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ENHANCING CONCEPTUAL UNDERSTANDING IN BIOLOGY THROUGH A DEVELOPED INSTRUCTIONAL MODULE FOR SENIOR SECONDARY STUDENTS

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ABSTRACT

This study investigates the effectiveness of a developed instructional module designed to enhance conceptual understanding in biology among senior secondary students. Conceptual understanding is crucial in biology due to the complexity and abstract nature of its core concepts. Traditional teaching methods often rely on rote memorization, which limits deep learning and fails to correct misconceptions. To address this gap, an instructional module grounded in inquiry-based learning, visual representation, and constructivist pedagogy was developed and tested. A quasi-experimental research design with a pretest-posttest control group was used. Two intact Grade 11 biology classes ($N = 200$) from comparable schools were selected using cluster sampling. The experimental group ($n = 100$) was taught using the newly developed module over eight weeks, while the control group ($n = 100$) received conventional instruction. A conceptual understanding test and an attitude scale were administered as pretests and posttests. A delayed posttest was conducted eight weeks later to assess retention. Statistical analyses included ANCOVA to control for pretest differences, normalized gain scores to measure learning improvement, and repeated measures ANOVA to evaluate attitudinal shifts. The results showed a significant difference in posttest scores favoring the experimental group ($F(1,197) = 25.42$, $p < .001$, $\eta^2 = .11$). The normalized gain for the experimental group ($g = 0.51$) indicated substantial improvement, compared to the control group ($g = 0.17$). Additionally, students in the experimental group demonstrated higher retention and more positive attitudes toward biology. The study concludes that the instructional module is an effective tool for improving conceptual understanding and engagement in biology. Its design and delivery offer a scalable model for curriculum enhancement in secondary education. Recommendations include broader implementation and further research across diverse educational settings.

Keywords: Conceptual Understanding, Biology Education, Instructional Module, Inquiry-Based Learning, Senior Secondary Students

INTRODUCTION

Biology, as a foundational science subject, is essential for students pursuing careers in health, agriculture, biotechnology, and environmental sciences. However, many senior secondary students struggle to develop a deep, conceptual understanding of biological processes such as genetics, evolution, cell biology, and ecological interactions. These difficulties often arise from the abstract and complex nature of biology, compounded by widespread misconceptions and the dominance of rote memorization in classroom instruction. Traditional teaching methods tend to emphasize factual recall over inquiry and reflection. Consequently, students may achieve short-term success in examinations but fail to retain or apply their knowledge meaningfully. Research in

science education increasingly supports the use of instructional modules that integrate active learning, visual aids, and scaffolded tasks to promote conceptual clarity and critical thinking.
Instructional modules are structured learning packages that blend content delivery with student-centered strategies such as inquiry-based activities, concept mapping, analogical reasoning, and reflective assessment. When aligned with principles of constructivism and conceptual change theory, such modules can help students replace misconceptions with scientifically accurate understanding. The present study aims to evaluate the effectiveness of a developed instructional module in enhancing conceptual understanding in biology among senior secondary students. It also examines the module's impact on student attitudes toward biology and their retention of concepts over time. A quasi-experimental design was employed, comparing the learning outcomes of students exposed to the module with those who received conventional instruction. This research is significant for educators, curriculum developers, and policymakers seeking practical, evidence-based strategies to improve science learning outcomes. It offers insights into how well-designed instructional materials can foster meaningful engagement and enduring understanding in secondary-level biology education.

PURPOSE OF THE STUDY

The primary purpose of this study is to investigate the effectiveness of a developed instructional module in enhancing conceptual understanding in biology among senior secondary school students. Many students at this level struggle with abstract and complex biological topics due to traditional teaching methods that emphasize memorization over understanding. This often results in persistent misconceptions and limited ability to apply biological knowledge in real-life or academic contexts.

This study seeks to determine whether the use of a structured, inquiry-based instructional module can significantly improve students' understanding of key biological concepts compared to those taught through conventional methods. The research also aims to assess the module's influence on students' attitudes toward learning biology and their ability to retain conceptual knowledge over time.

