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The Impact of Practical Experiential Learning on Shaping High School Students' Attitudes Towards Biology

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Abstract

The study explores the impact of experiential learning on students' attitudes in the biology classroom, addressing two primary research questions and corresponding hypotheses. Specifically, it examines how participation in practical biology work influences student attitudes and identifies the aspects of practical work with the greatest impact. The instruments underwent rigorous reliability and validity testing, achieving a Cronbach's alpha of 0.81 during field-pilot testing at a similar school. A convenience sample of 45 Form 2 General Science students from one class of Juaben Senior High School in Ghana was utilised, employing a one-group pre-test and post-test design. Data analysis used descriptive and inferential statistics, including paired samples t-tests, to evaluate attitude changes. Key findings reveal that participation in practical work significantly improves students' attitudes toward biology, with a notable increase in interest, understanding, and application of biological concepts. The aspects of practical work with the most significant impact include observation engagement and collaborative learning, both showing large effect sizes. These findings highlight the critical role of practical experiential learning in biology education, suggesting that integrating diverse and interactive practical activities into the curriculum can lead to improved student outcomes and a deeper appreciation for biology. The study recommends regular integration of practical activities in the curriculum, professional development for educators, fostering a supportive classroom environment, aligning with broader STEM initiatives, and advocating for policy changes prioritising experiential learning.

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INTRODUCTION

In contemporary educational practices, there is a growing recognition of the limitations associated with traditional, textbook-based learning on the impacts of students' learning attitudes, particularly in the sciences (Park & Choi, 2014; Kaya & Kaya, 2022; Daubenfeld, 2020). Biology, a subject rich with complex concepts and processes, often requires appropriate student-centered innovative approaches (Kalyani & Rajasekaran, 2018; Veselinovska et al., 2011). These approaches aim to bridge the gap between theoretical knowledge and real-world application, providing students with a more comprehensive learning experience (Jack, 2018; Badayi et al., 2022). As such, educators and researchers are currently exploring various strategies to enhance students' understanding and engagement in biology. These student-centered strategies foster a deeper interest in the subject, improve understanding of biological concepts, and cultivate positive attitudes towards scientific inquiry (Badayi et al., 2022; Okam & Zakari, 2017). Despite these potential benefits, these innovative approaches in many educational settings, including those in Ghana, are not yet fully integrated or are inconsistently implemented due to a lack of adoption of innovative teaching practices, insufficient skills and openness among teachers to utilise more engaging methods, and improper usage of practical skills (Apeadido & Amedeker, 2023; Kamba et al., 2018). Moreover, other external factors, such as limited resources, insufficient teacher training, and overcrowded classrooms, were also reported in the literature as barriers to effectively implementing these methods (Fufa et al., 2023; Tordzro et al., 2021). Consequently, students may not receive the full benefits that these engaging and interactive learning experiences can offer, hindering their exhibition of favourable attitudes towards the subject (Dagnew & Sitotaw, 2019; Sitotaw, 2019).

Attitudes are positive, negative, or neutral evaluations of objects, persons, or events (Albarracín et al., 2014). In the context of this study, students' attitudes refer to their positive or negative feelings and inclinations to learn biology. Students' attitudes toward a subject like biology significantly influence their engagement, motivation (Kamba et al., 2018), and overall success (Dagnew & Sitotaw, 2019; Owino et al., 2015). In the classroom, students' attitudes are exhibited in various ways. Enthusiastic students often show curiosity, asking questions and seeking additional resources to deepen their understanding. They may actively participate in experiments, collaborate effectively with peers, and demonstrate persistence in solving complex problems (Tenzin et al., 2019; Apeadido & Amedeker, 2023). On the other hand, students with negative attitudes toward a science subject may appear disengaged, exhibit disruptive behaviours, or show reluctance to participate in class activities (Khazanchi, & Khazanchi, 2019; Tenzin et al., 2019). These attitudes are critical to addressing because they impact individual student outcomes and the overall classroom environment and effectiveness of teaching strategies (Dagnew & Sitotaw, 2019; Oliveira & Bonito, 2023), thereby contributing to curiosity, scientific literacy, and identity among the students (Meuthia, 2018).

