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Enhancing Science Process Skills and Academic Performance in Biology: The Impact of Practical Work

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ABSTRACT

Purpose of the study: This study aims to determine whether the use of practical work can enhance General Science students' science process skills acquisition and academic performance students in biology at Juaben Senior High School in Ghana. The study sought to answer two research questions and test one hypothesis at a 0.05 significance level.

Methodology: The study used action research, and the sample consisted of 45 students, selected through convenience sampling. The study used various instruments, including pre- and post-tests, weekly intervention exercises, and scoring rubrics, to collect data. The analysis of the gathered data employed descriptive statistics and a paired sample t-test to reveal and solidify the findings of the study.

Main Findings: According to the study's results, the use of practical work resulted in a steady increase in students' acquisition of science process skills in each cycle, and all students were able to demonstrate some degree of required science process skills at the post-test level in contrast to the pre-test level. Furthermore, the pre- and post-test outcomes of a paired sample t-test analysis with a 95% confidence level showed a significant improvement in the academic performance of the students, attributed to practical work.

Novelty/Originality of this study: This research update confirms the need for practical work in biology education and shows that incorporating it into biology lessons enhances students' acquisition and development of science process skills, which in turn enhances their academic performance.

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1. INTRODUCTION

Nowadays, the forerunner of teaching and learning science concepts is practice-based education. Studies have shown that this mode of instructional delivery equips students with practical skills through learning by doing, which promotes their knowledge, skill acquisition and performance [1], [2]. As such, Ministry of Education included practical work to Ghana's senior high school biology curriculum. In light of this, the biology syllabus emphasised the necessity of using practical teaching techniques to enhance students' comprehension of what is being taught. Among the practical tasks that have been recognised to be essential to learning biology are doing experiments, gathering, analysing and interpreting data, and drawing diagrams [3].

Science process skills are cognitive and intellectual skills applied during the learning of science to help understand and solve scientific problems [4]. These skills, which are grouped into basic and integrated processes, include observation, experimental design, communication, inferring, and data interpretation [5]. Science process skills, such as critical thinking, data analysis, and problem-solving, are essential for students to effectively carry out practical work [6]. Inadequate development of these skills may hinder students' ability to design experiments, interpret results, and draw meaningful conclusions from their practical work experiences. As a result, students may struggle to fully grasp the practical applications of theoretical concepts [7], leading to the suboptimal academic performance in Biology practical assessments [8].

Biology is a natural science that deals with the study of living organisms [3]. The importance of biology is very necessary in education because it improves the quality of life and advances countries' technological abilities through scientific research, the development of new tools and techniques, and dealing with environmental issues. Biology is one of the key requirements in several fields, including health care, biotechnology, bio-informatics, and agriculture [3], [9]. Hence, any interference with the students' performance in biology must be dealt with so that the difficulties students exhibit in biology assessment can be resolved.

Yet, based on the observations of the researchers, biology students at Juaben Senior High School in the Ashanti Region of Ghana usually do not do well on the practical examinations. This is evident in WAEC Chief Examiners' reports that have consistently indicated unsatisfactory performance of SHS students in biology [10]–[12]. The reports revealed that more students fail in biology because they do not perform creditably in assessments that require practical applications, which usually test the ability of the students to demonstrate the science process skills needed for practical work. The preliminary observations by the researchers and WAEC reports suggest a significant gap between the ideal conditions required for effective practical work and the current practices in the school. The observed challenges point to deficiencies in the implementation of practical work sessions, where students may not be adequately guided through these crucial components of the curriculum [1], [6], [7]. The urgency of addressing this issue lies in the increasing number of students performing inadequately in biology. This not only hampers individual academic achievements but also reflects a systemic problem that requires immediate attention. To address this pressing issue, an innovative approach to teaching, such as the effective integration of practical work into biology instruction, is required.

