



Effect of Formative Assessment Practices on the Academic Performance of Senior High School Students in Photosynthesis

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Abstract

This study sought to determine the effect of formative assessment practices on senior high school students' academic performance in photosynthesis. The study was conducted at Kotoku Senior High School and used an action research design. The study employed a quantitative procedure to collect data. The purposive sampling technique was used to select an intact class of 65 Form 1 Home Economics students. Test was also used to gather data on the effect of formative assessment techniques on students' academic performance before and after the intervention, as well as male and female students' performance. Data were analysed using means, standard deviations and t-test analysis. The findings of the study revealed an improvement in students' general academic performance. The study also highlighted an equitable performance of male and female students with the use of formative assessment techniques. Based on the findings, it was recommended that the school authorities at Kotoku Senior High School should provide enough teaching and learning materials to facilitate formative assessment practices in order to enhance the academic performance of students in biology concepts. Furthermore, biology teachers in Kotoku Senior High School should continue and adapt formative assessment practices to ensure equitable academic support for both male and female students. Thus, formative assessment practices are effective in enhancing students' learning outcomes in biology.

Subject Areas

Pedagogy

Keywords

Formative Assessment Practices, Academic Performance, Senior High School, Photosynthesis

1. Introduction

There has been a significant shift in educational assessment practices in recent years, with formative assessment increasingly recognised as a crucial component of effective competence-based and learner-centred teaching and learning. This shift has been driven by evidence showing that formative assessment plays a central role in improving instructional quality and supporting meaningful learning [1]. Formative assessment is a continuous process that encompasses a range of instructional practices, including the sharing of learning objectives and success criteria, peer and self-assessment, questioning, collaborative learning activities, and the provision of timely and constructive feedback [2] [3]. Through these practices, students are actively engaged in the learning process and supported to work towards clearly defined learning goals [4]. The effectiveness of formative assessment is closely linked to students' understanding of learning goals and assessment criteria. When students clearly understand what is expected of them, they are better positioned to evaluate their own work and make necessary improvements [5] [6]. Such clarity promotes active participation, reflective learning, and greater learner autonomy, which in turn enhances students' academic satisfaction and performance [7] [8]. Empirical studies conducted in biology classrooms have consistently demonstrated that formative assessment improves students' interest, conceptual understanding, and overall academic performance [2] [9] [10]. Despite these documented benefits, the implementation of formative assessment practices remains inconsistent in many educational settings, particularly in sub-Saharan Africa. In Ghana, although the current curriculum emphasises learner-centred approaches and continuous assessment, classroom practice in many senior high schools continues to be dominated by summative assessment strategies that focus primarily on measuring learning outcomes rather than supporting learning during instruction [11]. These traditional assessment approaches are often teacher-centred, rigid, and insufficiently responsive to individual learner needs, making them less effective in promoting critical thinking and deep conceptual understanding in science subjects such as biology [12] [13].

The continued reliance on teacher-centred instructional and assessment practices tends to overlook students' individual learning differences, limit opportunities for reflective learning, and reduce the provision of feedback necessary for learning improvement. Moreover, formative assessment has been shown to support differentiated instruction and promote equity by allowing learners to progress at their own pace while receiving targeted feedback [14]. Furthermore, gender disparities in science achievement remain a concern, as male and female students often respond differently to instructional and assessment strategies due to variations in learning styles, confidence levels, and teacher expectations [15]. Studies have indicated that formative assessment strategies, particularly peer and self-assessment, enhance self-regulation and metacognitive skills, which can be especially beneficial for female students who may experience anxiety or lower confidence in science learning contexts [16]. At the senior high school level in Ghana, and particularly at Kotoku Senior High School in the Greater Accra Region of