However, through direct observation and interactions with students at Juaben Senior High School in the Ashanti Region of Ghana, the researchers have noted a prevalent issue of many students exhibiting negative attitudes toward biology, which may be attributed to the insufficient integration of student-centered approaches. These attitudes manifest as a lack of interest, minimal participation in class activities, and a general reluctance to engage with the subject matter. This problem is not unique to this location; similar trends have been observed across the country and globally, as documented in educational research, highlighting a link between negative attitudes and poor implementation of effective instructional strategies (Apeadido & Amedeker, 2023; Tordzro et al., 2021; Mazana et al., 2019). Studies have shown that students' negative attitudes towards subjects, including biology, are a widespread concern. Academically, these attitudes contribute to lower performance in biology, as disinterested students are less likely to engage with the material, complete assignments, or perform well on assessments. This disengagement can lead to a cycle of poor performance and increased disinterest, further exacerbating the problem (Tenzin et al., 2019; Owino et al., 2015). Additionally, a lack of student enthusiasm and participation creates a challenging classroom environment for teachers, making it difficult to deliver effective instruction (Kahu et al., 2017). From a broader perspective, these negative attitudes toward biology can impact students' future opportunities and career choices (Almasri et al., 2022; Razali, 2021). In an increasingly science-driven world, a strong foundation in biology and other sciences is crucial for many career paths. When students develop aversions to these subjects early on, it limits their potential career options and reduces the number of students pursuing higher education and careers in science, technology, engineering, and mathematics (STEM) fields (Kang, 2021; Blotnicky et al., 2018).

Analysing the problem reveals a clear need for solutions that effectively address and transform students' attitudes toward biology. The ideal solution would involve engaging students in a way that makes the subject matter interesting, relevant, and accessible, promoting positive attitudes toward the subject (Owino et al., 2015; Maryanto & Mundilarto, 2019). Experiential learning, specifically practical work, such as laboratory experiments, offers a promising approach to achieving this goal. Practical experiential learning encompasses a variety of hands-on activities designed to engage students actively in the learning process (Nwuba et al., 2022). This strategy can make learning more interactive and enjoyable, thereby fostering a positive attitude towards biology (Antwi et al., 2021; Dagnew & Sitotaw, 2019). Also, it allows students to see the real-world applications of what they are learning, making the subject matter more tangible and relevant to their lives (Goji, 2018; Badayi et al., 2022). Accordingly, studies have highlighted how hands-on learning can positively influence students' interests, perceptions, and enthusiasm for the subject. For instance, research has shown that students who regularly engaged in practical activities displayed increased motivation and a greater interest (Okam & Zakari, 2017; Holstermann et al., 2010). This increased interest is crucial in maintaining student engagement and preventing the development of negative attitudes towards the subject (Khazanchi, & Khazanchi, 2019). Moreover, practical work has proved to improve students' understanding and retention of biological concepts (Apeadido et al., 2024; Jack, 2018; Akinwumi & Falemu, 2020). As such, implementing practical work in the biology curriculum can help address the observed problem by making the learning experience more engaging and interactive. This approach can help break the cycle of disinterest and poor performance by providing students with opportunities to actively participate and take ownership of their learning. Moreover, it can help cultivate a more positive classroom environment, where students are motivated to learn and teachers can more effectively facilitate instruction (Oliveira & Bonito, 2023; Dagnew & Sitotaw, 2019; Antwi et al., 2021).

While substantial research indicates the positive impact of practical experiential learning activities on students' attitudes toward biology, some gaps remain that need further exploration, highlighting the necessity for more targeted and comprehensive studies aiming to fully understand the nuances of this relationship and to develop effective educational strategies. Although numerous studies have explored the general impact of practical work on students' attitudes toward science, there is a lack of detailed research specifically focused on biology. Most existing research tends to aggregate findings across various scientific contents, potentially obscuring subject-specific insights (Sitotaw, 2019). Another significant gap is the insufficient examination of which aspects of practical work have the most substantial impact on students' attitudes towards biology. While some studies mention the positive effects of laboratory experiments or fieldwork in broad terms, they often do not delve into the details of which elements are most influential (Holstermann et al., 2010). Understanding these nuances allows educators to design practical activities that enhance student engagement and attitudes by focusing on the most impactful aspects, leading to efficient resource use and better educational outcomes.

Hence, the primary purpose of this study was to investigate the impact of practical experiential learning on students' attitudes toward biology within a classroom setting. Specifically, the study sought answers to the following questions:

1. How does participation in practical experiential learning activities influence students' attitudes towards biology?
2. What aspects of practical experiential learning activities have the most significant impact on students' attitudes?

RESEARCH METHOD

The study employed a one-group pre-test and post-test design, utilising one intact class: O1, X, and O2 (Anjarwati & Nasrudin, 2022). Herein, O_1 is the pre-test measurement of the group's attitudes; X is the treatment of the group using practical experiential learning activities; and O_2 is the post-test measurement of the group's attitudes. This research design is suitable for answering the research questions as it allows for the measurement of changes in students' attitudes toward biology before and after their participation in practical work (treatment). The choice of using an intact class, rather than randomly assigning students to different groups, is justified by practical considerations such as the natural classroom setting and the feasibility of implementing the intervention. It ensures that the intervention is applied uniformly across all participants, and minimising disruption to the student's regular learning activities.

