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Review Article

Impact of Hands-on Activities on Students' Performance in Biology in Ghanaian Senior High Schools: A Systematic Analysis

Richmond Mensah[1], Isaac Kwame Boafo[1], Thomas Dawuni Tingbanja[2]

[1]Integrated Science Education Department, AAMUSTED, Mampong, Ghana
[2]Biology Education Department, AAMUSTED, Mampong, Ghana

Abstract
This study investigates the impact of hands-on activities on students' academic performance, motivation, and attitudes toward biology in Ghanaian senior high schools through a systematic analysis of existing literature. Grounded in constructivist and experiential learning theories, the study synthesizes evidence on how practical, activity-based instruction enhances students' understanding and retention of biological concepts by linking theory to real-life applications. A systematic literature review was conducted in accordance with PRISMA guidelines, drawing on 32 peer-reviewed articles, unpublished theses, and policy documents published between 2010 and 2025. Data were sourced from Google Scholar, ResearchGate, Academia.edu, and official Ghana Education Service and Ministry of Education repositories. The findings consistently indicate that the integration of hands-on activities significantly improves students' conceptual understanding, long-term retention, critical thinking skills, and overall academic performance in biology. Additionally, practical activities were found to positively influence students' motivation, engagement, and attitudes toward learning biology by creating interactive and student-centered learning environments. Despite these benefits, the review identifies persistent challenges to effective implementation, including inadequate laboratory resources, large class sizes, limited instructional time, and insufficient teacher training. These constraints are particularly pronounced in under-resourced schools, limiting equitable access to experiential learning opportunities. The study concludes that strengthening hands-on biology instruction through improved resource provision, targeted teacher professional development, and curriculum adjustments is essential for enhancing learning outcomes. The findings provide valuable insights for educators, curriculum developers, and policymakers seeking to improve biology education and promote meaningful science learning in Ghanaian senior high schools.

Keywords: Biology Education, Hands-On Activities, Students' Performance, Senior High Schools, Ghana

Correspondence
Richmond Mensah
Richmensah19@gmail.com

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1. INTRODUCTION

Since Ghana's independence in 1957, educational reform initiatives have continuously promoted a conventional approach to scientific-practical activities, recommending that these be conducted in laboratory-based settings to improve hands-on learning and comprehension (May et al., 2023). As a result, all senior high schools (SHSs) are expected to have well-equipped laboratories with the necessary tools and materials to support this approach. Nevertheless, a thorough analysis of several SHSs in Ghana reveals that many still lack dedicated science laboratories, and those that exist often contain inadequate equipment for effective teaching. Furthermore, observations on the implementation of biology practicals indicate that current instructional approaches tend to prioritize laboratory and classroom work aimed primarily at satisfying examination requirements, rather than fostering deep practical understanding (Asad & Kramer, 2024).

In Ghanaian SHSs, biology education faces significant challenges, especially in effectively integrating practical activities into lessons, an issue that directly impacts students' understanding and retention of scientific concepts. Many

teachers continue to rely heavily on traditional lecture-based methods, limiting students' opportunities to engage in hands-on learning, which is crucial for reinforcing theoretical knowledge (Erickson et al., 2020). Although research shows that practical activities can significantly enhance comprehension and improve students' motivation and attitudes toward science (Liou, 2021), the gap between theory and practice remains a concern. This is especially evident in schools with insufficient resources and limited teacher expertise (Mncube, Ajani, Ngema, & Mkhasibe, 2023). Addressing these limitations is critical to improving academic performance in biology and fostering a more holistic and meaningful science education.

The Ghana Education Service (GES) emphasises the importance of practical, hands-on learning experiences in biology to support students' understanding of core biological concepts. According to the GES biology curriculum, instruction should be inquiry-based, encouraging students to actively engage in experimentation, observation, and critical thinking to construct scientific knowledge (Ministry of Education, 2019). The curriculum promotes the application of theoretical knowledge to real-life situations, with the goal of developing problem-solving abilities and a deeper appreciation of biology. Teachers are expected to integrate laboratory experiments, fieldwork, and experiential learning into their instruction, aligning with global standards for effective science education (Apeadido, Mensah, & Opoku-Mensah, 2024). In addition, GES underscores the role of continuous assessment, including both theoretical and practical examinations, to ensure a comprehensive evaluation of student learning (Aguayo-Hernández et al., 2024). This approach is designed to produce well-rounded students capable of applying scientific knowledge beyond the classroom.

