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Conceptual Change Refutation Text: A Module Anchored on Senior High School Learners' Alternative Conceptions in Energy Transformation

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Index Terms:

refutation text, alternative conception, photosynthesis, cellular respiration, energy transformation, general biology, senior high school learners

Abstract. Refutation texts hold potential as a powerful tool for combatting misinformation. By directly addressing alternative conceptions and providing scientifically sound explanation, they create a cognitive dissonance that encourages critical thinking and knowledge acquisition. This developmental research aimed to develop a refutation text instructional module in General Biology anchored on learners' common alternative conceptions following the ADDIE model. Data were gathered from teachers, learners, and experts. The data gathering instruments were Photosynthesis and Cell respiration Two-tier Test, Educational Soundness General Evaluation Checklist, Focused Group Discussion (FGD) Protocol, and Evaluation Form for Printed Instructional Material. Findings revealed eighteen (18) alternative conceptions and were the bases for refutation texts integrated into the developed instructional module. The overall validation rating of the experts on the developed instructional module was Very Satisfactory. The learners' feedback was summarized by the following themes: well executed lesson; disturbed by unfamiliar science terms; suitable experiments and activities; and integration of refutation text. While the teacher-observers believed that the demonstration classes were engaging and interactive, having suitable content and activities, learning objectives were aligned and achieved, and integrating refutation text in lesson planning. The overall evaluation rating of the teachers was Very Acceptable. Experts and teachers recommended the developed instructional module as a valuable tool to address common alternative conceptions about photosynthesis and cellular respiration in the classroom.

Introduction

Energy transformation refers to the process by which living organisms convert energy from one form to another as living organisms need to acquire and utilize energy for growth, movement, reproduction, and all other biological processes (Reece et al., 2014). Because of this fundamental aspect of life, energy transformation is incorporated in the K to 12 Basic Education Senior High School General Biology 1 curriculum in the Philippines which discusses photosynthesis and cellular respiration that primarily investigates how cells generate, store, and utilize Adenosine Triphosphate (ATP), the primary energy currency of cells. These two topics, however, are not easy to understand as most of the concepts studied are events that cannot be seen directly by the eyes that forced most biology teachers to heavily rely on textbooks (Kidman, 2008) leading to senior high school STEM learners struggling to achieve conceptual understanding in the learning process, thus at times form alternative conceptions in these topics.

Alternative conceptions are incorrect understanding of ideas, objects or events that are constructed based on a person's experience, preconceived notions, non- scientific beliefs and theories, mixed conception, and conceptual

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misunderstandings (Martin et al., 2002) which are not necessarily in conflict with the accepted scientific knowledge. Previous studies revealed that learners acquire alternative conceptions before and during their school years which may be caused by poor instruction, improper reasoning, and poor memory (Ojose, 2015). Filipino high school learners had high levels of alternative conceptions on topics regarding photosynthesis and cellular respiration (Cuaderes, 2017). Moreover, photosynthetic reactions and acquisition and utilization of energy were still considered as the least mastered competencies among senior high school learners caused by the following factors: skipped lessons, teacher's lack of content mastery, unavailability of instructional materials, insufficient experiential learning, unstimulating nature and unfamiliar terminologies (Nagal, 2020).

Teachers are responsible for correcting the alternative conceptions of the learners to remove confusion among ideas. Familiarity with common alternative conceptions among learners could significantly impact learning for it may cause difficulty connecting new knowledge with their existing knowledge (Kazemi and Bayat, 2012). If not addressed, alternative conceptions can seriously undermine efforts to improve the scientific literacy of the general citizenry and the acquisition of accurate knowledge for those who proactively pursue science programs (Gooding and Metz, 2011).

One possible solution to this problem is to teach conceptual change. Taber and Vosniadou (2011) describes conceptual change as an approach that delves on a way of learning a particular subject matter such as science concepts that require significant restructuring or reorganization of existing knowledge and not merely adding up to what is already acquired. Refutation text is an approach designed to prompt conceptual change by having readers attend to conflicts between their own conceptions and those in a text (Tippet, 2010). Refutation text has been used in various disciplines (Broughton et al., 2010; Tippett 2010; Kowalski and Taylor, 2011) and has been shown to be particularly useful in combating alternative conceptions about science (Maria, 2000). While found effective in other disciplines, the use of refutation text has not been fully utilized in Biology textbooks and modules.

