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ORIGINAL ARTICLE

Implementing Student-Centred, Active-Learning Instructional Strategies in a Grade 10 Biology Classroom

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Ethical Statement
The project was conducted as part of a degree programme with institutional approval. Participants were informed of the risks and benefits and gave verbal assent which was documented by the researcher.

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No conflict of interest is present in the conduction or the reporting of this study.

ABSTRACT

This paper presents an analysis of the experiences of 28 grade ten Jamaican high school students and their teacher in an action research project involving the use of student-centred strategies to teach a unit on photosynthesis. Examples of these strategies include brainstorming, scenarios, and simulations. Three research questions guided the action research which utilised a unit test, questionnaire, structured interview, and a rating scale for data collection. The findings indicated a statistically significant gain on students' scores on the post-test for the unit on photosynthesis (t = -9.48; $p<0.05$). Results also indicated that the students generally responded positively to the use of student-centred strategies, for instance, increased engagement and linking concepts to real-life situations. The results imply that instructional strategies which involve students more in the learning process have the potential to increase their engagement and enhance learning. The teacher-researcher indicated that planning and implementing the strategies was rewarding but time consuming. To ensure successful implementation, teachers could benefit from professional development programmes that provide guidance on design and implementing student-centred strategies, while students could benefit from ongoing support and encouragement during the use of these strategies.

Keywords: biology, Jamaica, instructional strategies, student-centred

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INTRODUCTION

Science learning is essential for school children who will eventually be future citizens. Teachers are continuously looking for ways to improve teaching and learning as well as performances in science. In recent times, there has been a continuous focus on developing constructivist classrooms in which students play a role in building their knowledge using real-life experiences, rather than the teacher operating as a knowledge repository, as is the case in traditional or transmission approaches to instruction (Booyse & Chetty, 2016).

There has also been a shift away from practices that emphasize the summative assessment of learning, towards authentic tasks linked to real-life situations. Alternative forms of assessment such as performance-based assessment require students' in-depth responses, and utilise open-ended questions and tasks including oral presentations, essays, experiments, projects, and problem-solving scenarios (OECD, 2013). However, utilising these assessment forms effectively requires sustained support for teachers (OECD, 2020). While the body of research on science education in the Caribbean has been growing, more research is needed as students' under par performance in science continues to be of concern (Ogunkola, 2011; Singh-Wilmot, 2015).

The Jamaican National Standards Curriculum was designed for grades 1 to 9 and implemented in 2017 (Angus, 2016). Its science curriculum aims to develop scientifically literate citizens equipped with suitable knowledge, skills, values, and attitudes to cope with the challenges of the 21st Century. The curriculum promotes active learning and assessment strategies that incorporate the 4Cs: cooperation, critical thinking, creativity, and communication.

With new initiatives, the philosophy, content, and strategies may not be fully grasped immediately, and the key implementers such as classroom teachers, may even resist them (Pak et al., 2020). The first author of this paper, the teacher-researcher, initially learned about student-centred instructional strategies while interacting with the National Standards Curriculum during the early stages of its implementation. Prior to this, throughout her then eight years of teaching, her approach primarily involved providing information to students through lecturing, writing on the board, dictating notes, using PowerPoint presentations or reading from textbooks. During these sessions, students could ask questions, and she would also ask them questions. However, these exchanges were aimed at "imparting" knowledge without giving regard to students' prior knowledge, experiences, or learning preferences. This approach was nurtured, honed, and cemented by students' favourable performances on high-stakes examinations administered by the Caribbean Examinations Council (CXC), which are required for matriculation to post-secondary education in Jamaica. The teacher-researcher was, therefore, content with her teaching methods due to the students' success on examinations.

However, with the introduction of the new Jamaican curriculum, the teacher-researcher became aware of other approaches to teaching and received practical examples of active learning strategies through professional development workshops. The teacher-researcher also gained further insight on these strategies while enrolled in a graduate-level teacher education programme at a tertiary institution in Jamaica. Encouraged by her exposure to the National Standards Curriculum, and engagement in the teacher education programme, she took on the role of researcher to investigate the use of active learning strategies in her classes.

The purpose of the study was to determine how grade 10 students and the teacher-researcher responded to the use of selected active learning strategies in biology classes. This study was guided by the following questions:

1. How does the focused use of a variety of active learning instructional and assessment strategies affect the academic

performance of grade 10 biology students on a unit test on photosynthesis?

2. What are grade 10 students' impressions of the use of active learning instructional strategies in biology classes?
3. What are the lessons learned from using active learning instructional and assessment strategies for teaching biology to grade 10 students?

The findings from this study can be useful for science teachers in Jamaica as they implement the National Standards Curriculum. Additionally, teachers in other locations who would like to create a more student-centered, constructivist environment in biology and similar classes may find the results useful.

