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Research Article

Effectiveness of Computer-Aided Instruction on Students' Conceptual Understanding in Life Science

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ABSTRACT

The study aimed to determine the effectiveness of computer-aided instruction (CAI) on students' conceptual understanding in Life Science. The objectives of the study is to develop lesson plans with computer-aided instruction packages; assess the developed lesson plans in terms of congruency of objectives, learning experiences, assessment of learning outcomes, features of computer-aided instruction packages, and to determine the effect of CAI on students' conceptual understanding. The study utilized the pre-experimental method. The study involved 27 students who took a Bioenergetics Achievement Test (B.A.T) before and after CAI. It was found out that developed daily lesson plans are excellent; congruency of lesson objectives (WM = 4.80), learning experiences (WM =4.76), assessment of learning outcomes (WM =4.79), and features of computer-aided instruction (WM =4.39). The test of the difference between the pre-test and post-test scores showed a significant result ($t_{26}=-14.30$, $p<0.01$), and it was supported with the positive increase on the Learning Gain Score (LGS=3.18) which showed an increase in conceptual understanding and mastery in the learning competencies. Hence, there is sufficient evidence to show that the students' scores improved significantly after being taught in computer-aided instruction. Therefore, the developed lesson plans with the integration of computer-aided instruction are excellently and effectively improved the students' conceptual understanding and mastery of the learning competencies.

Keywords: *Computer-aided instruction, Conceptual understanding, Learning competency, Lesson plan*

Introduction

The 21st century entails a lot of challenges in the academe. Educators are bombarded with interventions to uplift and transform the young minds of the students. The global importance of science and technology that dominates in every

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society requires an educational system that provides a venue for developing scientific knowledge and understanding. Imam, Mastura, Jamil, and Ismail (2014) emphasized that in the Philippines, science was a mandatory subject in education. Moreover, the Philippine government is mandated to prioritize STEM education through training and innovation. Globalization and technological change have created new avenues in the Philippine educational system powered by technology, fuelled by information and technologically-driven knowledge. The Philippines, considering a fast-growing country in Asia, need to ponder the integration of Information and Communication Technologies (I.C.T.s) in education as the powerful enabling tools for educational change and reform.

. Students' achievement in Life Science, as with other disciplines, is an indicator of students' conceptual understanding and mastery in the learning competency. The challenge in science education and integrating educational technology interventions is an indicator of effectiveness in science instruction. The 2003 to 2009 National Achievement Tests in Science and Mathematics showed a poor mastery in the subject (Imam, 2010). The DepEd showed their record that 5,600 secondary schools (61.10%) scored within the "lower average" range (26 and 50% scores) in the National Achievement Test. In the study of Mishra (2001) revealed that practical, real-life activities, and students' experiements can be achieved with the use of teaching aids. Meltzer and Manivanna (2002) asserted that computer-based teaching provides several options to the students, this include visualization of abstract concepts that will likely optimized student s' understanding. Tambade and Wagh (2011) claimed that computer-aided instruction packages quickly achieved the educational goal of the lesson when properly used in the classroom.

The knowledge generated on the least mastered competencies and conceptual understanding of students in learning life science particularly under bioenergetics requires action and innovations that a STEM teacher should employ in the teaching and learning process. This is also to address the dismayed in the performance of Filipino learners in STEM education both in the local and international arena.

Thus, for best practice, C.A.I. is most effective when used as a supplement, incorporated in instruction, and encourages students' reflections when used appropriately, C.A.I. involves students in inquiry-based and authentic science explorations. To determine the students conceptual understanding in life science in one of the private schools in Masbate province, the need to investigate their competencies would elevate the existing status of the students in learning the subject.

Framework of the Study

The framework of the study adapted the Coombs System Approach (Coombs, 1998) with the following three elements; input, process, and output which were modified into three phases; (1) Assessment of Lessons, (2) Lesson Implementation, and (3) Effect of Conceptual Understanding.