Guided by Conceptual Change Theory (Tanner & Allen, 2005), Feedback Literacy Theory (Carless and Boud, 2018), and Instructional Design Theory (Molenda, Reigeluth, and Nelson, 2003), figure 1 presents the ADDIE models of instructional process design composite of analysis, design, development, implementation, and evaluation.

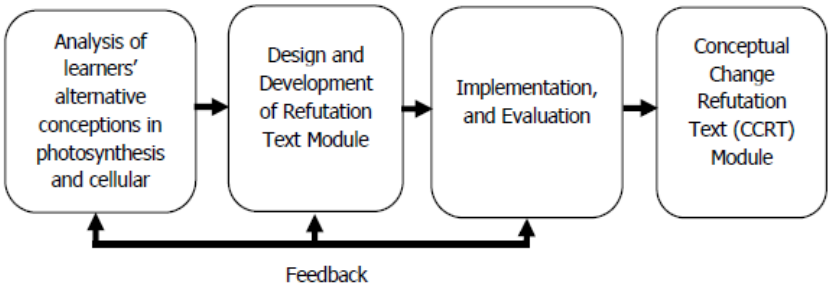

Figure 1. The ADDIE model of instructional process design

Statement of the Problem

This study employed developmental research design utilizing the ADDIE model as the research method in the development of a learning material anchored on senior high school learners' alternative conceptions in photosynthesis and cell respiration. Specifically, the study aimed at finding answers to the following questions:

1. What are the alternative conceptions in photosynthesis and cellular respiration among senior high school STEM learners?
2. What instructional material can be developed considering the learners' alternative conceptions in photosynthesis and cellular respiration?
3. What is the experts' validation of the developed instructional material in terms of (a) integrity, (b) learner focus, (c) usability, and (d) accessibility?
4. What are the learners' and teacher-observers' feedback on the developed instructional material?
5. What is the acceptability of the developed instructional material as evaluated Biology teachers in terms of (a) concept/content, (b) instructional quality, (c) technical quality (prints, illustrations, design and layout), (d) presentation and organization, (e) accuracy and up-to-datedness of information, and (f) assessment?

Methodology

Research Design

The study utilized developmental research design. Developmental research is the systematic study of designing, developing and evaluating instructional programs, processes and products that must meet the criteria of internal consistency and effectiveness (Seels & Richey, 1994). The development of the learning material followed the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model as the research method following the five phases: Analyzing a learning situation; Designing objectives and principles to address the issues in the learning situation; Developing of resources to meet these specifications; Implementing the learning resources in the learning situation; and Evaluating how these resources addressed instructional needs (Branch, 2009). Based on the analysis of learner's alternative conceptions in Photosynthesis and Cellular Respiration, the researcher developed an instructional module in General Biology 1 for Grade 12 senior high school STEM learners. Consequently, it was implemented and evaluated by the experts.

Locale and Participants of the Study

The study was conducted in two large public national high schools offering Science, Technology, Engineering, and Mathematics (STEM) strand in the first and second congressional district in Iloilo province, Philippines. The participants of this study were 5 Biology and Chemistry expert validators, 142 Grade 12 STEM learners, and 33 General Biology teachers selected using purposive sampling. The analysis phase of the study was conducted during the second semester of the school year 2023-2024 and the implementation of the developed learning material was conducted during the first semester of the school year 2024-2025.

The Grade 12 STEM learners must be a Grade 12 STEM learners who have taken General Biology 1. Learners who were above 18 years old at the time of the conduct of the study were given Informed Consent Forms and those who were below 18 years old were signed by their parents. Learners and parents who did not give consent to participate in this study or not available during data collection were excluded. The expert validators must be teaching for at least 10 years, a University lecturer or a high school teacher, and have a background in Biology or Chemistry with at least a master's degree identified by the researcher. Biology teachers who have not taught the subject, those who did not give consent to participate in this study or were not present during the data collection were excluded.