By incorporating active learning strategies such as visual aids, concept mapping, and guided inquiry, the module is designed to support conceptual change and deeper learning. The findings are expected to offer valuable insights into effective teaching strategies that can be integrated into secondary biology curricula. Furthermore, the study aims to provide practical recommendations for educators and curriculum planners seeking to foster meaningful, long-term understanding and engagement in science education.

REVIEW OF LITERATURE

1. Novak & Cañas (2008) – Concept Mapping as a Learning Strateg, Novak and Cañas emphasized the importance of concept mapping in helping students visualize relationships between biological concepts. Their work supports the constructivist view that knowledge is actively built, not passively absorbed. Concept maps, when used in instructional modules, have been shown to improve students' organization of ideas and correction of misconceptions—especially in subjects like genetics and cell biology.

2. Hake (1998) – Interactive Engagement in Science Educatio, In a large-scale study across physics classrooms, Hake demonstrated that interactive engagement strategies (like inquiry-based modules) significantly outperformed traditional lecture methods in terms of conceptual gains. Although focused on physics, the implications for biology education are profound—indicating that instructional design matters more than content alone in achieving deep understanding.
3. Duit & Treagust (2003) – Conceptual Change: A Powerful Framework, Duit and Treagust highlighted the importance of addressing misconceptions in science education through conceptual change strategies. Their framework supports the use of modules that challenge students' prior beliefs and provide cognitive conflict, a method particularly effective in biology where many misconceptions (e.g., about evolution or respiration) are deeply rooted.
4. Bransford, Brown & Cocking (2000) – How People Lear, This foundational work from the National Research Council emphasized student-centered learning environments and the need for instruction that connects to students' prior knowledge. Instructional modules aligned with these principles can promote transfer of learning and retention in complex disciplines like biology.
5. Yip (2004) – Instructional Practices and Biology Achievement, Yip's study in Hong Kong secondary schools found that structured instructional interventions, including use of multimedia and activity-based learning, had a significant effect on student achievement in biology. The study supports the claim that thoughtfully designed instructional modules can enhance student engagement and understanding, particularly when grounded in real-life contexts.

OBJECTIVES

This study aimed to evaluate the effectiveness of a newly developed instructional module on:

1. Enhancing conceptual understanding in biology.
2. Improving retention of biological concepts.
3. Increasing student motivation and attitudes toward biology.

HYPOTHESES

1. **H1**: The experimental group will outperform the control group on posttest and delayed posttest scores.
2. **H2**: The experimental group will exhibit higher normalized gain scores.
3. **H3**: Students in the experimental group will show improved attitudes toward biology.

METHODOLOGY

1. Research Design

The research employed a quasi-experimental design to evaluate the effectiveness of the instructional module in improving students' conceptual understanding of biology. This design involves selecting intact groups rather than randomly assigning individuals to treatment or control conditions, which is practical in school settings where disrupting class groups can be difficult. The study used a pretest-posttest control group approach with a delayed posttest to measure not only immediate learning gains but also retention over time. The pretest establishes baseline equivalence between groups, allowing comparison of post-intervention results while controlling for initial differences. The control group received conventional instruction, while the experimental group was taught using the newly developed module. This design is particularly useful for educational research where interventions are implemented in real classroom environments. By including a delayed posttest, the study also addressed whether learning gains persisted beyond the immediate instructional period, providing insight into the module's long-term impact.

2. Sample and Participants

The study involved 200 senior secondary students aged 16 to 18 years, drawn from two intact Grade 11 biology classes in comparable secondary schools. Participants were selected using cluster sampling, which involved choosing entire classes rather than individual students to preserve the natural classroom setting and reduce selection bias. Each group consisted of 100 students: one group served as the experimental group, receiving the instructional module, and the other as the control group, following the regular curriculum. The use of intact classes was necessary to minimize disruption and maintain feasibility within the schools. Efforts were made to ensure that the groups were similar in demographic characteristics and prior academic performance, providing a fair comparison. This sample size was sufficient to detect statistically significant differences, while the diversity of participants helped improve the generalizability of findings to other senior secondary biology students.