Practical work, often referred to as hands-on, experiential learning, experimental work, or laboratory teaching [13]–[15], has long been recognised as a fundamental component of science education [13]. It represents a pedagogical approach where students actively engage in activities that allow them to explore, experiment, and experience scientific concepts firsthand [14]. Practical work allows students to see the practical implications of biological concepts and theories. This connection to real-world applications often motivates students to perform better academically [16]. When students design experiments, make observations, and analyse data, they are actively engaging in the scientific process. This process-oriented learning fosters analytical thinking, helping students approach academic challenges more systematically and effectively. Numerous studies have demonstrated the many benefits of practical experience, including the growth of laboratory skills and scientific knowledge as well as the comprehension of scientific ideas and theories [17].

The literature underscores a significant relationship between science process skills, academic performance, and the incorporation of practical work in educational settings. A study by Kibirige et al. [15] emphasises that fostering science process skills is crucial for a deeper understanding of scientific concepts and subsequently contributes to improved academic performance. Preliminary studies conducted by Nwuba et al. [4] and Kusuma & Rusmansyah [7] align with the researchers' observations at Juaben Senior High School, indicating a correlation between deficient science process skills and suboptimal academic outcomes in biology. Notably, Kusuma and Rusmansyah's study [7] highlighted that those students who lacked exposure to well-structured practical sessions demonstrated lower proficiency in applying science process skills during assessments. Furthermore, the works of Twahirwa et al. [1], Nwuba et al., [4] and Dagnew & Sitotaw [13] highlight the positive impact of practical work on the acquisition of science process skills and subsequent academic performance. The findings revealed a statistically significant improvement in both skill acquisition and academic scores when practical work was effectively integrated into the curriculum. In light of these findings, the preliminary studies at Juaben Senior High School echo the observed trends. The deficiency in science process skills aligns with poorer academic performance, suggesting a possible link between these variables.

Considering the above, it is necessary to explore the effects of practical work on students' performance, focusing on selected topics in Biology. However, sufficient study has not been done on the effectiveness of a practiced-based approach on learners in different academic environments [1]. Hence, further investigation is required to better understand the relationship between practical work and students' science process skills acquisition and academic performance in biology. Therefore, at Juaben Senior High School, the study set out to examine the effect of practical work on General Science students' acquisition of science process skills in Biology. Additionally, the study was conducted to determine how the students' academic performance in Biology was affected by the incorporation of practical work.

The study sought answers to the following research questions: What is the effect of practical work on students' acquisition of science process skills in Biology? What is the effect of practical work on students' academic performance in Biology? Furthermore, the study sought to test the null hypothesis: There is no significant difference in the academic performance of the students in Biology after implementing practical work. The researchers' goal in conducting this research was to provide beneficial information to science educators. It is envisaged that teachers would be able to use the findings to design appropriate, practice-based instructional strategies that effectively enhance students' performance in a range of biology-related practical tasks.

2. RESEARCH METHOD

The study employed an action research design, which describes the process of systematic inquiry that studies a school situation to understand and improve the quality of the educational process [18]. Three cycles, Cycle A, Cycle B, and Cycle C, each represented by a weekly intervention, were used to perform the research. Each cycle of research process, as stated by Clarke, involved planning, acting, observing, and reflecting to continuously improve the effectiveness of practical work in enhancing academic students' performance, and the acquisition of scientific process skills in Biology [19]. Hence, this design was appropriate to help determine how inculcating practical work in the teaching and learning of selected concepts would impact students' performance in the study of Biology. The research design made use of practical work in teaching Biology as an intervention, and the use of pre-test, weekly intervention exercises, and post- test.

The population of this study was all Form 2 General Science students offering Biology in the Juaben Senior High School within the Juaben municipality in the Ashanti Region of Ghana. The choice of this year's group was based on the fact that they had already attended the school for a little more than a year and thus been exposed to some basic scientific process skills. A convenience sampling technique was used to select the Form 2 General Science class, 2GS4, made up of 45 students, to serve as a sample. The convenience sampling technique enables researchers to select samples from those whom they have easy access to [20]. This sampling strategy was used since it was feasible.