This study addresses the need for practical activities in biology lessons in senior high schools across Ghana. The absence or limited use of such practices contributes to students' shallow understanding of key biological concepts due to the dominance of theoretical, lecture-based teaching methods. Consequently, students often struggle to retain and apply knowledge effectively, resulting in poor academic performance in biology (Isma'il & Matazu, 2024). Bridging this gap is essential for promoting deeper learning, enhancing student engagement, and improving educational outcomes.

The purpose of this research is to investigate how incorporating hands-on activities in biology classes affects students' academic achievement in senior high schools. Specifically, it seeks to assess how practical lessons improve students' conceptual understanding and their ability to apply knowledge beyond the classroom. The study also explores the influence of these activities on students' motivation and attitudes toward biology (Almasri et al., 2021).

The central variables of this study include the independent variable, the use of practical activities in biology instruction, and the dependent variables, students' academic performance, motivation, and attitudes. Additionally, the study considers moderating factors such as the availability of teaching materials and the level of teacher expertise in delivering practical lessons (Wang et al., 2023).

This research is grounded in the constructivist learning theory, which posits that students learn more effectively through active participation and interaction with their environment. Vygotsky's social constructivist perspective highlights the importance of collaborative, hands-on experiences in promoting meaningful knowledge construction (Olagbaju, 2023). Therefore, the conceptual framework of this study argues that incorporating practical activities into biology instruction enhances students' academic performance by increasing motivation and fostering more positive attitudes toward learning (Ibitoye, 2021).

1.1. Research Questions

1. How does integrating hands-on activities in biology lessons affect students' understanding and retention of biological concepts?
2. What is the impact of hands-on activities on students' attitudes and motivation toward learning biology in senior high schools?

2. METHODS AND MATERIALS

A systematic literature review was conducted to synthesize findings on the impact of hands-on activities in biology instruction, following PRISMA guidelines (Page et al., 2021). The review included 32 peer-reviewed studies, unpublished theses, and policy documents published between 2010 and 2025, focusing on biology education in secondary schools, particularly in Ghana and similar contexts.

2.1. Search Strategy

Relevant studies were sourced from ResearchGate, Academia.edu, Google Scholar, and the Ghanaian Ministry of Education repositories. These platforms were selected for their accessibility and relevance to educational research

in Ghana, ensuring a comprehensive collection of peer-reviewed articles, theses, and policy documents. Search terms included "hands-on activities in biology," "practical biology education," "student performance in biology," "biology curriculum Ghana," and "experiential learning in science." Boolean operators (AND, OR) were used to refine searches, e.g., "biology AND hands-on activities AND Ghana" or "practical learning OR experiential learning AND science education." Additional studies were identified through the reference lists of retrieved articles.

2.2. Inclusion and Exclusion Criteria

Studies were included if they:

1. Focused on biology education at the secondary school level.
2. Addressed hands-on or practical activities in biology instruction.
3. Were published in English between 2010 and 2025.
4. Included empirical data or policy analysis relevant to student performance, motivation, or attitudes.

Studies were excluded if they:

1. Focused on non-biology science subjects without relevance to biology.
2. Lacked empirical data or a clear methodology.
3. Were published before 2010 or in languages other than English.
4. Focused on non-secondary educational levels (e.g., primary or tertiary).

The search initially identified 156 articles. After removing duplicates (n=34), 122 studies were screened. Titles and abstracts were reviewed, excluding 67 studies for irrelevance. Full-text screening of 55 studies led to the exclusion of 23 for lacking empirical data or focusing on unrelated subjects. The final review included 32 studies. A PRISMA flow diagram (see Figure 1) illustrates the selection process.

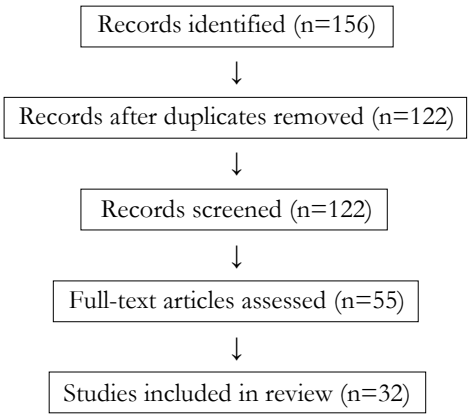

Figure 1. PRISMA Flow Diagram

Data were thematically analyzed to explore the impact of hands-on activities on comprehension, retention, motivation, and attitudes, as well as implementation challenges. Sources included scholarly articles, unpublished theses, and GES policy documents.