LITERATURE REVIEW

The Constructivist Classroom

Constructivism is a philosophy of education that emphasizes that learners should be cognitively active during learning (Schunk, 2020). It originated with the work of psychologist Jean Piaget who suggested that students have their own ideas, and teachers should not serve as information givers, while students are the passive receivers. This idea was further developed by Vygotsky, who proposed that sociocultural systems influence an individual's learning (Shabani, 2016). In constructivist classrooms, teachers provide scaffolding and guidance to support students by relating concepts to real-life situations, and engaging them in problem solving. The teachers also encourage students to use existing knowledge to construct new understanding (Booyse & Chetty, 2016).

Lave and Wenger (1991) proposed the theory of situated learning which suggests that learning is influenced by one's context and social interactions. They also suggested that information should be presented in a way that students can make connections, rather than in an abstract manner. Teachers can create meaningful learning experiences through cooperative learning, where groups of students of different abilities work together to discuss ideas and solve problems (Gillies, 2016), and anchored instruction where activities are linked to real-like situations and information (Kariuki & Duran, 2004). These theoretical constructs run counter to the traditional transmission model of teaching and learning (Itbar et al., 2020), where teachers are viewed as the primary source of knowledge, and students the passive receivers.

Student-Centred, Active Learning Strategies

Students taking centre-stage in student-centred teaching is based on constructivist principles, and encourages critical thinking and problem solving in authentic situations (Lukman & Krajnc, 2012; Ozola, 2012). The teacher guides students using strategies such as brainstorming, simulation, role play, discussion, and demonstrations (Fernando & Marikar, 2017; Miller, 2013; Singh et. al., 2019; Weimer, 2013). Kawalkar and Vijapurkar (2015) found that eighth-grade students had meaningful learning experiences when taught using discussions, activities and investigative experiments in comparison to traditional teaching, therefore, it is important for teachers to incorporate these strategies in their teaching. The 5E instructional model, which includes engagement, exploration and explanation, can be an effective framework for supporting student-centred teaching (Llego, 2022).

Brainstorming encourages active participation when students are given a stimulus and allowed to generate potential solutions to a problem. The strategy seems to be less-commonly used in science classrooms, however, Owo et al. (2016) and Wagbara (2020) found significant differences in academic performance between Nigerian secondary students taught

chemistry with brainstorming, and students who were not, in favour of the treatment group. Similarly, brainstorming improved students' motivation, confidence, class participation, critical thinking and problem-solving skills in studies conducted in Malaysia by Unin and Bearing (2016,) and Lim et al. (2018).

Simulations, role play, drama, and games can engage students and increase their understanding of scientific concepts by providing visualisations. There are different interpretations of the relationships among these strategies (McSharry & Jones, 2000; Overland, 2017), and Feinstein et al. (2002) argue for differentiation among them to evaluate the effectiveness of each as a teaching strategy. Simulations involve mimicking or modelling situations (e.g., via computers), while role play, drama and games provide opportunities for students to participate actively. Several studies have reported positive results for these strategies in science. For example, a study in Israel found that seventh-graders taught using simulations showed improvement in their understanding of the kinetic molecular theory when compared to a control group (Stern et al., 2008). Other studies reported positive results for role play, drama-based, and game-based learning in science among secondary school students (e.g., Abed, 2016; Franco-Mariscal et al., 2015; Maharaj-Sharma, 2008; McGregor, 2012; Stojanovska & Velevska, 2018; Tsai et al., 2020). These studies found that the strategies motivated students and teachers, enabled learning by connecting abstract concepts to real-life scenarios, and fostered positive attitudes towards science. Overall, interactive methods have been found to be effective in engaging students and improving their understanding of scientific concepts.

In addition to brainstorming, simulations, role play and drama, demonstrations have enhanced students' understanding and interest. For instance, Basheer et al. (2017) found that demonstrations enhanced eighth-grade Israeli chemistry students' understanding of oxidation and reduction. However, Odom and Bell (2015) observed that teacher-led demonstrations where students were passive did not improve eighth-grade students' scores on a science achievement test in the USA. The effectiveness of demonstrations may, therefore, depend on factors such as the design of the demonstration and the level of student engagement. For instance, Crouch et al. (2004) reported that pre-medical students in an introductory physics course experienced learning enhancement when allowed to make predictions on the expected outcomes of a demonstration. Videos when utilised in demonstrations can increase students' motivation and creativity (Mendoza et al., 2015; Rose, 2018), however, teachers must know how to incorporate them appropriately to effectively impact learning. The common thread among these strategies is their potential for promoting critical thinking and real-life application.

Assessment is the cornerstone of the classroom as it allows teachers to gauge their effectiveness in teaching, and students to evaluate their learning. While traditional pen and paper tests have been prominent in education, alternative forms of assessment are being incorporated in curricula due to the constructivist focus (Seng, 2014). Alternative assessments have the following attributes: (i) they are authentic, and teachers choose the methods that are used while accommodating students' initiative and choice; (ii) they consider the learner and the context; and (iii) they emphasise the learning process as equally or more important than the product (Janisch et al., 2007). Alternative assessment strategies include videos, simulations, portfolios, poems, songs, debates, and models, all of which prioritise student-centred approaches.