Instrumentation

The data needed were gathered using four data gathering instruments: (a) Researcher-made Photosynthesis and Cell respiration Two-tier Test. This 20-item instrument adopted from Malones (2022) was used to determine the alternative conceptions during the Analysis Phase. The test had undergone face and content validation, and pilot-tested following standard ethical considerations with a reliability coefficient of 0.788 using Kuder-Richardson 20; (b) Educational Soundness General Evaluation Checklist. This assesses and evaluates the design and development of learning resources using four sets of principles (Integrity, Learner Focus, Usability, and Accessibility); (c) Focused Group Discussion Protocol. The FGD protocol is divided into three parts: Introduction; Preliminary Questions; and, Learning Material Specific Questions; and (d) Evaluation Form for Printed Instructional Material. This evaluates the developed instructional module using the following criteria: concept/content; instructional quality; technical quality in prints, illustrations, design and layout; presentation and organization; accuracy and up-to-datedness of information; and assessment.

Data Collection and Analysis Procedure

Using the ADDIE Model, the activities were followed in every step of the instructional design model:

The Analysis Phase started by determining the STEM learners common alternative conceptions using the Photosynthesis and Cell Respiration Two-tier Test. The researcher administered the test to two (2) sections of STEM learners each from two (2) large public schools who were selected purposively with the help of their respective subject teachers. Informed consents were asked before the test administration. The participants were given 60 minutes to answer the 20-item test. Important instructions were also given to the learner-participants to ensure the correct procedure in answering the test. Results were encoded using the Microsoft Excel program. Common alternative conceptions in Photosynthesis and Cell Respiration among STEM learners were determined by assessing incorrect responses on the second tier of the Two-tier Test using frequency count, percentage, mean percentage and ranking of the responses. Only alternative conceptions with mean percentage score of 25.0 and above were considered as common alternative conceptions.

The Design Phase started with literature review to identify the conceptual change strategy to be integrated on the learning material. The teaching strategy used the refutation text which targeted learners' alternative conceptions in Science for better concept learning. The General Biology 1 Curriculum Guide was considered and served as the basis of the lesson contents and target competencies. The learning competencies were unpacked ensuring the breadth and depth of the learning contents. The instructional module followed the 5E lesson plan that consisted of five (5) parts: Engage; Explore; Explain; Elaborate; and Evaluate.

In the development phase, the assembly of the parts of the learning module was done. The module followed a step-by-step acquisition of knowledge and considered the necessary content. The common alternative conceptions identified in the analysis phase were assigned based on the lesson where they belong. After formatting and making sure every aspect of the instructional module was completed, the instructional material was subjected to validation by five (5) experts. The experts validated the instructional module for two (2) weeks. After the initial validation, a revised copy was sent to each expert based on their previous recommendations. The experts accomplished the DepEd Educational Soundness General Evaluation Checklist. A four-point Likert scale was used to measure the soundness of the instructional module based on the four sets of principles (Integrity, Learner Focus, Usability, and Accessibility). Upon their approval, copies of the instructional module were reproduced.

Prior to the implementation of the developed instructional module, the orientation of the learner-participants and teacher-observers were conducted in accordance with the ethical considerations of this study. A biology teacher conducted three (3) classes using the developed instructional module. After the trial implementation, a separate Focused Group Discussion was conducted using the FGD Protocol among ten (10) purposely selected STEM learners and (5) teacher- observers to solicit their feedback on the conduct of classes using the developed instructional material. The learners and teacher-observers signed the attendance sheets as proof of their participation. The researcher used an audio-recorder that documented the information shared by the key informants. After the interview, notes were transcribed. Their responses undergone thematic analysis to determine the themes for the qualitative aspect of the evaluation. Revisions were made on the module following their suggestions and recommendations.

Target schools were visited, asked permission and assistance from their respective school principals to distribute copies of the module and research instrument to their General Biology 1 teachers. In determining the module's acceptability, Biology teachers were given two (2) weeks to evaluate the instructional module. They were asked to complete the Evaluation Form for Printed Instructional Material. A four-point Likert scale used to measure the level for each criterion. The descriptive statistics used to analyze the quantitative data were frequency count, mean percentage, mean, and standard deviation.

Results and Discussion

Learners' Alternative Conceptions in Photosynthesis and Cellular Respiration

There were eighteen (18) alternative conceptions that were identified and categorized based on the item number and ranked as shown in Table 1.