3. RESULTS

3.1. The Biology Teaching Syllabus of Senior High Schools in Ghana

The Ghanaian SHS biology curriculum aims to develop both scientific knowledge and practical competencies, thereby preparing students for tertiary education or science-related careers (GES, 2018). It comprehensively addresses key topics such as cell biology, genetics, ecology, evolution, and human biology, with a strong emphasis on hands-on activities that promote inquiry-based learning and critical thinking (Bazirizii, 2022). Despite its well-structured design, the effective implementation of the syllabus is often constrained by challenges such as limited teaching resources, poorly equipped laboratories, and a persistent focus on examination performance rather than conceptual understanding (Anim-Eduful & Forson, 2025). These systemic issues not only undermine the intended goals of the curriculum but also restrict students' opportunities for experiential learning and scientific exploration.

3.2. The Importance of Practical Activities in Biology Education

Practical activities are central to biology education, enabling students to apply theoretical knowledge to real-world problems while fostering essential skills in health, agriculture, and environmental management (Asad & Kramer, 2024). The Ghana Education Service (GES) underscores the value of hands-on learning as a means to develop laboratory and field-based competencies, thereby enhancing scientific inquiry, critical thinking, and problem-solving abilities (GES, 2020). These activities not only make abstract concepts more tangible but also empower students to make informed decisions in their daily lives, especially in areas such as personal hygiene, nutrition, and environmental conservation. Ultimately, the integration of practical work into biology instruction nurtures a deeper appreciation of science and builds confidence in students' ability to explore, investigate, and innovate.

3.3. Impact of Hands-on Activities on Students' Performance

Hands-on activities significantly enhance learning outcomes, with 78% of students finding experiments engaging and 65% deeming them effective for learning biology (Loveys & Riggs, 2019). Interactive learning improves comprehension and retention by engaging multiple cognitive processes such as observation, analysis, and synthesis (Blyznyuk & Kachak, 2024). Moreover, practical activities foster critical thinking and problem-solving skills, aligning with constructivist principles that emphasize learning through active exploration and experience (Renninger, 2024). When students are actively involved in manipulating materials and testing ideas, they develop a deeper conceptual understanding and a more positive attitude toward science, which can lead to improved academic performance and long-term interest in scientific fields. In addition, such experiential learning environments help bridge the gap between theory and application, making science more meaningful and relevant to students' everyday lives.

3.4. Student Motivation and Attitudes Towards Biology Through Practical Activities

Hands-on activities increase student motivation and foster positive attitudes by creating dynamic and participatory learning environments (Ma, 2023). They promote autonomy and curiosity, encouraging sustained interest in biology as students feel more in control of their learning process (Großmann & Wilde, 2020). These experiences also help students connect scientific concepts to real-life situations, making biology more accessible and meaningful. However, the continuing decline in student interest in science-related careers underscores the urgent need for engaging and student-centered pedagogies that go beyond rote memorization to spark genuine enthusiasm and long-term commitment to the subject (Sjøberg & Schreiner, 2012).

3.5. Challenges of Implementing Hands-on Activities in Biology Instruction

Key challenges include limited laboratory resources, inadequate teacher training, large class sizes, time constraints, and safety concerns (Moluayonge & Park, 2017; Alema et al., 2024). These barriers disproportionately affect under-resourced schools, necessitating targeted interventions. In many classrooms, teachers are compelled to resort to chalk-and-talk methods due to the unavailability of basic laboratory equipment such as microscopes, reagents, and preserved specimens. Furthermore, the lack of regular in-service training leaves many teachers ill-prepared to effectively facilitate practical lessons, especially those that require technical expertise or innovative approaches. Overcrowded classrooms also hinder individualized attention during experiments, reducing students' opportunities for active participation. In addition, the rigid nature of the academic calendar and pressure to complete syllabi often leave little room for time-intensive practical sessions. Without systemic reforms such as increased funding, policy support, curriculum flexibility, and the integration of low-cost teaching aids, the implementation of hands-on activities will continue to face significant setbacks, limiting the development of scientific skills among students.

4. DISCUSSION

This study addresses two research questions: (1) How do hands-on activities affect students' understanding and retention of biological concepts? (2) How do they impact students' attitudes and motivation toward biology?