Challenges to Implementing Student-Centred, Active Learning Strategies

Interactive methods are effective in engaging students, however, teachers face several challenges when attempting to implement them. Aliusta and Ozer (2014) conducted a study involving 33 high school teachers in North Cyprus to identify

barriers to using this approach. The main barriers reported were the students' educational background and motivation, the curriculum, availability of educational resources, classroom structure, and parents' socio-economic background and attitudes towards teaching and learning. Additionally, teachers cited a lack of training on how to implement student-centred strategies. Studies on high school teachers by Aliusta et al. (2015) in North Cyprus and Seng (2014) in Malaysia revealed that strategies such as discovery learning, and group work were perceived to be difficult, time-consuming, and ineffective for syllabus completion.

Peters (2010) conducted a case study in a grade seven classroom in the USA, where student-centred strategies were employed to teach a four-week unit on genetics. The teacher facilitated students' exploration of information sources, and they engaged in student-led seminars, formulated questions based on genetics-related readings and discussions, completed a literature review paper, and participated in role play. However, the students expressed discomfort with this teaching approach. Peters (p. 330) noted that "…students have little experience with the skills and knowledge needed for successful learning in student-centred classrooms." Scaffolding is therefore needed, especially if students are accustomed to teacher-centred classroom formats. Scaffolding allows the breakdown of challenging and complex activities or concepts into manageable, single-step components (Ahmed et al., 2022). This can help students to transition more smoothly into student-centred environments.

METHOD

Research Design

This study utilised an action research design incorporating both qualitative and quantitative data collection methods. According to Mertler (2021), action research is valuable for improving practice in various sectors in life such as education. Action research involves practitioners and researchers working together to apply theory in real-life settings. In the current study, the first author took on the role of researcher to investigate ways to enhance her teaching. The research process involved one complete cycle including planning, acting, observing, and reflecting. Drawing on the theoretical knowledge of constructivism, and the professional experiences gained with student-centred, active learning strategies, the teacher-researcher designed and planned the implementation of varied student-centred teaching and assessment strategies in a grade 10 classroom.

The study was a requirement of the graduate programme pursued by the teacher-researcher, and was to be completed during the practicum period. The study's conceptualisation occurred during the first term of the school year, while the teacher-researcher participated in professional development activities related to the university programme. The implementation of the action research occurred over a four-week period during the second term (February - April) of the school year.

Participants

The study was conducted in an all-girls high school in Jamaica, and involved 28 biology students, aged 14-16. At the time of the study the school was piloting the new National Standards Curriculum, which led to a focus on implementing new instructional strategies. The class was selected for the study based on the variation in their range of scores on unit tests for the topic "Cells", indicating a diverse level of understanding compared to other grade 10 classes taught by the teacher-researcher in the first term. During the practicum period, the teacher-researcher's supervisor, who is the second author, visited the classroom, observed lessons, and provided feedback.

Data collection

The intervention focused on the unit topic "Photosynthesis" which is aligned to the specific objective "Nutrition," and sub-objectives 2.2 (the process of photosynthesis in green plants), 2.3 (relating the structure of a leaf to the function of photosynthesis), and 2.4 (environmental factors and the rate of photosynthesis) of the CXC examination syllabus (Caribbean Examinations Council - CXC®, 2017). The planned unit was organized into a series of five lessons (see Appendix A). The 5E model was utilised, and a variety of instructional strategies were planned for each lesson, for different stages of the model (e.g., brainstorming, videos, demonstration, simulation, scenarios) (see Table 1 and Appendix A).

Table 1. Outline of the lessons taught during the study

Lesson title	Instructional/ Assessment Strategy	5 E phase focus	Implementation: Students' tasks
1. **Adaptations of the leaf for photosynthesis**	Brainstorming	Engage Explore Explain Elaborate	• Inspect leaf samples; Observe pictures of the internal leaf structure; Connect everyday items with photosynthesis.
	Flow Chart	Evaluate	• Work in groups to create a flow chart using leaf structure names.
	Résumé writing	Evaluate (homework)	• Role play as a leaf structure and write a resume for a job at "The photosynthesis factory".
2. **Structure of the leaf**	Argumentative essay	Evaluate	• Write an essay based on a given scenario.
3. **Factors affecting photosynthesis**	Demonstration	Engage, Explore, Explain	• Watch a video on testing leaves for starch; Conduct tests on variegated and unvariegated leaves for the presence of starch.
4. **Limiting factors of photosynthesis**	Simulation, Scenarios	Explore, Evaluate	• Simulate a task related to limiting factors; Use scenarios for problem-solving activities.
5. **Testing the leaf for starch**	Laboratory activity	Explore	• Test variegated leaves for the presence of starch.