Item no.	Alternative Conceptions	f	%	Rank
1	Carbon dioxide is combined with water using light energy and produces glucose, oxygen and water as products.	37	26.06	18
2	Plants take in CO_2 and change it to O_2.	90	63.38	1
4	Photophosphorylation splits ATP molecules which generates energy.	68	47.89	3
5	NADPH is an electron acceptor in the light dependent reaction.	40	28.17	15
6	NADPH accepts and stores carbon dioxide for photosynthesis.	42	29.58	14
6	NADPH accepts electrons.	40	28.17	15
8	Non green plants like fungi which do not contain chlorophyll or similar pigments can also photosynthesize.	38	26.76	17
10	During respiration green plants take in carbon dioxide and water in the presence of light energy to form glucose.	54	38.03	8
10	Carbon dioxide and water are used by the green plant to produce energy during which time glucose and oxygen waste are produced.	45	31.69	10

11	Green plants take in carbon dioxide and give off oxygen when they respire.	77	54.23	2
12	Cells of green plants can photosynthesize during the day and therefore they respire only at night when there is no light energy.	47	33.10	9
13	Glycolysis converts FAD to $FADH_2$ by substrate level phosphorylation.	45	31.69	10
14	Glycolysis is a part of cellular respiration and uses oxygen to generate ATP, NADH, and $FADH_2$.	65	45.77	5
14	Krebs cycle is an anaerobic process.	43	30.28	13
16	NADPH oxidizes water in order to remove electrons.	63	44.37	6
16	ADP accepts electrons to create ATP.	45	31.69	10
18	Only leaves have special pores (stomates) for exchange gas.	55	38.73	7
20	Plants respire when they cannot obtain enough energy from photosynthesis (e.g. at night) and animals respire continuously because they cannot photosynthesize.	67	47.18	4

Table 1. Common Alternative Conceptions in Photosynthesis and Cellular Respiration (N=142)

The common alternative conceptions identified in this study were also similar to the findings of past researchers. "Plants take in CO_2 and change it to O_2" The oxygen produced during photosynthesis actually comes from water molecules, not carbon dioxide (Cimer, 2013). "Plants respire when they cannot obtain enough energy from photosynthesis (e.g. at night) and animals respire continuously because they cannot photosynthesize". Respiration and photosynthesis are perceived by students as difficult to learn. They claim that students should have mastered the concepts like chemical reactions, organic and inorganic molecules in their chemistry courses in order to understand the chemical nature of respiration and photosynthesis. Approximately, all biology teachers interviewed have rated photosynthesis as one of the most difficult topics for students (Tekkaya et al., 2001). "Carbon dioxide is combined with water using light energy and produces glucose, oxygen and water as products". Students most probably memorized the definition and chemical formula of photosynthesis and perceived it as a simple process. However, photosynthesis is a complex process including a number of conceptual aspects - ecological, biochemical, anatomical-physiological and energy change -that are interlinked with each other (Tekkaya et al., 2001). "Only leaves have special pores (stomates) for exchange gas". A high percentage of secondary school students did not comprehend the nature and function of respiration and had no understanding of the relationships between photosynthesis and respiration in plants. Students believed that green plants respired at night and thought that respiration in plants takes place in the cells of the leaves only, since they believed that only leaves have special pores for exchange of gasses (Tuysuz, 2009). "Cells of green plants can photosynthesize during the day and therefore they respire only at night when there is no light energy." Many undergraduates lack both a basic understanding of the role of photosynthesis in plant metabolism and the ability to reason with scientific principles when learning new content. Some students think plants photosynthesize during the day and respire at night. However, plants actually photosynthesize and respire simultaneously during the day (Parker et al., 2012; Cimer, 2013). "Krebs cycle is an anaerobic process". This result showed that new alternative conceptions were identified and previously identified alternative conceptions in these topics by the previously cited authors resurfaced. Alternative conceptions in photosynthesis and cellular respiration were indeed very challenging to be corrected.