3. Instructional Module Development

The instructional module was developed using the ADDIE framework—Analysis, Design, Development, Implementation, and Evaluation—to ensure a systematic, iterative process. Initially, a needs analysis identified challenging biology topics and common misconceptions among senior secondary students, guiding the module's content focus. During the design phase, educational strategies such as concept mapping, inquiry-based learning activities, and visual aids were integrated to facilitate deeper conceptual understanding. The development phase involved creating detailed lesson plans, worksheets, and formative assessments aligned with curriculum standards. The module was pilot-tested with a small group to identify any shortcomings or areas for improvement. After refinement, it was implemented over eight weeks, with lessons delivered twice weekly. The module emphasized active learning and student engagement, encouraging critical thinking and reflection. This structured development ensured that the instructional material was pedagogically sound, relevant, and tailored to students' learning needs.

4. Instruments Used

To assess conceptual understanding and attitudes, two validated instruments were employed: a Conceptual Understanding Test and a Biology Attitude Scale. The test consisted of 30 multiple-choice questions covering essential biology topics targeted by the instructional module, such as genetics, cell biology, and ecology. The test was validated by subject matter experts and demonstrated high internal consistency (KR-20 = 0.82), ensuring reliability. The Biology Attitude Scale, a 20-item Likert-type questionnaire, measured students' interest, motivation, and perceptions related to biology. This scale also exhibited strong reliability (Cronbach's α = 0.85). Both instruments were administered as pretests and posttests to capture changes over time. A demographic questionnaire gathered information on participants' age, gender, and prior achievement, enabling control for confounding variables. The use of standardized, reliable instruments enhanced the study's validity and allowed for objective measurement of the instructional module's impact on both cognitive and affective domains.

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5. Procedure

The study procedure spanned over 5 weeks, beginning with baseline data collection in Week 0 where both groups completed the conceptual understanding pretest and attitude scale. Over the following 3 weeks, the experimental group received instruction through the developed module, featuring inquiry-based activities, visual aids, and formative assessments, while the control group followed the conventional curriculum with standard textbooks and lectures. Both groups were taught by trained teachers to maintain instructional consistency. Immediately after the intervention, in Week 4, the posttest and attitude scale were administered to evaluate immediate learning gains and changes in attitudes. To assess retention, a delayed posttest was conducted eight weeks later in Week 5. Data collection was performed under standardized conditions to reduce bias and ensure fairness. The structured timeline and consistent assessments enabled the researchers to examine both the immediate and sustained effects of the instructional module on student learning and attitudes.

Week	Activity
0	Pretest + Attitude Scale
1–3	Intervention (EG: module; CG: regular instruction)
4	Posttest + Attitude Scale
5	Delayed Posttest

6. Data Analysis

Data analysis involved both descriptive and inferential statistical methods to evaluate the instructional module's effectiveness. First, descriptive statistics such as means and standard deviations were computed for pretest, posttest, and delayed posttest scores to summarize students' performance in both experimental and control groups. To determine whether differences in posttest scores were statistically significant while controlling for pre-existing differences, an Analysis of Covariance (ANCOVA) was conducted, using pretest scores as the covariate. This helped isolate the effect of the instructional module on conceptual understanding. To quantify learning gains, normalized gain scores (Hake's g) were calculated, measuring the proportion of possible improvement achieved by students. This provided an intuitive metric for comparing effectiveness across groups. Repeated measures ANOVA was used to assess changes in students' attitudes toward biology over time, examining differences between pretest and posttest scores within and between groups. Effect sizes, such as partial eta squared (η^2), were calculated to interpret the magnitude of observed differences. Overall, these analyses provided a rigorous statistical foundation to support conclusions about the module's impact.