The participants were aged between 14 and 18, with a diverse cultural background. The group consisted of 29 males and 16 females, reflecting varied perspectives. The previous instructional approach utilised lecture-based teaching methods for the participants, revealing a deficiency in employing student-centered instructional strategies and inadequate practical work sessions. Ethical considerations were integral, involving the acquisition of informed consent from all participants to ensure understanding and voluntary participation.

The main instruments used in this study to collect data were tests. The test was used to collect data on the performance of students in Biology at the three phases of this study (pre-intervention, intervention and post-intervention phases). It consisted of students' responses to given tasks in the pre-intervention test, weekly intervention exercises, and post-intervention test. The instruments were field-pilot tested at St. Sebastian Catholic Senior High School, which shares a lot of similarities with the study school and is located in the Juaben Municipality of the Ashanti Region, in order to determine reliability. A correlation, which was calculated using responses, resulted in an Alpha Cronbach value of 0.79 indicating a good reliability score. Before the fieldwork, the research tools were presented to the experienced colleagues for their approval and advice. This review assisted in removing skewed constructs and ambiguous items, ensuring the validity, precision, and proper format of the instruments' content.

Data was collected in three phases: pre-intervention, intervention, and post-intervention phases.

At the pre-intervention phase**,** a pre-test was administered to all participants before the implementation of practical work interventions. This was followed by the intervention phase, where practical work sessions were conducted in the three cycles (Cycles A, B, and C), focusing on the cells and cell divisions in Biology as the students were actively engaged in hands-on activities and experiments related to the topics. The students were assigned weekly exercises to practice and apply their knowledge gained from the practical work sessions. Subsequently, at the post-intervention phase, a post-test was administered after the completion of the practical work interventions to evaluate the students' improved performance in the selected Biology topics.

The analysis of the data involved summarising and interpreting the quantitative and qualitative data collected from the instruments. The pre-test and post-test scores were compared using descriptive statistics and paired samples t-test to determine if there was a significant difference in students' performance after the practical work interventions. The weekly exercise scores were analysed descriptively to examine students' progress, application of scientific process skills, and understanding of practical work.

The criteria as indicated in Table 1 for data interpretation were utilised to effectively determine the science process skills acquired by the students through pre-test, post-test, and weekly intervention exercises.

Table 1. Degree of science process skills acquired by the students

Degree of skill acquisition	Criteria for scoring
No skill	Blank space, unclear responses.
Partial skill	Responses that demonstrated acquisition of some of the skills
Complete skill	Responses that contain all parts of science process skills.

Table 1 represents the scoring rubric, adopted from Antwi et al. [2], used to record and analyse the students' levels of skill and competency development, accomplished by assessing students' demonstration of the required science process skills throughout the three phases.

3. RESULTS AND DISCUSSION

3.1 Effect of practical work on students' science process skills in Biology

Initial Proficiency Assessment (Pre-Intervention)

To assess students' initial level of science process skills, pre-intervention practical tasks were administered, yielding outcomes shown in Table 2.

Table 2. Analysis of Students' Responses to Pre-Intervention Test

Level of Skill Acquisition	Frequency	Percentage (%)
Correct skills	3	6.7
Partial skills	10	22.2
No skills	32	71.1
Total	45	100

Table 2 shows students' pre-intervention science process skills, revealing a significant deficit. Majority of the students (71.1%) exhibited no significant science process skills while only 6.7% demonstrated correct skills. This deficiency emphasised the crucial need for intervention to enhance their proficiency in science process skills.

Intervention Progression (Cycles A, B, and C)

During the intervention period, students were taken through tasks, and data were gathered on the students' performance in the weekly practical lessons (Cycles A, B, and C), as shown in Table 3.

Table 3. Analysis of Students Responses of Cycles

Level of Skill Acquisition	Frequency (Percentage)		
	Cycle A	Cycle B	Cycle C
Correct skills	28 (62.2%)	34 (75.6%)	37 (82.2%)
Partial skills	13 (28.9%)	9 (20.0%)	8 (17.8%)
No skills	4 (8.9%)	2 (4.4%)	0 (0.0%)
Total	45 (100%)	45 (100%)	45 (100%)

Table 3 details the students' performance during the intervention cycles. Notably, in Cycle A, 62.2% successfully set up experiments and utilised them, while in Cycle B, 75.6% set up the apparatus as needed and adeptly manipulated them. By Cycle C, 82.2% demonstrated comprehensive skills in tasks such as comparing animal and plant cells. This progressive improvement suggests the efficacy of the intervention method in cultivating essential science process skills.