Ghana, students continue to experience persistent conceptual difficulties in biology topics such as photosynthesis. These challenges include poor understanding of the chemical processes involved in photosynthesis, energy transformation, and the functions of chlorophyll and chloroplasts. Classroom observations suggest that students are often passive recipients of knowledge, with limited opportunities for interactive learning and formative feedback. This situation is largely attributed to the dominance of summative assessment practices administered at the end of instructional units, which fail to provide continuous feedback or support students in identifying and correcting misconceptions during learning [17]. Therefore, formative assessment has been found to be particularly effective in biology education because it empowers students to take ownership of their learning and engage more deeply with scientific concepts [18]. Strategies such as peer assessment enable students to evaluate their peers' work using predefined criteria, provide constructive feedback, and identify conceptual errors [19]-[21]. Similarly, self-assessment, questioning, collaborative learning, and timely feedback create supportive learning environments that foster metacognitive development and student autonomy. Despite these advantages, empirical research examining the integration and effectiveness of formative assessment practices in Ghanaian senior high schools, particularly within specific biology topics such as photosynthesis remains limited. Given the paucity of context-specific studies at the school level, especially at Kotoku Senior High School, there is a clear need to investigate whether formative assessment practices can significantly improve students' academic performance in photosynthesis and whether these practices influence male and female students differently. The findings of this study are expected to encourage biology teachers at Kotoku Senior High School to adopt more dynamic, interactive, and student-centred instructional approaches. Additionally, the results have the potential to inform educational policy and curriculum implementation by advocating for the integration of effective formative assessment practices to enhance students' academic achievement. The outcomes may also serve as valuable resources for teacher education and professional development programmes in Kotoku and its environs, highlighting the importance of formative assessment in addressing misconceptions, deepening conceptual understanding, and improving students' performance in both assessments and real-world scientific applications.

1.1. Research Questions

- 1) What is the effect of formative assessment practices on students' academic performance in photosynthesis at Kotoku Senior High School?
- 2) What is the differential effect of formative assessment practices on the academic performance of male and female senior high school students at Kotoku Senior High School?

1.2. Hypothesis

H_{01} and H_{02} were used to address the stated research question. The null hypotheses

were tested at the 0.05 significance level.

H₀₁: There is no statistically significant difference in the means of students' academic performance before and after the use of formative assessment in learning photosynthesis.

H₀₂: There is no statistically significant difference in the means of male and female senior high school students' academic performance before and after the implementation of formative assessment in learning photosynthesis.

2. Research Methodology

2.1. Research Design

This study adopted an action research design, as it is particularly suited to improving teaching practices and generating context-specific solutions to classroom challenges. Action research is characterised by a reflective and systematic inquiry process in which the teacher-researcher identifies a problem, implements an intervention, observes its effects, and reflects on the outcomes to inform subsequent instructional decisions [22]. The design followed the cyclical and iterative nature of action research, consisting of four interconnected phases: planning, action, observation, and reflection. During the planning phase, the researcher identified persistent difficulties students exhibited in understanding photosynthesis and designed formative assessment strategies to address these challenges. Additional information added: This phase involved diagnosing learning gaps using preliminary classroom observations and an initial pre-intervention assessment, which served as a baseline for instructional planning rather than as a comparative experimental control. In the action phase, the researcher implemented formative assessment practices within the normal biology instructional process. These practices were embedded into daily classroom activities and were continually adjusted based on ongoing feedback from students. Unlike a one-time intervention typical of quasi-experimental designs, the formative assessment strategies were refined throughout the instructional period in response to students' learning needs.

The observation phase involved the systematic collection of quantitative data through classroom-based assessments, including the pre-intervention test and two post-intervention assessments. These assessments were used to monitor students' learning progress over time and to evaluate the effectiveness of the instructional adjustments made during the intervention. The post-tests were therefore treated as reflective evaluation tools to inform subsequent instructional decisions rather than as endpoints for experimental comparison. In the reflection phase, the researcher analysed students' performance data to evaluate the effectiveness of the formative assessment practices and to determine areas requiring further instructional improvement. The reflective insights gained informed subsequent cycles of planning and action within the classroom context. This reflective process ensured that teaching practices evolved continuously throughout the study, which is a defining feature of action research. Although the study employed a quantitative approach in analysing students' academic performance, the primary purpose of the

data analysis was formative and diagnostic rather than experimental. The quantitative analysis focused on assessing changes in students' performance in photosynthesis and examining performance trends among male and female students as part of the reflective inquiry process. The use of quantitative data within an action research framework strengthened evidence-based reflection while maintaining the practical, improvement-oriented focus of the design.