Phase 1 includes assessing advanced lessons wherein Bioenergetics Achievement Test (B.A.T.) is also formulated for pre-test administration to diagnose the students' competencies on the structures and functions of cells, photosynthesis and energy flow, and energy utilization. Strengths and weaknesses of the B.A.T. at lessons were considered before its final administration to the participants. A reliability test was conducted to ensure the validity of the test. These topics were identified based on the less learned competencies documented by the teacher teaching the subject. Phase 2 was implementing the lesson taught in a typical classroom setup, and compounding factors such as students' readiness, motivation, and attitudes towards computer-aided instruction were also considered. Experts on its features assessed the computer-aided instruction (C.A.I.) packages.

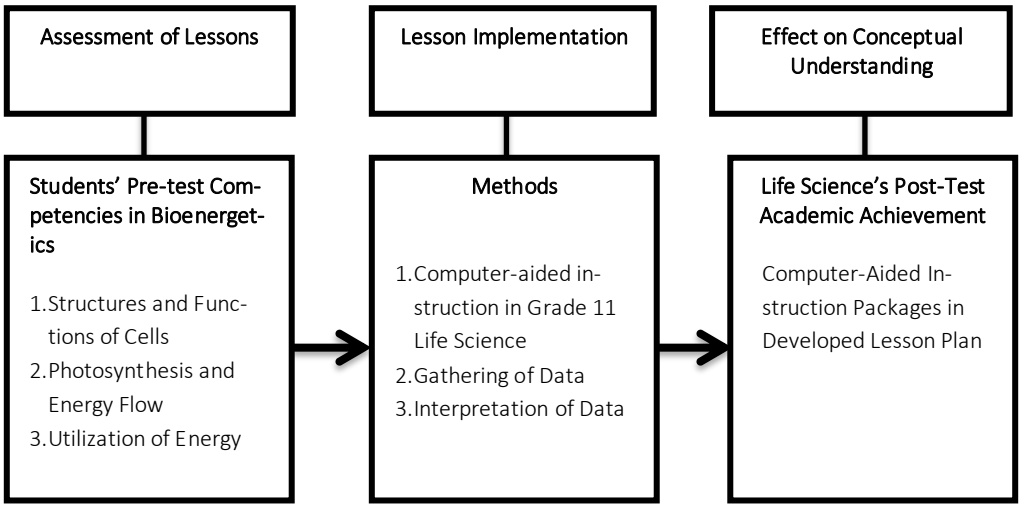

Fig. 1. Conceptual Paradigm of the Study

Phase 3 determines the effect of C.A.I. on students' conceptual understanding, mainly determined through post-test to look into the mean difference between the pre-test and the Learning Gain scores obtained by the respondents after being taught in a computer-aided instruction setting.

Objectives of the Study

The primary concern of this research inquiry is to determine the effectiveness of computer-aided instruction on students' conceptual understanding in Life Science. This study was guided specifically with these research questions:

1. What lessons may be developed using computer-aided instruction?
2. What is the assessment of experts in terms of:
   - Congruency of objectives
   - Learning experiences
   - Assessment of learning outcomes
   - Features of computer-aided instruction
3. What is the effect of computer-aided instruction in teaching Life Science in terms of conceptual understanding?

Methods

Research Design

This pre-experimental research study adopted the pre-test and post-test design. The dependent variable is measured once before the treatment is implemented and similar treatment at the end of the treatment. The study was conducted in a selected private school in Masbate Catholic Education Association (MACEA), Masbate Province, Philippines. It is located in the Municipality of Aroroy, which offers General Academic Strand (G.A.S.), Humanities and Social Sciences (HUMSS), and Home Economics Strand under the Senior High School (S.H.S.) curriculum.