Post-Intervention Mastery

At the post-intervention phase, a test assessed the impact of intervention on academic progress, and the results are presented in Table 4.

Table 4. Analysis of Students' Responses to Post-Intervention Test

Level of Skill Acquisition	Frequency	Percentage (%)
Correct skills	41	91.1
Partial skills	4	8.9
No skills	0	0.0
Total	45	100

As per Table 4, a notable shift occurred. Remarkably, 91.1% showed accurate skills, with none exhibiting no skills and 8.9% demonstrating partial skills. This marked improvement highlights the transformative impact of practical work on students' proficiency in microscopic examination of cells. Also, this comprehensive analysis illuminates the progression from initial challenges to substantial skill acquisition, emphasising the effectiveness of the practical work in enhancing students' skills in biology.

Skill Acquisition Progression and Development

Over the course of the intervention, the students' development of the necessary skills for practical work was tracked. Weekly records of the number of students who were seen to be improving their necessary skills during the intervention period were kept, and the results are presented in Table 5.

Table 5. Science Process Skills Acquired by the Students via the Practical Work

Required Process Skills	Process Skills Acquired by the Students		
	Cycle A (Lesson 1)	Cycle B (Lesson 2)	Cycle C (Lesson 3)
Setting up of apparatus	29	39	42
Procedure following	23	30	39
Observation	31	40	44
Measurement	21	33	45
Drawing and Labelling	19	37	43
Identification and Classification	30	41	45
Recording	28	32	45
Critical thinking	12	23	38
Comparison	18	31	39
Inference	14	23	37

Tracking the students' development of science process skills over the intervention period, as indicated in Table 5, reveals a steady increase in skill acquisition. By the third lesson (Cycle C), more than 82% of students had mastered the necessary skills for the practical work. This signifies a substantial enhancement in their ability to engage with practical biology tasks.

Interpretation of Findings

The findings revealed that the majority of the students' pre-test responses were inaccurate and lacked the necessary science process skills for practical work with a few chosen concepts related to cells (Table 2). The initial lack of proficiency, as evident in the pre-intervention data, highlights the necessity for targeted intervention. The students' science process skills did, however, significantly increase as they were exposed to laboratory practical work and remediation during the intervention (Table 3). At the conclusion of the intervention, the majority of students demonstrated the appropriate skills required for the practical task, indicating that they had mastered the process skills necessary to flourish in their learning of Biology (Table 4). Additionally, over the course of the intervention, the students' level of science process skill development significantly improved (Table 5). The consistent improvement across intervention cycles and the ultimate mastery demonstrated at the post-intervention affirm the effectiveness of practical work in elevating science process skills. The intervention not only corrected deficiencies but also fostered a profound understanding of key biology concepts related to cells.

These findings are in agreement with the results of the studies by Nwuba et al. [4] and Tsobaza & Njoku [21]. These studies found that the use of practical work significantly improved students' acquisition of science process skills, emphasising its positive impact on students in that regard.

3.2 Effect of practical work on students' academic performance in Biology

Each student's overall performance on the pre- and post-intervention tests was noted, and the outcomes are presented in Table 6 and Table 7.

Table 6. Descriptive Analysis of Pre- and Post-Intervention Test Scores

Test	Mean	Minimum	Maximum	Sum
Pre-intervention test	8.11	3	16	365
Post-intervention test	15.37	9	20	692

Table 6 reveals that the students' mean post-test score (15.37) surpasses the mean pre-test score (8.11). The results show that, on average, practical work incorporated into the teaching biology of concepts related to cells may have improved the test scores, indicating a potential enhancement in academic performance.

Hypothesis testing

A paired samples t-test was carried out to assess the significance of the difference between pre- and post-intervention test scores and substantial improvement in academic performance.