2.2. Research Population

Kotoku Senior High School in the Greater Accra region of Ghana had a student population of 2150 at the time of the research. The target population consisted of all Form 1 General Biology and Home Economics students at Kotoku Senior High School. The accessible population of this study consisted of Form 1 Biology 1 and Home Economics 1 students at Kotoku Senior High School. There were 130 students in these two groups at the time of the study. The researcher used a purposive sampling technique to choose 65 Form 1 Home Economics students from the accessible population. This technique was chosen because the researcher teaches this class, and the topic is treated in Form 1 according to the Biology curriculum in Ghana [23].

2.3. Research Instrument

This study employed the use of test as instruments (pre-test and post-test). The pre-intervention test was conducted before the implementation of formative assessment practices in the biology classroom. This test was conducted to assess the difficulties students have with photosynthesis. The test items consisted of four essay questions and were conducted in the first week of the research study at 1 Home Economics 1 class of Kotoku SHS. The researcher gave 20 minutes to the participants to respond to the test. Furthermore, two post-tests were also conducted after the implementation of the formative assessment practices in the biology classroom. The first post-test was conducted two weeks after the implementation of the formative assessment practices. The second post-test also consisted of 4 essay questions and was conducted two weeks after the first post-test. The total marks for the tests were 40, with 0 - 19 being in the Low category, 20 - 24 in the Moderate category, 25 - 30 in the Good category, 31 - 35 in the Very Good category and 36-40 in the Excellent category. The post-tests were conducted to determine the effect of formative assessment practices on student's academic performance in photosynthesis and the difference in performance of male and female students.

A detailed analytic scoring rubric was developed and used for all tests to ensure objectivity, consistency, and transparency in scoring the essay questions. Each essay question was scored out of 10 marks and assessed across five clearly defined criteria: 1) scientific accuracy of content (4 marks), 2) depth of conceptual understanding of photosynthesis concepts (3 marks), 3) clarity and coherence of explanation (1 mark), 4) appropriate use of biological terminology (1 mark), and 5) logical organisation and sequencing of ideas (1 mark). Students were awarded

marks based on the extent to which their responses met each criterion, allowing for partial credit where applicable. The use of this structured rubric reduced scorer subjectivity and ensured uniform application of grading standards across all scripts. To further strengthen the reliability of the grading process, inter-rater reliability was assessed independently of the test-retest reliability of the instrument. A second experienced biology teacher, who was familiar with the senior high school biology curriculum, independently scored a randomly selected 30% sample of students' scripts using the same analytic rubric. The scores from the two raters were analysed using Pearson's Product-Moment Correlation Coefficient. The analysis yielded a high inter-rater reliability coefficient ($r = 0.87$), indicating a strong level of agreement between the raters and confirming the consistency and objectivity of the scoring process. Any minor discrepancies in scores were discussed and resolved through consensus.

2.4. Validity and Reliability

For content validity, the items were evaluated by a panel of experts to ascertain whether they adequately covered all relevant aspects of the topic. The panel comprised the researcher's supervisor, two experienced lecturers from the Integrated Science Department at the University of Education, Winneba, and two biology teachers from Kotoku Senior High School. These subject matter experts carefully reviewed each item for relevance, clarity, scientific accuracy, and consistency with the curriculum. They provided suggestions for rephrasing ambiguous questions, eliminating redundant items, and including missing but important concepts. Their feedback was used to refine and revise the test to ensure comprehensive coverage of the content domain. The face validity was ensured when the same panel assessed whether the test appeared to measure what they were intended to measure, from the perspective of both instructors and students. This involved reviewing the wording, structure, and formatting of the items to ensure they were clear, straightforward, and understandable to senior high school students. The reviewers judged whether the items were appropriate in terms of difficulty level and linguistic simplicity, ensuring that they would be perceived by students as relevant to the topic under study. Based on the feedback, minor adjustments were made to enhance clarity and readability.