The procedure for the research design was conducted using a systematic approach by Sa'adah et al. (2024). Initially, a representative sample of the students was selected from the population. Then, a pre-questionnaire was administered to gauge their attitudes towards biology. Subsequently, students participated in practical experiential learning activities to enhance their subject engagement and interest. After the treatment, a post-questionnaire identical to the pre-test was administered to measure any attitude changes. The collected data were processed and analysed statistically, followed by a discussion of the findings and their educational implications, resulting in the study's conclusion. Figure 1 shows the procedure for the research design.

The population was all students at Juaben Senior High School within the Juaben municipality in the Ashanti Region of Ghana. The target population specifically included all General Science students, with the accessible population being Form 2 General Science students enrolled in Biology. The choice of this year group was strategic: they had been in the school for over a year, exhibiting varied attitudes towards Biology. And, it had acquired some fundamental practical skills in Biology during their first year. Additionally, as they were not in their final year, they were not constrained by the imminent pressures of external examinations. From this target population, the Form 2 General Science class 2GS4, consisting of 45 students, was selected as the sample for the study. This particular class was chosen because it was taught by one of the researchers. A convenience sampling technique was employed to select this class. According to Cohen et al. (2018), convenience sampling allows researchers to select samples based on accessibility and feasibility. This approach was deemed suitable for this study due to its practicality and the ease of access to the selected class. This sampling strategy ensured that it was conducted efficiently within the available resources and time constraints while still providing insights into the students' attitudes.

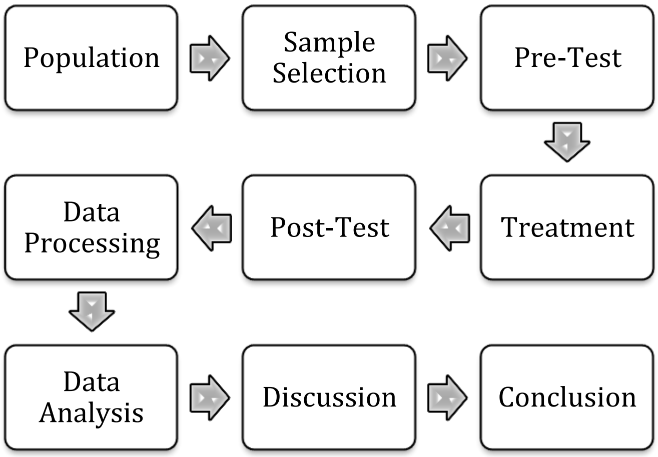

Figure 1. Procedure for the Research Design (Sa'adah et al., 2024: 3)

The primary research instruments 111 mphasiz in this study were pre- and post-questionnaires, designed to gauge the transformation of students' attitudes following engagement in practical work. These questionnaires were structured into sections (A and B) to delve into the perceived attitudes of students towards the study of select biological concepts, such as cells and cell divisions, through the lens of practical activities. Section A of the questionnaires was crafted based on the model devised by Antwi et al. (2021), focusing on four principal thematic areas i.e. students' ability to comprehend the learned concepts, sustain interest throughout the lesson, communicate and interpret results, and link theoretical knowledge to real-world applications. Each questionnaire item in this section was framed as a close-ended question, employing a five-point Likert scale with options ranging from strongly agree (5), agree (4), neutral (3), to disagree (1) and strongly disagree (1). Scores of 1 and 2 were 111mphasizes111 as low scores, while scores of 4 and 5 were categorised as high scores. A score of 3 was considered average and considered neutral. Section B of the questionnaires evaluated different facets of practical work, particularly focusing on the examination of plant and animal cells using microscopes. This section probed students' perspectives on various components of microscopy techniques and cellular analysis, encompassing hands-on microscopy techniques, specimen preparation, observation of cell structures, comparative analysis of animal and plant cells, and understanding of cellular functions and adaptations. Additionally, Section B delved into broader aspects of practical work, including experimental design, data analysis, critical thinking and problem-solving, collaborative learning, and the critical component of reflection and evaluation. Each item in Section B mirrored the format of Section A, employing a five-point Likert scale to ensure a cohesive and standardised approach to data collection.