Respondents of the Study

The study participants were the twenty-seven (27) Senior High School students conveniently selected from private schools in Masbate Province, Philippines. These participants are endorsed for treatment by the subject teacher in Life Science, which belongs to those students who failed to master the learning competency. The respondents were fully informed relative to the purpose of the study and given the right to data privacy.

Data Collection

The proponents sought permission from the MACEA Superintendent and endorsement from the school principal to include the 27 students as participants and at the same time to conduct the classroom discussion. Prior to the conduct of the study, the proponents requested the students' monthly class records in the subject to validate that students are failed in this

area. The self-designed Bioenergetics Achievement Test composed of 30-items was administered as the respondents' pre-test. A day after the pre-test, the researcher conducted a classroom discussion using the pre-planned lesson using computer-aided instruction packages.

Data Analysis

Arithmetic mean was used to find the students' average scores before and after the test (Broto, 2016). Learning Gain Scores (LGS) is also utilized to compute which of the topics obtained out of the possible total scores that it would have gained from pre test and post test (Lapada and Lapada, 2017). Additionally, the Average Weighted Mean (A.W.M.) was included in calculating the average scores of the experts' assessment of the Bioenergetics Achievement Test and the nine developed lesson plans. Kuder-Richardson Formula 20 (K.R. 20) is intended to measure the reliability of the achievement test with binary variables-answers that are right or wrong- or those items that are all about the same in difficulty. Finally, a t-test paired sample for means was used to compute the significant difference between the students' pre-test and post-test results, which determined the effectiveness of computer-aided instruction on students' conceptual understanding.

Ethical Considerations

This study observed the ethical considerations mandated in the A.P.A. Ethics Code (cited in Smith (2003). There is a letter of permission to conduct the study in the identified area to the MACEA superintendent, school director, and the school principal. The purpose, procedures, and duration were discussed to ensure transparency and awareness relative to the conduct of the study. Moreover, the participants have the right to raise questions or decline from participating in the study. Further, it was emphasized that any information and data collected would be dealt with with utmost professionalism and confidentiality.

Results and Discussion

Developed Lesson Plan

The developed daily lesson plan integrating computer-aided instruction packages adheres to the DepEd order no.42. s. of 2016, which utilized the standards and principles of the K-12 curriculum that is a student-centered and inquiry-based approach. It is a mandate in designing a lesson in 7Es format, Elicit, Engage, Explore, Explain, Elaborate, Evaluate, and Extend. In these nine lessons developed, the integration of computer-aided instruction packages can be found in the Explore part of the lesson. The students are gauged to enter into self-paced learning with embedded activity to deepen their conceptual understanding. The creation of specific learning outcomes is simplified, which are extracted from the curriculum guide of science.

Table 1. Distribution of Developed Lesson Plan

Content Standards	Learning Competencies	Developed Lesson	Specific Learning Outcomes
Cell structure and function of cells	Explain how cells carry out functions required for life. (S11/12LT-IIbd-4)	Lesson 1. Difference between Prokaryotic and Eukaryotic cell and Functions of Difference Cell Structures Lesson 2. Structures Unique to Plant Cell and Animal Cell	Describe the differences between prokaryotic and eukaryotic cells. Explain the functions of various cell structures/organelles Enumerate structures unique to plant cells and animal cells. Construct or draw a typical cell.