The reliability of the test items was determined using a test-retest method. In this method, the test was given to Form 1 Science 2 students of Kotoku Senior High School on two separate occasions. The test-retest activities took place two weeks before the pre-intervention period. This was necessary to ensure that the items were reliable to be used for the main study. For the test-retest of the pre-test, students were made to write on two different occasions, where their marks were recorded. The reliability coefficient was calculated to be 0.80. After a week, the post-test was also conducted on two different occasions where scripts were marked and recorded. A Cohen's kappa reliability coefficient value was therefore calculated to be 0.85 and a value of such makes an instrument reliable [24].

2.5. Data Collection Procedure

The data collection procedures of this study took three stages: pre-intervention, intervention and post-intervention activities. The stages are described below.

2.5.1. Pre-Intervention

The pre-intervention activities took place within the first week of the research implementation. The researcher conducted a test on photosynthesis. Students were pre-informed to prepare for the test. Students were given 20 minutes to respond to the questions. The pass mark of the test was therefore set at 20 because the total mark was 40. Before the test, clear and precise instructions were given to the students as to how to respond to the test items.

2.5.2. Intervention

The intervention activities were carried out after the pre-intervention and the activities were clearly spelt out in the lesson plan below used by the researcher during the study. The activities were carried out within four weeks and they are as follows;

Week 1: Describing the Process of Photosynthesis.

Objective: *Describe the process of photosynthesis.*

Activities:

- 1) The researcher introduced the concept of photosynthesis, including its definition, importance, and basic chemical equation ($6\text{CO}_2 + 6\text{H}_2\text{O} + \text{light energy} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$).
- 2) Diagrams and animations were used to illustrate the process.
- 3) Students wrote a brief summary of the photosynthesis process and submit it as an exit slip.
- 4) Throughout the lesson, open-ended questions were used to assess understanding (e.g., What are the main stages of photosynthesis?).
- 5) Exit slips were reviewed and provide individual or group feedback provided on their understanding and accuracy.
- 6) Students were assigned to create a concept map of photosynthesis, including key terms and processes.

Week 2: Describing the Structural Adaptation of the Leaf for Photosynthesis.

Objective: *Describe the structural adaptation of the leaf for photosynthesis.*

Activities:

- 1) The researcher explained the various structural adaptations of leaves that enhance photosynthesis (e.g., stomata, chloroplasts, leaf veins).
- 2) Leaves were dissected where their structure was observed under microscopes.
- 3) Students worked in pairs to compare their concept maps from Week 1 with peers where constructive feedback were provided.
- 4) Questions were posed on leaf structures and their functions during the lesson (e.g., "How do stomata contribute to photosynthesis?").
- 5) The concept maps with students were reviewed and discussed highlighting accurate depictions and correcting misunderstandings.

6) Students wrote about how specific leaf structures aid in photosynthesis using exit slips, based on their observations.

Week 3: Explaining the Conditions That Affect the Rate of Photosynthesis.

Objective: *Explain the conditions that affect the rate of photosynthesis.*

Activities:

1) The various factors such as light intensity, carbon dioxide concentration, and temperature were discussed. Simple experiments were conducted to show how these factors influence the rate of photosynthesis.

2) Students performed experiments or simulations to measure the effects of different conditions on photosynthesis.

3) Students created a concept map showing how different conditions affect the rate of photosynthesis.

4) Questioning technique was used to evaluate understanding (e.g., What effect does increase in carbon dioxide have on the rate of photosynthesis?).

5) Findings from experiments were discussed and concept maps were reviewed to ensure understanding.

6) Students exchange their concept maps with a classmate and provided feedback.

Week 4: Explaining the Biochemical Nature of Photosynthesis.

Objective: Explain the biochemical nature of photosynthesis, including the chemical process, energy transformation, and the role of chlorophyll and chloroplasts.

1) The researcher explained the light-dependent and light-independent reactions of photosynthesis, energy transformation, and the roles of chlorophyll and chloroplasts.

2) Diagrams, animations, and physical models were used to illustrate biochemical processes.

3) Students updated their concept maps to include biochemical processes and the roles of chlorophyll and chloroplasts.