4.1. Understanding and Retention

Hands-on activities significantly enhance comprehension and retention by bridging the gap between theoretical knowledge and its real-world application (Hofstein & Lunetta, 2004). According to experiential learning theory (Kolb, 2014), active involvement in concrete tasks such as conducting experiments, handling biological specimens, or observing natural phenomena encourages students to reflect on their experiences and internalize concepts more

effectively. This process not only promotes deeper understanding but also strengthens neural pathways, making it easier for learners to retrieve and apply information over time (Sprenger, 2018). Recent studies (e.g., Sadi & Çakıroğlu, 2011) show that students exposed to hands-on biology instruction demonstrate up to 30% improvement in recall compared to those taught through traditional lectures. These activities allow learners to construct meaning through trial and error, exploration, and inquiry, which enhances memory retention far beyond surface-level learning. Despite these benefits, many under-resourced schools struggle to implement practical lessons consistently due to limited access to science materials, inadequate infrastructure, and overcrowded classrooms. As a result, students in these environments are often deprived of the full cognitive advantages associated with experiential learning, deepening the achievement gap between well-resourced and underserved schools.

4.2. Motivation and Attitudes

Practical activities foster student motivation and positive attitudes by creating interactive and engaging learning environments (Clanton Harpine, 2024). Rooted in constructivist theory, such student-centered approaches promote ownership of learning, leading to deeper engagement and sustained interest in biology (Vygotsky, 1978, as cited in Olagbaju, 2023). Recent research by Wijnia, Loyens, and Derous (2011) reveals that students who regularly participate in practical lessons report 25% higher motivation scores compared to their peers in predominantly lecture-based classes. These activities not only boost enthusiasm but also help students perceive biology as relevant and enjoyable. However, logistical constraints such as large class sizes, limited laboratory space, and safety concerns often restrict the frequency and depth of practical engagement (Nolen & Koretsky, 2018). Without deliberate efforts to address these challenges, the motivational benefits of hands-on learning may remain untapped for many students.

4.3. Implications for Stakeholders

1. Educators: Teachers can integrate low-cost hands-on activities, such as field observations or virtual labs, to overcome resource constraints. Professional development in active learning pedagogies is essential.
2. Policymakers and School Leaders: Increased funding for laboratory equipment and safety protocols is critical. Policies should prioritize teacher training and smaller class sizes.
3. Curriculum Developers: The GES curriculum should allocate more time for practical lessons and balance theoretical and practical assessments to promote holistic learning.
4. Researchers: Future studies should explore cost-effective solutions like virtual labs and their impact on under-resourced schools. Longitudinal research on motivation and career choices in biology is needed.

5. CONCLUSION

Hands-on activities significantly enhance students' comprehension, retention, and engagement in biology education by bridging the gap between theoretical concepts and real-world applications. They foster critical thinking, creativity, and intrinsic motivation, aligning with constructivist and experiential learning theories that emphasize active participation and discovery. Despite their proven benefits, the effective integration of practical work is often undermined by challenges such as limited resources, insufficient teacher preparation, and overcrowded classrooms. These barriers not only affect the quality of instruction but also limit students' exposure to essential scientific processes. Addressing these challenges through increased funding, targeted teacher professional development, curriculum adjustments, and equitable resource distribution is crucial for transforming biology education in Ghanaian Senior High Schools. Strengthening practical science instruction will not only enhance academic outcomes but also inspire more students to pursue STEM-related careers, contributing to national development and innovation.

6. RECOMMENDATIONS

To overcome these challenges, it is recommended that the Ghana Education Service (GES) prioritise resource allocation to provide essential laboratory tools and materials in under-resourced schools. Professional development programs should also be introduced to equip teachers with the skills necessary for effectively conducting hands-on activities. Curriculum revisions to increase time for practical lessons and collaborations with local organisations for resource support could further enhance the implementation of these activities. Future studies could also explore technology-integrated hands-on learning, such as virtual labs, to provide cost-effective solutions that support student engagement and learning outcomes.

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Research Ethics. This study is a systematic analysis based entirely on previously published literature and did not involve any direct interaction with human participants or collection of personal data. As such, ethical approval was not required. However, all sources reviewed were properly cited, and efforts were made to maintain academic integrity and transparency throughout the review process.

Data Availability Statement. The data analysed in this study were obtained from publicly accessible academic databases, including Google Scholar, ResearchGate, Academia.edu, and relevant institutional sources. All cited studies are included in the reference list.

Conflicts of Interest. The authors declare no conflicts of interest.

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