Content Standards	Learning Competencies	Developed Lesson	Specific Learning Outcomes
Photosynthesis and Energy Flow	Explain how photosynthetic organisms use light energy to combine carbon dioxide and water to form energy-rich compounds. (S11/12LT-IIbd-5)	Lesson 3. Forms of Energy and the Nature of Enzymes Activity	Review the forms of energy. Describe how energy is converted from one form to another. Differentiate the nature of enzyme activity.
		Lesson 4. The Anatomy of Chloroplast and Light-Dependent Reaction	Explore the anatomy of leaf and chloroplast. Locate the area where the light reaction takes place. Illustrate the events in light reactions.
		Lesson 5. The Light-Independent Reaction	Identify the area where the light-independent reaction takes place. Illustrate the events in light-independent reactions.
Utilization of Energy	Trace the energy flow from the environment to the cells. (S11/12LT-IIbd-6)	Lesson 6. The Overview of Cellular Respiration	Enumerate the stages of cellular respiration. Illustrate then identify the important molecules involved in aerobic respiration.
	Describe how organisms obtain and utilize energy. (S11/12LT-IIbd-7)	Lesson 7. The Concept of Glycolysis	Enumerate then describe the important stages involved in glycolysis. Illustrate the sequential events in glycolysis.
		Lesson 8. The Concept of Kreb's Cycle	Discuss and describe the citric acid cycle. List down the steps involved in the cycle and its corresponding output or products being produced.
	Recognize that organisms require energy to carry out functions required for life. (S11/12LT-IIbd-8)	Lesson 9. The Concept of Electron Transport Chain	Discuss the electron transport chain Identify the relationship between photosynthesis and cellular respiration.

Computer-Aided Instruction Packages

Lesson 1 focuses on the specific learning outcomes expected from the students to perform. They are guided to describe the difference between prokaryotic and eukaryotic cells and to explain the functions of various cell structures/organelles. The lesson is patterned to the released format by the Department of Education – the 7 Es – in making the daily lesson plan (Deped order no. 42, s. 2016). Figure 2

presents the C.A.I. application. It is an online instruction that aids the students in doing the activity in practicing their skills. This activity aims to identify the parts of the bacterial cell and sketch/draw the structure of an animal and plant cell and state its functions.

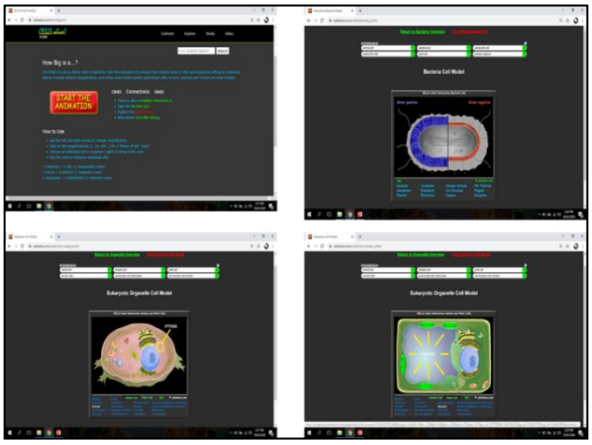

Fig. 2. Lesson 1 CAI Package

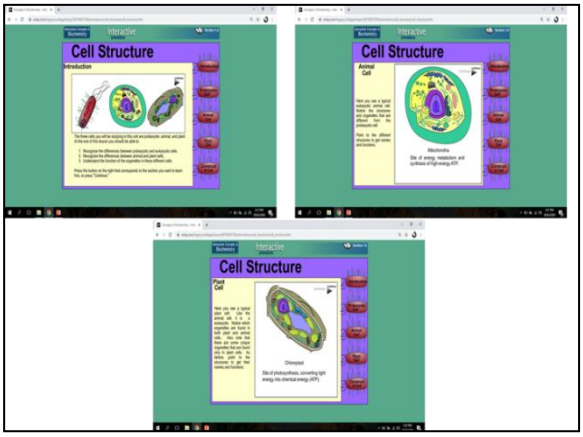

Fig. 3. Lesson 2 CAI Package

Lesson 2 enumerates the structures unique to plant and animal cells and construct/draw a typical cell. Figure 3 presents the computer-aided instruction that allows the students to explore in the "Unique from Each Other." Showed also the features present in every cell example that the students are directly guided in making the activity.

Lesson 3 guides the students that they will be able to review the forms of energy, describe how energy is converted from one form to another, and lastly, differentiate the nature of enzyme activity. The students explored using the computer-aided instruction in the "Conversion of Energy from one Form to Another." Five essential questions guide them to finish the activity directly.

