variables. The investigation was implemented by the Nsukka Local Government Area. The population of the research was 2691 biology students in senior secondary school two (SS II) from all 32 public secondary schools in Nsukka LGA. 85 SS II Biology students were recruited from two public secondary schools in Nsukka LGA using a multi-stage sampling procedure for the study's sample. The Biology Achievement Test (BAT) was chosen as the instrument for data collection. The BAT consists of two sections: A and B. Students' demographic data fills Section A, while 20 objective questions from the secondary school biology curriculum, specifically the digestive system, make up Section B.

The instruments were validated in person and content-wise by three experts, two from the biology unit and one from the measurement and evaluation program. The instrument underwent a reliability test using the K-R 20 and was subjected to a trial by the researcher, resulting in an internal consistency reliability of 0.88. The researcher provided training to biology instructors who instructed SS II students in the two institutions prior to the commencement of the investigation. The training was designed to assist the instructors in both the experimental and control groups in understanding the teaching methodologies employed in each group. The designated instructors from the experimental groups were instructed on the lesson plan of the hands-on teaching method and the administration of the pre-test and post-test during the training period. The selected teachers for the control groups received training on administering the treatment (problem-based learning) using the method's developed lesson plan. We addressed the research questions by utilizing the mean and standard deviation, and we evaluated the null hypotheses using ANCOVA at the 0.05 significance level.

RESULTS AND DISCUSSION

Table 1. The mean and SD achievement scores for students

Group	N	Pre-test		Post-test		Mean gain
		$\bar{x}$	SD	$\bar{x}$	SD	
Hand-on-activity method	38	8.11	3.39	16.47	2.50	8.38
Problem-based-learning	47	9.47	3.74	11.51	5.49	2.04

Table 1 shows that the hand-on-activity group had a pre-test mean score of 8.11 with a SD of 3.39 and a post-test mean score of 16.47 with a SD of 2.50. On the other hand, the pretest mean achievement score of students taught using problem-based learning was 9.47 with a SD of 3.74, while the post-test mean achievement score was 11.51 with a SD of 5.49. The group using hand-on activities recorded a mean gain of 8.38, while the group using problem-solving methods recorded a mean gain score of 2.04. The results indicate that the students taught with the hand-on activity method achieved higher grades in biology than those taught with problem-based learning

Table 2. ANCOVA of mean achievement scores of students

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	538.007a	2	269.00	13.81	0.00	0.25
Intercept	1941.14	1	1941.14	99.69	0.00	0.55
Pre-Achievement	20.45	1	20.45	1.05	0.31	0.01
Instructional-Approach	537.98	1	537.98	27.63	0.01	0.25
Error	1596.77	82	19.47			
Total	18157.00	85				
Corrected Total	2134.78	84				

a. R Squared = .252 (Adjusted R Squared = 0.234)

Table 2 demonstrate that instructional approach as a main factor has a effect on students' achievement in biology ($F(1,82) = 27.63$, $P = 0.01 < 0.05$, $\eta 2 = 0.25$). We reject the null hypothesis one (H_0) because the associated sig. value of $0.01 < 0.05$. Furthermore, the moderating effect size ($\eta 2 = 0.25$) indicates that 25 percent of the variance in students' biology achievement is attributed to the instructional approach. Therefore, we infer that students who engage in hands-on activities and problem-based learning significantly differ in their biology achievement.

Research findings indicate a significant difference in average achievement scores between secondary school students taught biology using hands-on activities and PBL. Our findings indicate that the hands-on activity method is more effective in improving students' biology learning achievement than PBL. These findings are in line with Ateş and Eryilmaz (2011), who found that hands-on activities can improve middle school students' academic achievement in science subjects. Other findings by Hussain and Akhtar (2013) also revealed

the same results that the average science achievement of hands-on group students was better than non-hands-on activity.

Schwichow et al. (2016) that using hands-on activities can improve students' procedural abilities, but not conceptual understanding. However, in our research, we found that hands-on activities allow students to improve their learning knowledge. This is proven by their better performance. According to Sadi and Çakiroğlu (2011), hands-on instruction in science lessons enhances learning success by involving students in hands-on activities and guiding them. The PBL used in this research has not achieved better results than hand-on activity. PBL has an effect on increasing student achievement, but hands-on activities show more high achievement scores.

CONCLUSION

The study concluded that using hands-on activities in biology teaching is more effective in enhancing students' achievement in the subject. The study's findings led to the following recommendations:

1. Biology teachers should always incorporate hands-on activities into their instruction.
2. Students should learn biology, and biology teachers should receive training through workshops, orientation courses, and seminars on how to incorporate hands-on activities in their teaching to enhance students' academic performance and interest in biology.

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