The teacher-researcher designed a 5-point rating scale to evaluate various factors related to the instructional and assessment strategies (e.g., planning and execution time, resources required, resources used) (see Appendix B). Lower ratings (e.g., "1" or "2") indicated that the activity required more resources or resources were difficult to source, higher planning and execution time, as well as decreased student-attentiveness and engagement. The teacher-researcher also designed an 8-item multiple choice test to determine students' performance on the photosynthesis concepts. The test items were validated for content by one science education, and two biology experts, one of whom was the second author and co-researcher (see Appendix C). The test was administered before the lesson taught on "The factors affecting photosynthesis", and after the lesson on "Limiting factors of photosynthesis". Seeing there was no control group, the benchmark for comparison was the test scores from the unit test on "Cells" in term one when students were taught mainly with the lecture method.

Drawing on the work of Basheer et al. (2017), the teacher-researcher designed a questionnaire to obtain quantitative responses on students' perceptions of the instructional strategies used in the lessons. The questionnaire consisted of 13 Likert-type items organized into two themes that addressed students' opinions on the instructional and assessment strategies used (see Appendix D). The second author reviewed the questionnaire for content validity. The questionnaire was administered at the end of the photosynthesis unit. The teacher-researcher used questioning throughout the unit to gather students' opinions about the instructional strategies, usually at the end of selected lessons. These sessions included up to six students who voluntarily responded to two open-ended questions: "What did you like about the instructional strategies which were used in the lesson?" and "What did you dislike about the instructional strategies which were used

in the lesson?" The teacher-researcher wrote down the students' responses.

Data analysis

The test scores were analyzed using descriptive statistics (mean and standard deviation). Paired sample t-test was used to compare the pre- and post-test mean scores for the photosynthesis test. Further, the photosynthesis post-test mean score, and the previous term's score on cells, were compared using an independent sample t-test. Questionnaire data were collated and converted to percentages. Qualitative data from the teacher-researcher's and students' reflections were read and re-read to get a sense of the entirety of the data. Data were then coded and analysed for patterns, which were grouped into themes. The quantitative and qualitative data were collectively used to gain a deeper understanding of the specific issue under study.

Ethical considerations were addressed in the project. The study was conducted as part of a course for which institutional approval was granted. Students were informed that completing the questionnaire and participating in the end-of-lesson reviews was voluntary. They were told not to provide any identifying information on the questionnaire, and the activities that the students were expected to participate in were a part of their regular curriculum requirements.

RESULTS

Research Question 1: *How does the focused use of a variety of active learning instructional and assessment strategies affect the academic performance of grade 10 biology students on a unit test on photosynthesis?*

The biology students had different levels of knowledge between the first and second administration of the unit test on photosynthesis. Their mean score increased by 1.8 points from 6 (SD 1.07) out of a possible 8 points (75%) to 7.8 (SD 0.42) or 97.5%. Additionally, the range of scores decreased from "4" for the pre-test to "1" for the post-test, indicating a narrowing of the variation in understanding among the students. Furthermore, the t-test results showed that there was a statistically significant difference between the two test means (t = -9.48; $p < 0.05$). The results of the unit test, therefore, suggest a significant improvement in the biology students' knowledge, as evidenced by the increase in their mean scores.

The difference in the scores could have been due to item familiarity between the first and second administration of the photosynthesis unit test. However, when the photosynthesis pre-test scores (75%) were compared with students' scores on the previous test on cells (67%), the t-test results showed that there was a statistically significant difference (t= -3.65; $p < 0.05$). This suggests that the active learning instructional strategies could have contributed to the students' better performance on the photosynthesis unit test. Overall, the biology students' knowledge improved significantly on the photosynthesis unit test, compared to the previous unit taught by traditional strategies.

Research Question 2: *What are grade 10 students' impressions of the use of active learning instructional strategies in biology classes?*

There was mixed feedback about the instructional methods garnered from students' responses on the questionnaire and reflection items. The students gave several reasons why they liked the photosynthesis lessons, and they also provided reasons why the strategies appeared to be challenging. Six themes were identified from the data. These are: *Link with real world experiences*, *Enjoyable classroom environment*, *Easier assessments*, *Work demand and pace*, *Strategy choice and design*, and *Scaffolding*.

Most of the students indicated that they liked the types of instructional and assessment strategies used. In response to the questionnaire statement, "I prefer when my teacher uses simulations, videos, demonstrations and other types of activities to aid me in discovering and learning the information", most students (57%) agreed or strongly agreed. Further, 61% of the students indicated that they preferred the new instructional techniques to the traditional approaches. With respect to the assessment strategies, 68% of the students indicated that they liked the tests, quizzes, resume writing, flow charts, scenarios, and argumentative pieces. The majority of students (78%) indicated that the teacher-researcher should continue using these assessment methods.

Link with real world experiences

The students indicated they liked the instructional strategies because they provided links with familiar experiences, which made information more relatable and understandable. The simulation activity of "limiting factors" in photosynthesis appeared to be the most memorable of the strategies. It was gamified in the form of a competition, which could have contributed to its lasting impact on the students' learning. The following statements from two students illustrate this, "Miss I can see the application of it now, it makes sense now." and "The simulation that was used to explain the limiting factors allowed me to visualize the effect that small amounts of carbon dioxide or light would have on photosynthesis." Additionally, the simulation used everyday items such as a pair of scissors, paper, and markers to simplify a concept that students often find abstract and challenging.