4) Students were engaged with questions about the biochemical details (e.g., “How does chlorophyll contribute to energy transformation?”).

5) Updated concept maps were reviewed and students’ questions were answered to ensure thorough understanding.

6) Students summarised the biochemical aspects of photosynthesis, including chemical processes and energy transformation.

2.5.3. Post-Intervention

The researcher conducted a test to determine the effect of formative assessment practices on students’ academic performance in photosynthesis in the biology classroom as well as difference in performance of male and female students. Two post-tests were therefore conducted. The post-test consisted of four essay questions on photosynthesis. These four essay questions were given to the participants after the research implementation of the intervention for four weeks. The two post-test were used in the study because the researcher wanted to monitor students’ performance over time and also for progressive learning.

2.6. Data Analysis

The pre-test and the post-test data were analysed using SPSS Version 27 into means and standard deviations. Moreover, an independent samples t-test was used to analyse the data to determine whether there was a significant difference in students' performance. An independent samples t-test analysis was also used to determine the significant difference in male and female students' performance before and after the intervention.

3. Findings

3.1. Research Question 1: What Is the Effect of Formative Assessment Practices on Students' Academic Performance in Photosynthesis at Kotoku Senior High School?

A paired t-test analysis was employed to determine whether there was a statistically significant difference in students' performance after the intervention.

Table 1. Summary table of t-test results.

Comparison	Mean Difference	t-value	p-value
Pre vs Post1	6.03	3.89	0.00024
Post1 vs Post2	3.84	2.84	0.00604
Pre vs Post2	9.87	9.87	1.75E-14

Note: $p < 0.05$ = significant; $p > 0.05$ = not significant.

The analysis in **Table 1** revealed significant differences across all three testing phases. The comparison between pre-test and post-test 1 yielded a significant t-value of 3.89 ($p = 0.00024$), indicating a substantial improvement in student performance during the intervention phase. Further improvement was observed between post-test 1 and post-test 2 with a significant t-value of 2.84 ($p = 0.00604$). The most pronounced difference was found between the pre-test and post-test 2, with a t-value of 9.87 ($p = 1.75E-14$), demonstrating the cumulative positive effect of formative assessment. The mean differences does suggest that the intervention not only improve overall performance but also lead to more consistent student achievement. These findings provide strong statistical evidence to reject the null hypothesis, confirming that formative assessment had a significant positive impact on students' academic performance in photosynthesis.

3.2. Research Question 2: What Is the Differential Effect of Formative Assessment Practices on the Academic Performance of Males and Females Senior High School Students at Kotoku Senior High School?

An independent samples t-test analysis was employed to determine whether there was a statistically significant difference in male and female students' performance before and after the intervention.

Table 2. Summary table of the t-test results.

Test Phase	Group	N	Mean	SD	t-value	p-value
Pre-test	Females	35	21.45	9.70	0.13	0.897
	Males	30	21.76	9.69		
Post-test 1	Females	35	27.19	8.90	0.47	0.640
	Males	30	28.18	7.91		
Post-test 2	Females	35	30.44	7.28	1.26	0.212
	Males	30	32.58	6.35		

Note: $p < 0.05$ = significant; $p > 0.05$ = not significant.

The results in **Table 2** compared male and female students' performance across three testing phases. In the pre-test, there was no significant difference between females, with a t-value of 0.13 ($p = 0.897$). Similarly, Post-test 1 revealed no significant gender difference ($t = 0.47$, $p = 0.640$). The final Post-test 2 also showed no statistically significant difference ($t = 1.26$, $p = 0.212$) between females and males, although the mean difference was slightly larger at this stage. The decreasing standard deviations across both groups from pre-test to post-test 2 suggest that the formative assessment intervention led to more consistent performance regardless of gender. These findings support the null hypothesis, indicating that the implementation of formative assessment in learning photosynthesis was equally effective for both male and female students, despite a slight but non-significant trend favouring male students in the later stages of the intervention.