Development of Refutation text Instructional Module

Refutation text has been used in various disciplines and has been shown to be particularly useful in changing alternative conceptions about science (Kowalski & Taylor, 2011; Broughton et al., 2010; Tippett 2010). Refutation texts is an approach designed to prompt conceptual change by having readers attend to conflicts between their own conceptions and those in a text (Tippet, 2010). Refutation has three key components: the alternative conception is explicitly stated, the alternative conception is then identified as being false, then scientific information is given that refutes the alternative conception (Kowalski & Taylor, 2011). It is essential that the refutation text explicitly states an alternative conception and then refutes it with evidence.

The learning competencies under Energy Transformation of the General Biology 1 Curriculum Guide were revisited to ensure the breadth and depth of the learning content. The developed refutation text module was composed of nine (9) lessons in reference to the prescribed learning competencies. Lesson 1 was about Electron Carriers, Lesson 2 was about ATP or Adenosine Triphosphate, Lesson 3 discussed Plant Pigments, Lesson 4 was about Photosynthesis: Light Dependent

Reactions, Lesson 5 talked about Photosynthesis: Calvin Cycle Reactions, Lesson 6 was about Cellular Respiration: Glycolysis, Lesson 7 was about Cellular Respiration: Krebs Cycle, and Lesson 8: Cellular Respiration: Electron Transport Chain. The developed instructional module followed the 5E lesson plan that consisted of five (5) parts: Engage; Explore; Explain; Elaborate; and, Evaluate that offered a wide range of benefits for both teachers and learners. For example, it provided a simple and clear framework that teachers can use to easily plan standard-aligned lessons. This is beneficial to novice teachers considering its pedagogical features. In addition, it enhances learner engagement and motivation through a constructivist approach. The lesson contents were mostly taken OpenStax College textbook which is a non-profit organization that aims for quality learning by providing learners access to rich, detailed sources for free or for a minimal cost. The contents however were modified especially for Filipino learners. In addition, this module was peer-reviewed by educators to ensure completeness in terms of scope and sequence, accuracy, and readability. The activities included were carefully crafted to be performed with the available materials especially in public schools. Figure 2 shows a sample lesson.

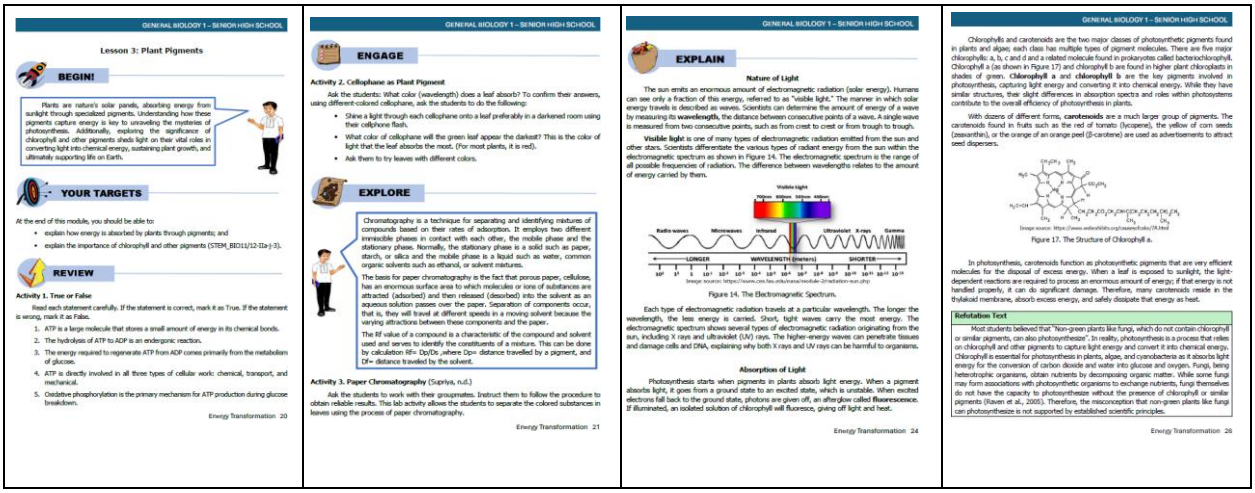

Figure 2. The developed instructional module followed the 5E lesson plan

The developed instructional module features refutation texts which were texts that refute the identified alternative conceptions during the Analysis Phase. It was composed of alternative conceptions about a subject, refutes it, and provides an explanation of the correct conception. For this discussion the following refutation texts based on the identified alternative conception were arranged based on the topics assigned in the module. For example, in Light Dependent Reactions: "Plants take in carbon dioxide (CO_2) and change it to oxygen (O_2) directly". In reality, during photosynthesis, plants absorb CO_2 from the atmosphere and, with the help of sunlight, convert it into glucose and oxygen. The oxygen released during photosynthesis is a byproduct of this process, and the primary purpose of photosynthesis is to produce glucose as a source of energy for the plant (Raven et al., 2005). Therefore, while it is true that plants release oxygen as a result of photosynthesis, they do not directly convert CO_2 into O_2.