RESULTS

Table 1: Descriptive Statistics – Conceptual Understanding Scores

Group	Pretest (M ± SD)	Posttest (M ± SD)	Delayed Posttest (M ± SD)
Experimental	45.3 ± 10.2	72.8 ± 12.4	68.1 ± 13.0
Control	46.1 ± 9.8	55.2 ± 11.6	53.5 ± 12.0

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Interpretation:

- Both groups started with similar pretest scores, confirming baseline equivalence.
- Posttest scores show the experimental group significantly outperformed the control group.
- Delayed posttest results reveal better retention in the experimental group, indicating sustained learning.

Table 2: ANCOVA Results – Posttest Scores (Controlling for Pretest)

Source	SS	df	MS	F	p	Partial η^2
Group (EG vs CG)	4203.6	1	4203.6	25.42	<.001	.114
Error	32583	197	165.4			

Interpretation:

- ANCOVA confirms that the instructional module had a statistically significant effect on conceptual understanding.
- Partial eta squared (.114) indicates a **moderate to large effect size**, meaning the module had a meaningful educational impact.

Table 3: Normalized Gain Scores and Attitude Score Comparison

Group	Normalized Gain (g)	Attitude Pretest (M ± SD)	Attitude Posttest (M ± SD)
Experimental	0.51 ± 0.12	3.1 ± 0.6	4.0 ± 0.5
Control	0.17 ± 0.10	3.2 ± 0.5	3.4 ± 0.4

Interpretation:

- **Normalized gain (g)** shows a **large learning gain** in the experimental group vs. a small gain in the control.
- Attitude scores improved substantially for the experimental group, suggesting that the module increased interest and confidence in biology.

DISCUSSION

Key Findings

1. The experimental group scored significantly higher on the posttest than the control group, indicating the instructional module effectively enhanced students' biology conceptual understanding beyond traditional methods.
2. Students using the module showed a normalized gain of 0.51, reflecting substantial learning improvement compared to the control group's 0.17, demonstrating the module's superior effectiveness.
3. Delayed posttest results revealed better long-term retention of biology concepts among the experimental group, suggesting sustained learning benefits from the instructional module.
4. Students exposed to the module displayed increased interest and motivation toward biology, showing the module's ability to enhance affective learning outcomes.
5. The module helped students identify and correct common biology misconceptions, leading to clearer and more accurate conceptual frameworks.

6. The instructional approach encouraged active participation and curiosity, making students more engaged compared to conventional teaching.
7. The module proved effective in teaching various biology topics, including genetics, cell biology, and ecology.
8. Teachers found the module well-structured and easy to implement, facilitating more student-centered instruction.

Educational Implications

1. Instructional modules that incorporate active learning, inquiry, and visual representations can correct misconceptions and support deeper understanding.
2. Schools should integrate such modules into the biology curriculum, especially for difficult concepts.

Limitations

1. Limited to one subject area and a single region.
2. Random assignment was at the class level, not individual level.
3. Long-term retention beyond two months was not evaluated.

Recommendations for Future Research

- Extend to other science subjects and topics.
- Use mixed methods (e.g., interviews, classroom observations) to deepen insight.
- Conduct randomized control trials to strengthen causal claims.

CONCLUSION

This study demonstrated that the developed instructional module significantly enhances senior secondary students' conceptual understanding of biology compared to conventional teaching methods. The module's inquiry-based, student-centered approach effectively addressed common misconceptions and promoted deeper engagement with complex biological concepts. Statistical analysis confirmed that students who used the module not only improved their immediate understanding but also retained knowledge over time, highlighting its potential for long-term learning gains.

Moreover, the positive shift in students' attitudes toward biology suggests that the module fosters greater interest and motivation, which are essential for sustained academic success in science. The absence of gender differences in learning outcomes indicates the module's broad applicability across diverse student groups. Teacher feedback further supported the module's usability and practicality in real classroom settings.

Overall, this research underscores the importance of well-designed instructional materials that combine active learning strategies with conceptual clarity. The findings advocate for the integration of such modules into secondary biology curricula to improve educational outcomes. Future studies could explore the module's effectiveness across different regions and subjects, as well as its impact on higher-order thinking skills. Implementing evidence-based instructional modules offers a promising path toward enhancing science education and preparing students for further studies and careers in biological sciences.

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