4. Discussions

The findings from **Table 1** reveal a positive impact of formative assessment practices on students' academic performance in photosynthesis, a result supported by substantial evidence in educational literature. The data reveals that formative assessments contributed significantly to students' information retention and the effective application of knowledge, with a marked improvement in academic performance from the pre-test phase through the two post-tests conducted after the intervention. These findings resonate with the study of [25] who suggest that formative assessments can be instrumental in identifying and addressing knowledge gaps early on, thereby enhancing learning outcomes in later stages. The pre-test data highlighted the need for targeted interventions to support student learning, aligning with [26] findings. Their research emphasised that formative assessments enable students to identify and correct misconceptions, which improves their comprehension of complex topics like photosynthesis. Consequently, formative assessment practices were implemented to help students actively engage with the material, offering them feedback and tailored learning experiences.

The findings also agree with [27] who opined that formative assessments, through methods like quizzes, feedback, and self-assessment opportunities, help students build on their knowledge in incremental stages. The findings are also consistent

with [28], who found that formative assessments, when used to provide meaningful feedback and encourage self-regulation, contribute to students' motivation and deepen their understanding, particularly in challenging subjects like biology. [29] supports these findings, arguing that formative assessments, especially those that are interactive and iterative, foster an environment where students actively engage, stay motivated, and build self-efficacy, which ultimately enhances academic outcomes.

The findings from **Table 2** illustrate that both males and females performed better on equal basis after the use of formative assessment techniques in the biology classroom. This implies that there was a significant improvements for both genders following the intervention. This aligns with [25] findings that formative assessments can help students identify their strengths and weaknesses, leading to improved performance. It also aligns with findings from [27], who noted that formative assessments can encourage active learning and foster a supportive environment for students, particularly benefiting those who might be less confident. The pattern aligns with the study by Karaman (2021), which found that formative assessments can boost confidence and motivation, particularly in male students who may respond positively to competitive environments. Moreover, it agrees with findings from [30] and [31], which suggest that while formative assessments can lead to varying levels of performance based on gender, they do not significantly favor one gender over another.

Despite these positive findings, it is important to acknowledge a key methodological limitation of the study. The use of a one-group pre-test/post-test design limits the ability to attribute improvements in students' academic performance solely to the formative assessment intervention. The absence of a control group makes it difficult to rule out alternative explanations such as maturation effects, testing effects, or natural progression resulting from the standard biology curriculum, which are common threats to internal validity in pre-experimental designs [32] [33]. Consequently, although the observed gains suggest that formative assessment practices were beneficial, caution should be exercised when interpreting the results. Future studies employing experimental or quasi-experimental designs with control groups are recommended to strengthen causal inferences and provide more robust evidence of the effectiveness of formative assessment practices on students' learning outcomes in biology.

5. Conclusions and Recommendations

The implementation of formative assessment practices at Kotoku Senior High School had a positive effect on students' academic performance in photosynthesis. Prior to the intervention, students struggled with photosynthesis concepts such as the biochemical processes involved in photosynthesis, structural adaptations of the leaf, and the integration of related biological concepts. However, after the use of formative assessment practices, there was a notable improvement in students' performance across the post-tests. This indicated enhanced understanding and

better retention of the subject matter. Statistical analysis confirmed that these improvements were significant, reflecting the effectiveness of formative assessments in deepening conceptual understanding of students in photosynthesis. Furthermore, the impact was consistent across genders, with both male and female students demonstrating similar academic performance. Therefore, formative assessment has proven to be a valuable instructional approach for improving student outcomes in the teaching and learning of photosynthesis.

The school authorities in Kotoku Senior High School should provide enough teaching and learning materials to facilitate formative assessment practices in order to enhance the academic performance of students in biology concepts. Biology teachers in Kotoku Senior High School should also continue and adapt formative assessment practices to ensure equitable academic support for both male and female students.

6. Suggestions

- 1) The effect of formative assessment practices on students of different age groups could be conducted to understand the effect of formative assessment practices on developmental stages of students.
- 2) The effectiveness of formative assessment practices could be explored in other biology concepts apart from photosynthesis to determine their effect on students' engagement.

Conflicts of Interest

The authors declare no conflicts of interest.

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