Before the fieldwork, the instruments were field-pilot tested at St. Sebastian's Senior High School, which shares many similarities with the study school. And, it is located in the Juaben Municipality of the Ashanti Region, to determine reliability. A significant correlation between each question and the overall score was found after a sample of science students responded to the questions. This correlation, which was calculated using responses, resulted in an Alpha Cronbach value of 0.81. The specified objectives were measured by the questionnaires, to determine the face and content validity of the instruments. Moreover, the research tools were presented to the supervisor and senior colleagues for approval and advice. This review assisted in removing skewed constructs and ambiguous items, ensuring the validity, precision, and proper format of the instruments' content.

The intervention design lasted for five weeks and was structured properly. The first week was used for the administration of the pre-assessment questionnaire and lesson preparation. The second, third, and fourth weeks were dedicated to the treatment, which included practical experiential activities. The last week was used to administer the post-assessment questionnaire to students to determine the effect of the treatment on students' attitudes. One of the researchers carried out the treatment intended for the main lesson over three weeks, focusing on specific aspects of practical work related to cells in Biology and how these activities impact students' attitudes towards experiments on plant and animal cells using microscopes. In Week 1, students engaged in hands-on microscopy techniques, learning to properly use microscopes, adjust magnification, focus, and observe slides containing plant and animal cells. They also learned how to prepare specimens, including staining and mounting plant and animal tissues to enhance cell visibility and contrast. Week 2 involved observing and identifying different cell structures in both plant and animal cells. Students conducted comparative analyses to highlight the differences between plant and animal cells. In Week 3, students explored the functional significance of observed cell structures. They also designed experiments to investigate specific aspects of plant and animal cells, such as the effect of environmental factors on cell structure or cellular responses to different stimuli. Throughout the three weeks, students engaged in experimental design, data analysis, critical thinking, problem-solving, collaborative learning, and reflection and evaluation. These activities were integrated into each week's tasks, allowing students to design and conduct experiments, analyse collected data, develop problem-solving skills, work in collaborative groups, and reflect on their practical experiences to enhance their understanding of cell biology.

Data was collected in two phases using pre- and post-questionnaires. During the pre-intervention phase, a pre-questionnaire was administered to gather baseline data on students' attitudes towards the study of Biology. Following the intervention, during the post-intervention phase, a post-questionnaire was administered to collect data on any changes in students' attitudes towards Biology and their perceptions of the impact of practical work on their learning experience.

The data analysis involved summarising and interpreting quantitative data from questionnaires using descriptive and inferential statistics, analysed with Microsoft Excel 2019 and SPSS 25. Descriptive statistics was used to establish baseline attitudes towards biology and assess changes and pre- and post-intervention analysis of specific aspects of practical work. The inferential analysis included paired samples t-tests to evaluate the significance of attitude changes after practical experiential learning activities. Specifically, paired samples t-tests were employed to test the null hypothesis ($H0_1$). Then, there is no significant difference in students' attitudes towards biology before and after practical work. Additionally, the study tested the null hypothesis ($H0_2$) that different aspects of practical work do not significantly impact students' attitudes towards biology by quantifying and comparing mean scores before and after practical work using paired samples t-tests and effect size measures to determine the magnitude of differences. Both hypotheses were tested at a significance level of 0.05.

RESULT AND DISCUSSION

Influence of students' attitudes due to participation in practical works

Aiming to determine the impact of practical experiential learning activities on students' attitudes toward learning about cells in biology, the analysis of the results focused on four key themes: ability to understand concepts learned (A), ability to arouse and maintain interest in the lesson (B), ability to communicate and interpret results (C), and ability to relate concepts learned to life activities (D).

According to Table 1, more students gave high responses to all four attitudinal areas in the post-intervention period compared to the pre-intervention phase than other responses, which were neutral and low. The data showed that more students (88.9%) in the post-intervention phase comprehended the subjects after receiving instruction than these same students did in the pre-intervention period (26.7%). Compared to students in the pre-intervention phase (31.1%), there were fewer students in the post-intervention phase (4.4%) who were unsure of whether they understood the subjects. 91.1% of the students in the post-intervention phase reported having a greater interest in biology after participating in the practical intervention session, compared to only 33.3% of the same students in the pre-intervention phase. Approximately 42.2% of students in the pre-intervention phase and 2.2% of students in the post-intervention phase claim that the teaching strategy did not help to increase their interest in the subject. Regarding the issue of being able to communicate and interpret results, 82.2% of students in the post-intervention phase were able to do so, as opposed to just 28.9% of students in the pre-intervention phase who felt they could not interpret the data they had acquired or first transmit it. In the post-intervention phase, 73.3% of the students believed they could apply the concepts outside the classroom and in everyday activities. Meanwhile, just 20.0% of these students did so in the pre-intervention phase. The findings showed that, as a result of the practical-based activities, the students showed favourable attitudes about cellular concepts.