Table 7. Paired Samples t-Test of Pre- and Post-Intervention Test Scores

	Pre-intervention test	Post-intervention test
Mean	8.11	15.37
Variance	7.37	10.46
Observations	45	45
Df	44	
t Stat	-18.28	
P(T<=t) two-tail	3.53E-22	
t Critical two-tail	2.01	

As shown in Table 7, the calculated t-value (t Stat = 18.28) is higher than the critical t-value (2.01) at a confidence level of 95% ($\alpha = 0.05$). Also, the p-value (3.53E-22) is less than the significance level of 0.05, suggesting a substantial difference between the pre- and post-intervention scores. Hence, the null hypothesis is rejected, confirming a statistically significant improvement in academic performance due to practical work.

Interpretation of Findings

The study clearly shows that there is a significant difference in the academic performance of the students caused by the practical intervention lessons (Tables 6 and 7). The results provide robust evidence supporting the positive impact of practical work on academic performance in biology. The mean post-test score significantly surpassed the mean pre-test score, signifying the efficacy of practical work in enhancing student learning.

This finding agrees with the studies by Dagnew & Sitotaw and Kambaila & Kayamba that utilising practical activity significantly enhances students' academic performance in Biology [13], [22]. A similar finding was made by Shana and Abulibdeh, who showed through their study that there is a relationship between practical work and the academic attainment of students. This highlights the beneficial correlation between academic success and practical work [17].

The current study contributes to the growing body of evidence supporting the efficacy of hands-on, practical learning methods in biology. The outcomes carry significant educational implications for advancing science process skills and overall academic performance in biology through practical work. To leverage these findings, it is recommended to prioritised integration of practical work into biology teaching strategies. Tailored intervention strategies should address specific shortcomings, ensuring a comprehensive improvement of science process skills and academic performance, given the positive impact of well-designed practical activities among students [23]-[28]. Also, teachers should be equipped with the necessary training and resources to effectively incorporate practical work into their teaching methodologies. This will help ensure that practical work is executed in a manner that maximises its benefits [29]-[34]. Additionally, education authorities and institutions should consider revising assessment methods to reflect the importance of practical work, potentially giving more weight to practical examinations.

This study's credibility is reinforced by a number of strengths. The clear presentation of descriptive statistics of process skills acquired and pre- and post-intervention scores offers a transparent view of the students' performance progression and facilitates a straightforward interpretation of how practical work improves overall academic outcomes. Moreover, the use of a paired samples t-test offers a rigorous statistical assessment, enhancing the robustness of the conclusions drawn. Also, the study extends beyond a mere examination of academic performance by delving into the comprehensive development of science process skills, enhancing the richness of the findings, and offering a nuanced understanding of the multifaceted impacts of practical work on students. Additionally, the study's findings resonate with existing literature, reinforcing the consistent positive correlation between practical activities and enhanced academic achievement. The relevance of the study is further highlighted by its focus on practical-oriented topics, specifically Cells and Cells Division in Biology, ensuring that the strengths identified are directly applicable to areas where hands-on learning is particularly crucial.

However, the study was restricted to only Form-two General Science students offering Elective Biology at Juaben Senior High School within the Juaben municipality and some selected practical-oriented topics. Hence, generalisability of the findings may be limited. Future research could explore different practical work approaches in various school settings and assess the long-term effects of practical work on students' academic and career trajectories. Also, a study could be carried out on the development and effectiveness of teacher training programs to enhance their capacity to guide students through practical work. Exploring the transferability of science process skills gained in biology to other subjects or real-life situations could offer a broader perspective on the impact of practical work.

4. CONCLUSION

The findings of the study highlight the pivotal role of practical work in shaping students’ performance in Biology. These findings emphasise practical work as an invaluable tool for fostering skill development and nurturing academic achievement in the field of science education. As shown in this research, practical work plays an indispensable role in promoting academic excellence. This study provides invaluable insights for educators and curriculum developers, emphasising the significance of practical work in science education. It is a key component of education that enriches students’ scientific proficiency and improves their academic success.

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