Enjoyable classroom environment

Students expressed that the general classroom environment was more enjoyable when using student-centred and active learning strategies, compared to when traditional methods are used. One reason for this was less notes-giving in class by the teacher-researcher, which allowed the students to feel that more time was available to be involved in class activities, allowing for greater self-expression. One student explained, "I like when I can easily share views with the class Miss. In some of your classes, you were rushing to give us notes so we could not share…" Another student similarly expressed that the strategies used broke the monotony of "simply listening to the teacher explaining all the time." Overall, the students expressed that the use of student-centred and active learning strategies created an engaging classroom environment.

Easier assessments

The benefits of using more relatable activities were also applicable to the assessment tasks. One student said that because the resume writing exercise was relatable it was easier for her to write about the adaptations of the leaf for photosynthesis. She stated, "In a résumé, you write about your skills and why you should be hired, so [I understand] I am supposed to write about the 'skills' of the leaf…" Another student explained that she found the assessment tasks to be easier because they were focused on a particular area of the topic, rather than the entire topic. Thus, the students' feedback suggests that using relatable activities in assessment can be beneficial for students, as it can make tasks more meaningful and relevant.

Work demand and pace

The students' impressions about the work demand of the strategies was mixed. Although some students thought the strategies and assessments were easy, others expressed that the tasks required too much work for students and less for teachers. Some students also felt that the strategies slowed down the pace of the lessons, leaving them falling behind

the students in other grade 10 biology classes. One student stated with respect to the brainstorming activity, "Miss, thinking is a lot of work" and suggested that the teacher should "find similar activities which would not require too much work" for students.

Strategy choice and design

Some students provided feedback on how to make the tasks more meaningful and engaging. They mentioned that some assessment tasks reminded them too much about traditional assessments such as essays, and recommended alternative approaches. For example, students suggested conducting a job interview or, having a debate, as alternatives to the résumé writing exercise and the argumentative piece. Indirectly, these students could be suggesting that they found writing tasks to be more difficult and/or time-consuming. However, a positive idea being noted here is that the students themselves were proposing strategies that would require their active involvement. The students' recommendations provide valuable insights into how to improve the learning experience for all students.

Scaffolding

Students indicated a preference for the teacher finding other ways of sharing new strategies or information with them as they felt "they [students] can make mistakes" if left on their own. One student stated that they were not getting enough notes stating, "I like when you give us the notes in class, Miss". This feedback from the students suggests that while they may appreciate the use of student-centred instructional strategies, they also valued guidance and support from the teacher in the form of notes and other instructional materials.

Research Question 3: *What are the lessons learned from using active learning instructional and assessment strategies for teaching biology to grade 10 students?*

Table 2 reports on the teacher-researcher's impressions of various factors related to planning and using the instructional strategies. With respect to the criterion "Planning the lessons", finding appropriate videos, and planning the demonstration and simulation activities took the longest time, with ratings of "2", "1" and "2" respectively, indicating these activities required at least 30 minutes of planning. The resources used for all the assessment methods and the simulation were accessible, receiving the highest rating of "5". However, the teaching strategies such as videos and demonstrations required resources which were less accessible and were more difficult to set up.

Table 2. Teacher researchers' rating of factors related to planning, resources and implementing various instructional and assessment strategies

Instructional/ Assessment strategy	Rating*				
	Lesson planning time	Lesson execution time	Resources utilised	Real-world application	Student attentiveness
Scenarios	4	4	5	5	2
Argumentative essay	4	4	5	4	5
Flow chart	4	4	5	3	4
Resume writing	4	5	5	4	4
Videos	2	4	3	3	5
Simulation	1	2	5	5	4

Demonstration	**2**	**2**	**3**	**3**	**2**
Brainstorming	**4**	**2**	**3**	**5**	**3**

*** Lower numbers on the scale indicate more effort in sourcing resources, planning, and executing the lesson by the teacher-researcher. The lower numbers also mean students were less attentive during the task and there were fewer opportunities for real-world applications.**

During lesson implementation, the simulation, brainstorming, and demonstration exercises exceeded the planned time by more than 15 minutes. This time difference was large in comparison to other strategies which either finished on time, or had a minor overrun of up to five minutes. The teacher-researcher rated brainstorming, scenarios, simulation, argumentative essay, and resume writing as highly effective in providing opportunities for real-world application and fostering higher-order thinking skills. The students were observed to be concentrating, and approximately 90% attentive while viewing videos and writing the argumentative essay. Similarly, during the flow chart, résumé writing and simulation activities, students remained on-task approximately 80% of the time. The brainstorming exercise received a rating of "3" indicating moderate engagement. The demonstration and scenario exercises received the lowest rating of "2", indicating that students appeared to be least engaged during these strategies. There was, therefore, no clear pattern between the teacher-researcher's intended purpose of the strategies and the students' actual response. For example, despite the teacher-researcher's high rating for scenarios, expecting they would be more relevant and interesting to the students, they seemed least engaged while working with the scenarios.