Test of Null Hypothesis One (HO_1)*:* To test the HO_1, categories (A, B, C, and D) of students' responses to high sentimental levels of both pre-and post-intervention attitudinal scores were analysed using a paired samples t-test, and the result was presented in Table 2.

As shown in Table 2, the mean pre-intervention attitude score was 12.25 (SD = 2.50), while the mean post-intervention attitude score was 37.75 (SD = 3.59), demonstrating a significant increase in the mean and a change in attitude. The t-statistic was 26.63, far exceeding the critical t-value of 3.18 at an alpha level of 0.05, with a p-value less than 0.001. These results indicate a statistically significant improvement in students' attitudes following the treatment (intervention), supporting the rejection of the $H0_1$ that there is no significant difference in students' attitudes towards biology before and after participating in practical biology work. The substantial increase in mean scores indicates that engaging in hands-on practical activities positively influenced students' attitud

Table 1. Pre- and post-intervention attitudinal scores of students

Item Examined	Sentimental Level of Responses					
	Pre-Intervention Attitude Score			Post-Intervention Attitude Score		
	High N (%)	Neutral N (%)	Low N (%)	High N (%)	Neutral N (%)	Low N (%)
A	12 (26.7)	14 (31.1)	19 (42.2)	40 (88.9)	2 (4.4)	3 (6.7)
B	15 (33.3)	11 (24.4)	19 (42.2)	41 (91.1)	3 (6.7)	1 (2.2)
C	13 (28.9)	7 (15.5)	25 (55.5)	37 (82.2)	6 (13.3)	2 (4.4)
D	9 (20.0)	16 (35.6)	20 (44.4)	33 (73.3)	7 (15.6)	5 (11.1)

Table 2. Paired samples t-test of attitudinal mean scores obtained by students

Test	N	Mean	SD	Df	t-statistic	t-critical (2-tailed)	P value (2-tailed)
Pre-Intervention Attitude	4	12.25	2.50	3	26.63	3.18	< 0.001
Post-Intervention Attitude	4	37.75	3.59				

Statistically significant at Alpha (α) = 0.05 level. P<0.05

Discussion of the Findings

The analysis of the data reveals that participation in biology practical experiential learning activities has a profound and positive impact on student's attitudes towards the subject. The findings in Table 1 indicate a substantial shift in students' perceptions and enthusiasm towards biology. Significantly more students comprehended the subjects better in the post-intervention phase compared to the pre-intervention phase. This significant increase in comprehension suggests that practical work makes abstract concepts more tangible and understandable, reinforcing findings from other studies that highlight the importance of experiential learning in improving student comprehension and retention (Akinwumi & Falemu, 2020; Apeadido et al., 2024). Furthermore, the increase in students' interest demonstrates the engaging nature of practical activities. It aligns with the works of Sitotaw (2019) and Holstermann et al. (2010), who found that practical work enhances student interest and motivation in science subjects. This boost in interest is crucial for sustaining long-term engagement and encouraging students to pursue further studies and careers in science. In terms of students' ability to communicate and interpret results, the result highlights the development of essential scientific skills through practical work. Supported by educational research emphasises the role of hands-on activities in developing critical thinking and data interpretation skills (Apeadido et al., 2024; Antwi et al., 2021). Additionally, the increase in students' ability to apply biological concepts outside the classroom suggests that practical work not only enhances understanding but also helps students see the real-world relevance of what they are learning. This real-world application is a key factor in fostering a deeper appreciation and sustained interest in biology. The paired samples t-test results showed a significant increase in mean attitude scores, providing robust statistical evidence of the positive impact of practical work, affirming that practical biology work significantly enhances student attitudes. This finding confirms the benefits of practical experiential learning in science education, which is consistent with broader educational literature. In particular, Tenzin et al. (2019), Sitotaw (2019), and Antwi et al. (2021) emphasise that practical work enhances students' attitudes toward science by making learning more understandable, interactive, and enjoyable.

Aspects of practical work that have the most significant impact on students' attitudes

Aiming to investigate the aspects that had the most impact on students' attitudes, it analyzed students' responses to the various practical work aspects during each phase. The results are presented in Tables 3, 4, 5, and 6.