Experts' Validation of Refutation text Instructional Module

Table 2 shows the results of experts' validation of the refutation text instructional module. Results revealed that the overall validation rating of the experts was Very satisfactory. Similar results were achieved by Torrefranca (2017) that instructional modules should have objectives which are clearly stated in behavioral form, specific, measurable, and attainable. Also, they strongly agreed that the objectives are well-planned, formulated, organized, and relevant to the topics of each lesson of the modules, and they take into account the needs of the learners. Maliga (2018) stated that the contents of learning materials must be valid and acceptable. To ensure high-quality learning, it's crucial to carefully evaluate learning materials. Without adequate and effective learning resources, learners may struggle to acquire the necessary knowledge, skills, and attitudes to be fully prepared and confident in their studies.

This could hinder their ability to compete with learners from other parts of the world. Mijares (2023) revealed that teachers should look for a standardized tool that focuses on accuracy and visual appeal, alignment to standards and depth of knowledge, ease of use and support, engagement, and ability to meet learner needs. The developed instructional module used appropriate language for the level of the students. Instructions were made clearly for both learners and teachers. This developed module can be used by the teacher and can also be used as a self-learning module for the students. According to Memebrebe and Anadia (2015), it is suggested that the contents of supplementary learning materials must be carefully

assessed following the content criterion provided by the DepEd so it can be used as instructional material to improve science teaching, facilitate the learning process, and to improve learners' achievement on least mastered competencies.

Principles	SD	Mean	Descriptive Rating
Integrity	0.298	3.80	Very Satisfactory
Learner Focus	0.168	3.93	Very Satisfactory
Usability	0.000	4.00	Very Satisfactory
Accessibility	0.245	3.80	Very Satisfactory
Overall	0.178	3.88	Very Satisfactory

Note: Interpretation is based on the following scale: 3.51-4.00 (Very Satisfactory); 2.51-3.50 (Satisfactory); 1.51-2.50 (Poor); 1.00-1.50 (Not Satisfactory), N=5

Table 2. Experts' validation of Refutation text Module

Validation is highly advisable to improve the overall characteristics of any supplementary learning material made (Mijares, 2023). Validating instructional materials is critical before they are widely used to ensure quality. This allows teachers to change certain parts that need revision. The experts' validation provides strong evidence that the refutation text module is an effective and valuable educational resource.

Learners' Feedback on Refutation text Instructional Module

The Focused Group Discussion was conducted to elicit the learners' feedback about their experience in the utilization of refutation text instructional module. The following themes were generated such as Well-executed lesson, Disturbed by Unfamiliar Science terms, Suitable Experiments and activities, and Integration of refutation text.

Well-sequenced lessons benefit both the teacher and the learners. Well-organized and properly sequenced lesson plans allow for a smother functioning classroom; classroom disruptions are minimized, the stress on the teacher is reduced and the learning environment is optimized for the learners. Most learners were disturbed by unfamiliar Science terms. The researcher considered this feedback by defining technical/unfamiliar words on the module for the benefit of the learners. Yongco and Del Valle (2022) pointed out that learners generally accepted the content of the instructional module if attainable and suited to their learning comprehension level, has logically arranged content that were interesting to them. The learners believe that the experiments and activities helped them to understand the lesson better. The learners strongly supported the integration of refutation texts in the discussion because they believed it would help them change their wrong beliefs. They also believed that teachers should also be aware of their own alternative conceptions to prevent spreading wrong information to their learners. Tippett (2010) reviewed two decades of refutation text research in the fields of science and reading education, and found than reading refutation text rather than expository text is more likely to result in conceptual changes.