Most of the student-centered activities kept students attentive (Table 2). However, it required more time for the teacher-researcher to plan and execute the lessons. Reflecting on a lesson that included demonstration, the teacher-researcher noted, "I thought the demonstration went well, however I think it took up too much time. Time was lost in setting up the workstations." In lesson planning, the teacher-researcher considered the appropriateness of activities, the supporting content information, and questions to stimulate students' thoughts. The teacher-researcher summed up her experiences with the instructional strategies stating:

> Initially, I was apprehensive about including these methods in my typical classroom routine. However, as I began to use these methods and noticed the response of the students and the changes in their performance, I became more amenable to these methods. I took up the challenge to create my own activities and succeeded in creating an innovative simulation for teaching the limiting factors of photosynthesis.
>
> In my final evaluation…I was commended for the use of an unusual but effective simulation, to teach an abstract concept. This simulation was my own design, and it took a great deal of thought to create. I was very proud of my creation.

Overall, while student-centered activities required more time and effort from the teacher-researcher, they appeared to be effective in increasing student engagement and biology understanding.

DISCUSSION

One aim of the study was to investigate the effectiveness of student-centred, active learning strategies on biology students' academic performance. Results of the pre-test on photosynthesis revealed a significant increase in students' knowledge compared to a previous test on a topic taught mainly by traditional lecture methods. The use of student-centred, active learning-oriented strategies might have contributed to the improvement in students' academic

performance. This finding aligns with other studies that have highlighted the effectiveness of strategies such as brainstorming, simulations and role play on students' academic performance (e.g., Maharaj-Sharma, 2008; Owo et al., 2016; Stern et al., 2008; Unin & Bearing, 2016).

The students responded positively to instructional methods, such as role play, stating reasons like their ability to connect content with real-life experiences. This finding aligns with Kawalkar and Vijapurkar's (2015) study where eighth-grade students indicated a preference for non-traditional teaching methods. The idea of using activities like role play because of their potential to make learning more relevant (McSharry & Jones, 2000), is supported by the principles of anchored instruction and constructivism (Booyse & Chetty, 2016; Kariuki & Duran, 2004; Schunk, 2020). Constructivism emphasizes the active role of learners in knowledge-building, while anchored instruction links lesson activities to real-world situations. Through role-play, students actively engaged with the material and made connections with personal experiences, promoting a deeper understanding of the concepts taught.

Some students appreciated the resume writing activity and scenarios as they allowed self-expression without the requirement to conform to a specific answer or format. These strategies also increased engagement and potentially improved content assimilation, aligning with the findings of other studies (e.g., Franco-Mariscal et al., 2015; Tsai et al., 2020). The gamified limiting factors simulation using everyday materials, might have assisted in making the abstract concept of photosynthesis more concrete (Stojanovska & Velevska, 2018). Overall, the photosynthesis test results indicate that student-centred and active learning strategies are effective for teaching biology topics and enhancing academic performance.

While the use of student-centered and active learning strategies can positively impact students' learning, their implementation is not without challenges. These challenges include heavy work demand, slow lesson pacing, dissatisfaction with strategy choice and design, and the need for scaffolding to support students' learning. Students' impressions of the work demands varied, with some finding them manageable, and others finding them too demanding, shifting the workload from teachers to students. Some students also felt that the strategies slowed down the pace of the lessons. Additionally, students proposed changing writing tasks to oral presentations to make them more meaningful and reduce resemblance to traditional assessments.

Janisch et al. (2007) emphasized that teacher-chosen strategies in constructivist classrooms should accommodate students' choice and context. Teachers should know the strategies suitable for intended learning outcomes and how to design them. Aliusta and Ozer (2014) similarly highlighted the concern of teachers lacking training in implementing student-centered strategies. It is important for teachers to consider their students' varying needs and preferences when implementing new teaching methods. Notably, in this study, students themselves proposed strategies which required their active involvement.

Students expressed the need for teachers' involvement in their learning when new strategies are being introduced. They expressed a desire for teachers to find alternative ways of sharing new strategies or information with them and concern about being left without guidance to make mistakes. Peters (2009) emphasized the need for scaffolding in student-centered settings, as students lack the experience, skills and knowledge for success in such classrooms. If teachers are strategic in scaffolding, students' fears can be alleviated. Scaffolding is effective in student-centered techniques such as simulations and brainstorming, as it breaks down content into simpler, manageable components (Ahmed et al., 2022), allowing for deeper understanding when students put the pieces back together. Although student-

centered methods consider students' individual contexts and experiences, catering to everyone's varied preferences is challenging. However, addressing these challenges is necessary for successful implementation of student-centered and active learning strategies.