The analysis of Table 3 demonstrates a substantial improvement in students' attitudes towards specific aspects of practical biology work post-intervention. Pre-intervention, a high percentage of students displayed low attitudes towards all aspects, with microscope use at 57.7%, slide preparation at 66.6%, observation engagement at 71.1%, comparative analysis at 75.5%, and understanding functions at 62.2%. Post-intervention, the high attitude percentages rose dramatically for all aspects, with microscope use at 86.6%, slide preparation at 51.1%, observation engagement at 84.4%, comparative analysis at 57.7%, and understanding functions at 60%. The enhanced students' positive attitudes towards these aspects. The results suggest that different aspects of practical experiential activities were impacted differently, which would be confirmed through statistical significance tests.mean scores also showed significant increases, indicating that the practical activities effectively

Table 3. Pre- and post-intervention of analysis of specific aspects of practical work

Aspect of Practical Work	Sentimental Level of Responses			Mean	S D
Part A: Pre-Intervention Attitude Scores					
	Low N (%)	Neutral N (%)	High N (%)		
Microscope Use	26 (57.7)	10 (22.2)	9 (20.0)	1.62	0.80
Slide Preparation	30 (66.6)	12 (26.6)	3 (6.6)	1.40	0.61
Observation Engagement	32 (71.1)	8 (17.7)	5 (11.1)	1.40	0.68
Comparative Analysis	34 (75.5)	9 (20.0)	2 (4.4)	1.28	0.54
Understanding Functions	28 (62.2)	12 (26.6)	5 (11.1)	1.48	0.69
Part B: Post-Intervention Attitude Scores					
Microscope Use	0 (0.0)	6 (13.3)	39 (86.6)	2.86	0.34
Slide Preparation	11 (24.4)	11 (24.4)	23 (51.1	2.26	0.83
Observation Engagement	3 (6.6)	4 (8.8)	38 (84.4)	2.77	0.55
Comparative Analysis	9 (20.0)	10 (22.2)	26 (57.7)	2.37	0.80
Understanding Functions	9 (20.0)	9 (20.0)	27 (60.0)	2.4	0.80

Table 4. Pre- and post-intervention of analysis of broader aspects of practical work

Aspect of Practical Work	Sentimental Level of Responses			Mean	S D
Part A: Pre-Intervention Attitude Scores					
	Low N (%)	Neutral N (%)	High N (%)		
Experimental Design	25 (55.5)	11 (24.4)	9 (20.0)	1.64	0.80
Data Analysis	28 (62.2)	15 (33.3)	2 (4.4)	1.42	0.58
Critical Thinking and Problem-Solving	33 (73.3)	11 (24.4)	1 (2.2)	1.28	0.50
Collaborative Learning	27 (60.0)	12 (26.6)	6 (13.3)	1.53	0.72
Reflection and Evaluation	27 (60.0)	15 (33.3)	3 (6.6)	1.46	0.62
Part B: Post-Intervention Attitude Scores					
Experimental Design	1 (2.2)	3 (6.6)	41 (91.1)	2.88	0.38
Data Analysis	6 (13.3)	15 (33.3)	24 (53.3)	2.40	0.71
Critical Thinking and Problem-Solving	10 (22.2)	14 (31.1)	21 (46.6)	2.24	0.80
Collaborative Learning	0 (0.0)	4 (8.8)	41 (91.1)	2.91	0.28
Reflection and Evaluation	6 (13.3)	7 (15.5)	32 (71.1)	2.57	0.72

Table 5. Paired samples t-test results of changes in attitudes based on aspects of practical work

Aspect of Practical Work	Mean Change	t-statistic	t-critical value (2-tailed)	p-value (2-tailed)	Statistical Significance
	Specific aspect				
Microscope Use	1.24	10.79	2.01	5.98E-14	Yes
Slide Preparation	0.86	8.37	2.01	1.17E-10	Yes
Observation Engagement	1.37	11.89	2.01	2.45E-15	Yes
Comparative Analysis	1.09	9.56	2.01	2.56E-12	Yes
Understanding Functions	0.92	8.33	2.01	1.33E-10	Yes
	Broad aspect				
Experimental Design	1.24	10.40	2.01	1.92E-13	Yes
Data Analysis	0.98	11.24	2.01	1.59E-14	Yes
Critical Thinking and Problem-Solving	0.96	9.52	2.01	2.89E-12	Yes

Collaborative Learning	1.38	12.90	2.01	1.48E-16	Yes
Reflection and Evaluation	1.11	10.43	2.01	1.76E-13	Yes

Statistically significant at Alpha (α) = 0.05. $P<0.05$

Table 4 reveals significant attitudinal improvements in broader aspects of practical biology work. Initially, students exhibited low attitudes towards experimental design (55.5%), data analysis (62.2%), critical thinking and problem-solving (73.3%), collaborative learning (60.0%), and reflection and evaluation (60.0%). Post-intervention, the high attitude percentages improved significantly, with experimental design at 91.1%, data analysis at 53.3%, critical thinking and problem-solving at 46.6%, collaborative learning at 91.1%, and reflection and evaluation at 71.1%. The increase in mean scores across these aspects highlights the effectiveness of practical experiential learning in fostering a more positive attitude towards broader biological concepts and skills. These results further indicate that various aspects of practical work have impacted attitudes differently, necessitating further statistical tests to determine the significance of these differences.