Biology Teacher-Observers' Feedback on Refutation text Instructional Module

The Focused Group Discussion was conducted to elicit the teacher-observers' feedback on how the demonstration teacher utilized the refutation text instructional module during instruction. The following themes were generated such as Engaging and interactive, Suitable content and activities, Learning objectives are aligned and achieved, and Integration of refutation text in lesson planning.

The teachers observed that the class was engaging and interactive. The learners were actively involved in the discussion and participated well in the activities. Findings of Torrefranca (2017) revealed that the instructions in the modules in the view of learners should be well-emphasized, and tables/diagrams, illustrations, pictures, and captions are properly laid out for easy reference. The teachers also believed that the lesson content and activities were suitable for the target learners. Moreover, the teachers believed that the learning objectives were aligned and were achieved in the allotted time evident in the summative scores of the learners s. According to Torrefranca (2017), learning module objectives are specific competencies that learners must master before going on to the following session. Learning objectives serve as a guide to choosing the appropriate lesson content, learning activities, and evaluation in order to achieve a more thorough learning progression.

The teachers saw the importance of refutation text as they promoted deeper understanding, improve comprehension and retention, and can correct alternative conceptions of the learners. It can also challenge teachers subject matter knowledge and can be a good initiative to start a debate. The conditions for changing alternative conceptions include being highly motivated, the information must be understandable, the alternative concept must be plausible, and the information needs to be perceived as being useful in helping solve problems (Hughes et al. 2013).

Acceptability of Refutation text Instructional Module

Table 3 shows the Biology Teachers' Acceptability of Refutation text Instructional Module. Results revealed that the overall evaluation rating was Very Acceptable. Moreover, every factor was rated Very Acceptable. In terms of Concept/Content, the material was easy to read and had clear illustrations, included hands on experiment, and refutation texts. The content was comprehensive, suited to the level of learners. The module is culturally relevant and applicable in the local context for SHS STEM learners. Also, results imply that the objectives of the modules can be rendered into its target output.

Factors	SD	Mean	Descriptive Rating
Concept/Content	.359	3.71	Very Acceptable
Instructional Quality	.450	3.60	Very Acceptable
Technical Quality	.307	3.79	Very Acceptable
Prints	.287	3.88	Very Acceptable
Illustrations	.409	3.73	Very Acceptable
Design and Layout	.328	3.77	Very Acceptable
Presentation and Organization	.400	3.72	Very Acceptable
Accuracy and Up-to-Datedness of Information	.380	3.65	Very Acceptable
Assessment	.440	3.65	Very Acceptable
OVERALL	.389	3.69	Very Acceptable

Note: Interpretation is based on the following scale: 3.51-4.00 (Very Acceptable); 2.51-3.50 (Acceptable); 1.51-2.50 (Moderately Acceptable); 1.00-1.50 (Barely Acceptable), N=33

Table 3. Biology Teachers' Acceptability of Refutation text Instructional Module

In terms of Instructional Quality, there was explanation/ summary in every lesson. Some teacher-evaluators suggested putting replacement materials in the activity sheets if not available, adding assessment checks from time to time to confirm understanding, and important concepts should be displayed in bullet form for quick understanding and emphasis. In support to the present study, Jones et al. (2007) in their initial research outcomes highlighted the impact of pedagogical content knowledge on classroom and school practices. For Technical Quality, the design and lay-out was simple yet comprehensively consolidated. The material looked attractive because it was colorful and learner-friendly. Print legibility influences the readability as it gives ease to the learner to distinguish letters and words while reading. The clear, simple, and relevant illustrations and presentations piqued their interest and made learning effective and enjoyable, and provided concrete visual clues (Maile & Cooper, 2018).

For, Presentation and Organization, the material was presented well, it includes higher order thinking skills (HOTS) questions. In addition, the material is interesting and clearly structured. Salandanan (2011) stated that modules should be written in clear and correct language suitable to the level of the target learners so as to achieve efficient communication between the learner and the module. For Accuracy and Up-to-Datedness of Information, there should be more diagrams, figures, illustrations. They also wish it to have more updated references, and the material should be subjected to grammar and plagiarism checks. Chinwendu (2014) has stated lexico-syntactic errors contained in the teaching materials if not corrected will make learners the conveyor belt of the errors contained in the teaching material. This means errors in the teaching material should be corrected so as not to multiply the commission of mistakes since most teachers and learners are dependent on these materials for teaching and learning. Lastly, for Assessment. The teacher-evaluators suggested including more varied assessment types, and more exercises but overall, they were satisfied with the module for learners. According to Jabbarifar (2009), classroom assessment and evaluation are highly concerned with qualitative judgments that are used to improve learners' knowledge and learning.