Implementing active learning strategies presents benefits but also challenges for teachers, as indicated by the study findings. It is crucial to consider time and resource requirements when planning lessons. The teacher-researcher reported that most of the methods had accessible resources, however, some required more time and less accessible resources, making set up and execution more difficult. For instance, simulation, brainstorming, and demonstration exercises exceeded the allocated implementation time in the lesson plans, indicating a need for additional time for teachers to plan and implement active learning strategies. In studies by Aliusta et al. (2015) and Seng (2014), teachers expressed concerns about their ability to complete the syllabus on time when using active learning strategies. Similarly, students in the current study lamented about lagging behind their peers in other biology classes.

Lukman and Krajnc, (2012) and Ozola, (2012) found that students respond positively to active learning strategies incorporating real-life situations. Student-centered activities, therefore, have the advantage of capturing students' interest and engagement (Franco-Mariscal et al., 2015; Tsai et al., 2020). The teacher-researcher identified brainstorming, scenarios, and simulations as being well-suited for real-life application and higher-order thinking skills. Additionally, some strategies like videos and argumentative essays, appeared to support students' ability to remain focused.

Furthermore, simulation, flow-chart, and demonstration activities facilitated active, hands-on learning. According to Odom and Bell (2015), demonstrations where students are passive have limited impact on students' academic performance. Crouch et al. (2004), therefore, recommend incorporating opportunities for student participation even in teacher-led demonstrations. In the current study, both the teacher-researcher and students participated in a demonstration activity involving a video on testing a leaf for starch, followed by doing the task. However, students appeared to exhibit reduced engagement during the task, highlighting the need to captivate their attention even during the use of active learning strategies.

The benefits of student-centred, active learning strategies in promoting student engagement and academic performance have been highlighted in this study. However, Aliusta and Ozer (2014) raised concerns about teachers' lack of training on how to implement the strategies. This is possibly due to the shift required from familiar traditional strategies to take on a facilitator role. The findings of the study revealed a slight disconnect between the teacher-researcher's intended purpose for student-centred strategies and the students' actual response. The students perceived some tasks as demanding more effort from them and less from their teacher. On the other hand, strategies such as scenarios did not seem to engage students as the teacher-researcher had anticipated. This highlights the importance of providing instructional support for teachers to strike a balance between selecting informative and engaging strategies, while ensuring manageable workload for both students and teachers.

The teacher-researcher initially felt apprehensive about incorporating student-centered activities into her classroom, but became more comfortable after observing students' positive responses and performance improvements. The teacher-researcher gained confidence over time and even created her own activities, tailored to the students' context. The teacher-researcher's growing confidence could have been partly due to the mentorship received from her supervisor (Mertler, 2021), who provided guidance during the action research process. This experience highlights the importance of offering teachers training and mentorship to effectively implement student-centered strategies.

CONCLUSION AND RECOMMENDATIONS

This study provides valuable insights into the use of student-centered learning strategies in high school science classes often characterised by teacher-centred approaches. The study yielded positive cognitive and affective outcomes for grade 10 biology students. The study also revealed the effectiveness of action research in assisting teachers' professional development. The teacher-researcher gained greater understanding, appreciation, and confidence in using student-centred teaching and assessment methods. These findings highlight value in these strategies that science teachers should take note of and consider implementing.

Based on the findings, several recommendations are proposed for future implementation. Teachers should focus on fewer strategies when planning lessons to prevent overburdening students and ensure a meaningful learning experience. Additionally, teachers should consider students' needs, incorporate their suggestions for lesson activities, and properly oriented them to the use of these strategies. Furthermore, seeing that classrooms are diverse, it is also recommended that these strategies be used along with traditional teaching and learning strategies. The findings of the study indicate that mentorship programmes or inclusion in teacher education programmes can provide valuable support to classroom teachers who are implementing active learning strategies.

One limitation of the study was that it was conducted in a single classroom with only girls. The ideas shared, however, could be beneficial to classroom teachers in other country contexts who are implementing new curricula. Further research, including comparative studies between experimental and control groups, is warranted to expand on these findings.

This study provides evidence that student-centered instructional methods can positively impact academic performance and attentiveness in high school science classes. With appropriate training and support, teachers can create an engaging classroom environment that promotes student success. These findings could inspire further research and implementation of student-centred methods in Caribbean science classes, leading to positive educational outcomes for students in the region.