Test of Null Hypothesis Two ($H0_2$): The paired samples t-test results in Table 5 demonstrate a significant improvement in students' attitudes towards various aspects of practical experiential learning following the interventions. For specific aspects, the t-statistics for microscope use (10.79), slide preparation (8.37), observation engagement (11.89), comparative analysis (9.56), and understanding functions (8.33) all significantly exceeded the critical value of 2.01 at an alpha level of 0.05, with p-values far below 0.05, indicating statistical significance. Similarly, for broader aspects, the t-statistics for experimental design (10.40), data analysis (11.24), critical thinking and problem-solving (9.52), collaborative learning (12.90), and reflection and evaluation (10.43) also significantly surpassed the critical value, with corresponding p-values well below the 0.05 threshold, confirming statistical significance. These results support the rejection of the null hypothesis ($H0_2$) that there is a significant difference in students' attitudes towards different aspects of practical work before and after interventions. The significant t-statistics and p-values for all aspects suggest that practical interventions substantially and positively impacted students' attitudes toward biology, highlighting the effectiveness of different areas of practical experiential learning activities in enhancing students' engagement and perception of the subject. Furthermore, the results indicate that aspects of practical work were impacted differently, with variations in the p-values and t-statistics demonstrating varying levels of influence on students' attitudes.

Accordingly, the specific aspect of practical work that had the most significant impact on students' attitudes, as indicated by the effect sizes in Table 6, showed Observation Engagement yielded the highest impact. With a Cohen's d of 1.77, this aspect demonstrates a very large effect size, highlighting its crucial role in positively shaping student attitudes. Microscope Use followed closely, with a Cohen's d of 1.60, which also indicates a very large effect. Comparative Analysis showed substantial influence with a Cohen's d of 1.42. Slide Preparation and Understanding Functions, each with a Cohen's d of 1.24, while slightly less impactful than the top three, still represent large effect sizes, demonstrating significant positive changes in student attitudes toward biology. These findings suggest that hands-on and observational activities are particularly effective in engaging students and enhancing their attitudes toward biology. Also, the broader aspects of practical work reveal similar trends, with Collaborative Learning exhibiting the highest impact among all examined aspects. It achieved a Cohen's d of 1.92, marking it as the most influential broad aspect of student attitudes. Data Analysis also had a very large effect size, with a Cohen's d of 1.67. Experimental Design and Reflection and Evaluation had a Cohen's d of 1.55, underscoring their substantial contributions to improving student attitudes. Critical Thinking and Problem-Solving, while the least impactful among the broad aspects, still demonstrated a large effect size with a Cohen's d of 1.42, indicating its positive influence on students' perspectives towards practical work in biology. These results indicate that collaborative, analytical, and reflective practices are highly effective in fostering positive student attitudes.

Effect Size Interpretation for Cohen's d is: small = $0 \leq 0.2$, medium = $0.2 < d < 0.8$, and large = $d \geq 0.8$, adapted from Aarts et al. (2014). Comparing the specific and broad aspects of practical experiential learning activities, it is evident that both categories exhibit massive effect sizes, underscoring the overall effectiveness of practical work in enhancing students' attitudes. The highest impact from a specific aspect, Observation Engagement is closely comparable to the most impactful broad aspect, Collaborative Learning. Even the least impactful aspects, Understanding Functions, and Critical Thinking and Problem-Solving, both show large effect sizes, indicating significant positive changes. These results show that every aspect of practical work considerably impacts positively students' attitudes in biology lessons.

Table 6. Effect Size results for each aspect of practical work

Aspect of Practical Work	Mean Change	Cohen's d
Specific aspect		
Microscope Use	1.24	1.60
Slide Preparation	0.86	1.24
Observation Engagement	1.37	1.77
Comparative Analysis	1.09	1.42
Understanding Functions	0.92	1.24
Broad aspect		
Experimental Design	1.24	1.55
Data Analysis	0.98	1.67
Critical Thinking and Problem-Solving	0.96	1.42
Collaborative Learning	1.38	1.92
Reflection and Evaluation	1.11	1.55