Conclusion and Implications

Conclusions

Learners continue to demonstrate weak foundational understanding of photosynthesis and cellular respiration, with both newly identified and previously documented alternative conceptions persisting among learners. To address these alternative conceptions, the integration of refutation texts into lesson planning is recommended. The developed instructional module, structured using the constructivist 5E model, effectively embeds refutation strategies within carefully designed activities aligned with the General Biology 1 curriculum. Expert validation confirmed that the module meets high educational standards, making it suitable for reproduction and classroom implementation. Findings from demonstration classes indicate that the module positively influenced learners' engagement and overall learning experience. Students found the lessons organized, interactive, and meaningful, particularly appreciating the hands-on activities and experiments. The inclusion of refutation texts supported the development of critical thinking and argumentation skills. However, some learners encountered difficulty with complex scientific terminology, highlighting the need for clearer explanations or additional scaffolding. The refutation text module is a high-quality, curriculum-aligned, and pedagogically sound resource for Biology instruction, with strong potential to enhance conceptual understanding while addressing persistent alternative conceptions.

Implications

This study reinforces the importance of conceptual change theory, feedback literacy, and instructional design theory in science education. Conceptual change (Tanner and Allen, 2005), occurs when learners' and teachers' alternative conceptions are deconstructed, either naturally or through instructional interventions. The study highlights the value of formative assessments to identify alternative conceptions, allowing educators to design activities that directly challenge and replace them with scientifically accurate knowledge. Feedback literacy (Carless and Boud, 2018) as learners' ability to make sense of information and use it to enhance learning, can be fostered through classroom debates, critical thinking exercises, and peer feedback. Moreover, the study emphasizes that systematic instructional design (Ritchey, Klein, & Tracey, 2011)—including learner analysis, clear objectives, structured content, and active teaching strategies—enhances the effectiveness of instruction and promotes meaningful conceptual change. In practice, the study highlights the critical role of developing instructional materials as a tool for effective teaching. The module developed in this study, which applies a conceptual change approach and integrates refutation texts, offers a practical resource for addressing alternative conceptions in photosynthesis and cellular respiration. Supported by expert feedback, the module guides teachers in planning, implementing, and assessing lessons, while fostering a learning environment that encourages critical thinking, problem-solving, and collaboration. Biology teachers can use the module to identify common learner alternative conceptions, apply appropriate teaching strategies, and improve learners' performance in General Biology, even during class disruptions or alternative learning contexts.

Recommendations

On the basis of the aforementioned findings and conclusions, the following recommendations were advanced: (1) STEM learners may need to have more references in studying their lessons to compare information from one author to another for complete understanding. This ensures that the knowledge from what they gain by studying is up-to-date and correct. (2) Teachers may need to be aware of their own and their learners' alternative conceptions in these topics. Traditional teaching needs to be more rigorous or by adapting known effective strategies to address these alternative conceptions. (3) Teachers may utilize this instructional module as a template for their lessons, enhancing the effectiveness and efficiency of both teaching and learning. Additionally, it can serve as a resource for developing customized modules tailored to specific learning modalities. (4) School administrators with the help of master teachers may include refutation text as one of the topics in seminars workshop during In-service Trainings (INSET) as refutation texts can be used also in other disciplines. (5) School administrators with the help of master teachers may provide content enrichment programs to their teachers who may potentially have alternative conceptions to avoid sharing it with their learners. (6) Textbook authors may include refutation texts in discussing science concepts in their textbooks for meaningful learning. (7) Other researchers can conduct further studies by using refutation text module as a teaching intervention to further study its effectiveness in the teaching-learning process.

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Competing Interests Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study; all data used were obtained from previously published sources as cited in the reference list.

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Appendices

No appendices are attached in this study.