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APPENDIX A

Outline of the tasks involved in the five lessons implemented in the study

Lesson	**Instructional/ Assessment Strategy**	**5 E phase**	**Implementation: Students' tasks**
1.Adaptations of the leaf for photosynthesis	Brainstorming	Engage	Inspect leaf samples to identify features related to photosynthesis.
		Explore	Observe pictures of the internal leaf structure and suggest the function/s of the various layers.
		Elaborate	Use pictures of everyday items (e.g., wood, cotton, paper, solar panels) to determine possible connections with photosynthesis.
	Flow Chart	Evaluate	Create a flow chart with leaf structure names on paper/cards, to show how tissues are linked in photosynthesis.
	Résumé writing	Evaluate (homework)	Role play as a leaf structure, and write a resume for "The photosynthesis factory" explaining their job qualification, function and how they plan to carry out their task/s efficiently.
2. Structure of the Leaf (laboratory activity)	Argumentative essay	Evaluate	Draw and label a local dicotyledonous leaf then provide answers for Maria based on a prompt. "*Maria does not believe that plants make their own food…"*
3. Factors Affecting Photosynthesis Nb. The pre-test was given at the beginning of this lesson	Demonstration	Engage	Watch a video on testing leaves for starch and answer related questions.
		Explore and Explain	Work in groups and are given a vial containing iodine, corn-starch, and unvariegated and variegated *Hibiscus* leaves previously boiled to extract the chlorophyll. Students put drops of iodine on the corn-starch and note the colour change. Next they put drops of iodine on the leaves and note the colour changes. Students make inferences which are discussed in class.
4. Limiting Factors of Photosynthesis Nb. The post-test was given two weeks later at the end of this lesson	Simulation	Explore	Work in pairs at one of three imaginary hat factory workstations, each short of one of three components (paper, markers, worker) needed to make a paper hat. Students learn how to make paper hats, then have two minutes at each workstation to make as many as possible. Student observers note the number of hats made by each group. Students suggest the factors which affected the rate of hat-making at each workstation.
	Scenarios	Evaluate	Identify the limiting factor of photosynthesis in scenarios from different climate contexts, including, plants growing on a woodland floor in winter and summer, and banana trees in a plantation in the morning and later in the day.
5.Testing the Leaf for Starch (laboratory activity)	Photosynthesis chemical test		Test variegated leaf for the presence of starch.

APPENDIX B

Teacher's rating scale used to record experiences of various factors related to instructional strategies

Factor	Rating				
	1	2	3	4	5
Lesson planning time	>60 minutes	Up to 60 minutes	Up to 50 minutes	Up to 40 minutes	Up to 30 minutes
Lesson execution time: Met or exceeded	Exceeded by >15 minutes	Exceeded by 15 minutes	Exceeded by 10 minutes	Exceeded by 5 minutes	Execution time met
Resources required	Individuals/ equipment that are sourced outside the school	Expensive or limited equipment	Laptop, projector	Lab equipment	Simple items e.g., pen, paper
Activity links to higher order thinking skills; Real-world application (using Webbs' Depth of Knowledge)	10% and lower	20%	30%	40%	50% and above
Student engagement/ attentiveness with the task	20%	40%	60%	80%	100%

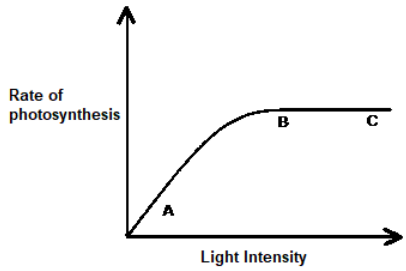
APPENDIX C

Biology Test Sample Items

1. Choose the list which correctly identifies the factors which affect the rate of photosynthesis.
   A. Carbon dioxide, oxygen, light.
   B. Water, chlorophyll, glucose.
   C. Temperature, oxygen, chlorophyll.
   D. Light, carbon dioxide, temperature.

2. Study the graph below then choose which of the following options **BEST** explains which factor is limiting photosynthesis in segment A of the graph.

   A. The volume of water is limiting the rate of photosynthesis
   B. The light intensity is limiting the rate of photosynthesis
   C. The temperature is limiting the rate of photosynthesis
   D. The carbon dioxide concentration is limiting the rate of photosynthesis



APPENDIX D

Questionnaire for students' perceptions regarding selected instructional strategies

Instructions: Read the following statements carefully and indicate your response by placing a tick (✓) in the appropriate box.

Key: Strongly Agree, SA; Agree, A; Neutral, N; Disagree, D; Strongly Disagree, SD

Number	Statement	SA	A	N	D	SD
1	I prefer to discover new information about a topic than to have my teacher give me the information.					
2	I prefer when my teacher uses simulations, videos, demonstrations, and other types of activities to aid me in discovering and learning the information.					
3	I believe that discovering the information for myself through the different activities set up by my teacher, allows me to have a better understanding of the topic.					
4	I thought the lessons on photosynthesis were very good because my teacher used many different activities to help me figure out the information for myself.					
5	I believe that other topics taught this way would improve my understanding.					
6	I prefer these new techniques to the typical 'chalk and talk' that my teacher did before.					
7	I would pay attention more and be less bored in class if my teacher used these techniques more often.					
8	I do not like these strategies.					
9	I like the tests and quizzes that were given in class.					
10	If given the opportunity I would prefer to be assigned a grade based on other methods such as project, a model, or a poem					
11	I liked the assessment methods used by my teacher such as the resume, flow chart, scenarios, and argumentative piece.					
12	These other assessment methods require as much work as a typical test.					
13	My teacher should continue to use these other assessment methods.					