Discussion of the Findings

The findings from the analysis of specific aspects of practical work in biology classrooms disclose that Observation Engagement had the most significant impact on student's attitudes. It indicates that students are particularly responsive to activities that involve direct interaction and engagement with biological phenomena. For biology education stakeholders, such as educators and curriculum developers, this underscores the importance of incorporating hands-on observational activities into the curriculum. These activities not only make learning more interactive and engaging but also help students develop a deeper understanding and appreciation for biological concepts. The high impact of Observation Engagement aligns with existing studies that emphasise the effectiveness of experiential learning, suggesting that increasing opportunities for students to observe and engage with biological specimens and processes can significantly enhance their attitudes and interest in the subject (Dagnew & Sitotaw, 2019; Sitotaw, 2019). Microscope Use also showed a significant positive impact, reinforcing the value of providing students with opportunities to use scientific tools in their learning process. In contrast, Understanding Functions, while still showing a large effect size, was the least impactful among the specific aspects studied. This finding suggests that while understanding the functions of biological structures and processes is important, it may not be as immediately engaging or impactful on students' attitudes as more interactive and observational activities. Furthermore, Slide Preparation and Comparative Analysis showed significant positive impacts, though slightly less than Observation Engagement and Microscope Use. For educators, these results imply that teaching the functions of biological elements and preparing slides are essential. They should be complemented with engaging practical experiential learning activities to maintain student interest and enthusiasm. These findings consistently indicate that while theoretical understanding is crucial, its impact on student attitudes can be enhanced by combining it with practical, hands-on experiences (Akinwumi & Falemu, 2020).

The broader aspects of practical work also significantly impacted students' attitudes, with Collaborative Learning having the highest impact. It indicates that students greatly benefit from working in groups, which fosters a sense of community, enhances communication skills, and promotes deeper understanding through peer interaction. For stakeholders, this highlights the importance of designing practical work that encourages student's collaboration. Studies have shown that collaborative learning environments not only improve academic performance but also positively influence student attitudes and behaviours towards the subject (Mendo-Lazaro et al., 2022; Keramati & Gillies, 2022; Goji, 2018). Implementing group projects, peer reviews, and cooperative experiments can thus be particularly beneficial in biology education. Also, Experimental Design, and Reflection and Evaluation showed a massive effect size, indicating their significant positive impact on students' attitudes. These aspects involve analytical skills and reflective practices, which are essential for developing scientific literacy and a deeper understanding of biological concepts. The positive impact of these aspects suggests that practical experiential learning should be designed to not only involve hands-on activities but also include elements that require students to analyse data, design experiments, and reflect on their learning. This comprehensive approach ensures that students develop a well-rounded understanding of biology and its methodologies, which is supported by literature emphasising the importance of inquiry-based learning on students' learning attitudes in science education (Liou, 2021). Critical Thinking and Problem-Solving, while the least impactful among the broad aspects, still demonstrated a large effect size, indicating its positive influence on students' perspectives towards practical work in biology.

When comparing the specific and broad aspects of practical work, it is evident that both categories play a crucial role in enhancing students' attitudes toward biology. Existing research indicates that a well-structured classroom environment, combined with thoughtfully chosen interactive activities, significantly enhances student engagement, which is essential for effective learning and improved academic performance (Khazanchi, & Khazanchi, 2019). These findings align with our study's results, which suggest that practical experiential learning activities, whether focused on specific skills or broader educational strategies, play a critical role in fostering positive attitudes in biology students and contribute to a more engaging and effective learning environment. The significant impacts observed across all aspects further reinforce the idea that a diverse and interactive approach to practical work is essential for fostering positive student attitudes and engagement in biology. Overall, the findings from the analysis of practical experiential learning activities indicate that various aspects influence students' attitudes differently, which follows Holstermann et al. (2010). This comprehensive approach leverages the strengths of each aspect to foster engagement, critical thinking, and collaborative learning, providing a richer and more impactful biology education.

CONCLUSION

This study highlights the critical role of practical experiential learning in biology education, revealing significant enhancements in student attitudes and engagement. By integrating diverse and interactive practical experiences into the curriculum, educators can foster essential skills such as critical thinking and collaboration. This approach aligns with broader STEM and experiential learning initiatives, emphasising real-world applications in science education. To enhance the effectiveness and relevance of biology education, educators and policymakers should prioritise hands-on practical work and create supportive classroom environments that promote active learning. Continuous evaluation, professional development for educators, and partnerships with local industries are crucial steps toward enriching student learning experiences. Ultimately, effective integration of practical experiential activities prepares students for academic success and future scientific pursuits.

Based on the scope of the study, some limitations are identified. The study's intervention strategy, conducted over three weeks, focused on specific aspects of practical work related to microscopy techniques and cellular analysis. However, the short duration of the intervention may not fully capture long-term changes in students' attitudes towards biology or the sustained impact of practical activities over an extended period. Furthermore, while the study provided valuable insights into how practical work can influence students' attitudes, additional research across diverse educational settings and disciplines would be beneficial to further validate and generalise the findings.

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