Figure 4 presents the C.A.I. application to do the activity on converting energy from one form to another. The objectives are to identify examples of energy conversions, discuss how energy transformations are essential in everyday life, and identify conversions in a series of energy transformations. Lesson 4 explored the leaf and chloroplast anatomy, locate the area where the light reaction takes place, and illustrate the events in light reactions. Figure 5 presents the C.A.I. application about interactive photosynthesis where the students are tasked to pilot the plane until it reaches the site of light-dependent reaction, the thylakoid membrane. The four (4) guide questions are answered by following the procedures in doing the activity.

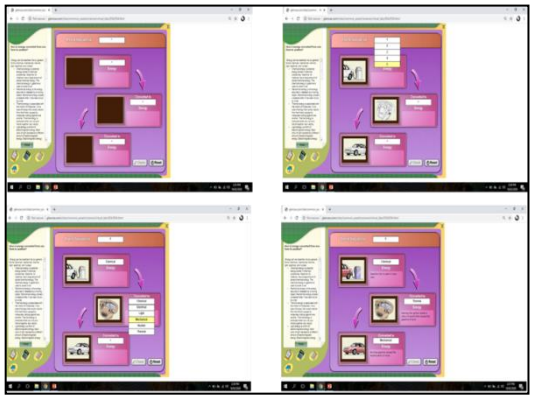

Fig. 4. Lesson 3 CAI Package

Fig. 5 Lesson 4 CAI Package

Lesson five (5) focuses on identification on the area where the light-independent reaction occurs and illustrate the events in light-independent responses. The instruction in this lesson is intended for one hr. and 10 mins. At first, the students are asked how important are the products of the light-dependent reaction.

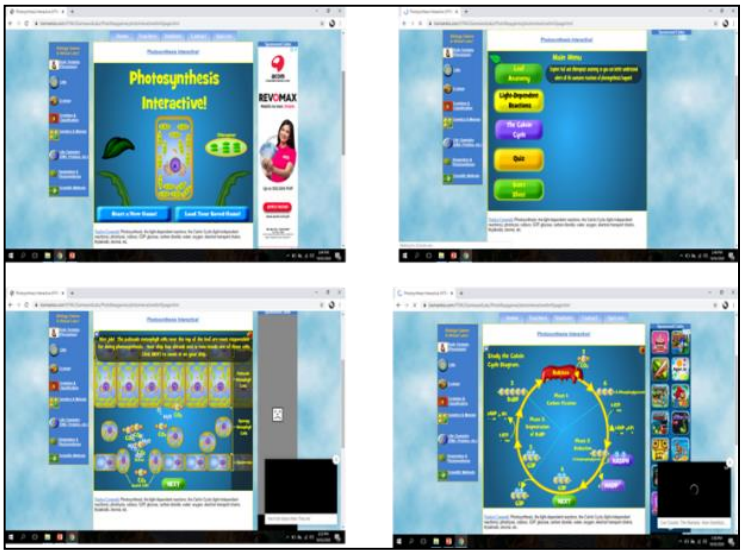

Fig. 6. Lesson 5 CAI Package

Figure 6 shows how the students are interactively engaged to do the simulated reaction happening in the Calvin cycle. At first, they are to observe the molecules reactants or any materials involved in the process, and as they keep going, they will perform the events in light-independent reactions on their own. Lesson 6 presents the specific learning outcome that the students will be able to enumerate the cellular respiration stages and then identify the important molecules involved in aerobic respiration. To illustrate the introduction to cellular respiration, the teacher gave the overview of glycolysis, Kreb's cycle, and oxidative phosphorylation via the electron transport chain. The furtherly evaluate the students' learning experiences, they are tasked to illustrate the overview of cellular respiration then identify the important molecules involved in aerobic respiration – Evaluate. Figure 7 helps the students accomplished the activity.

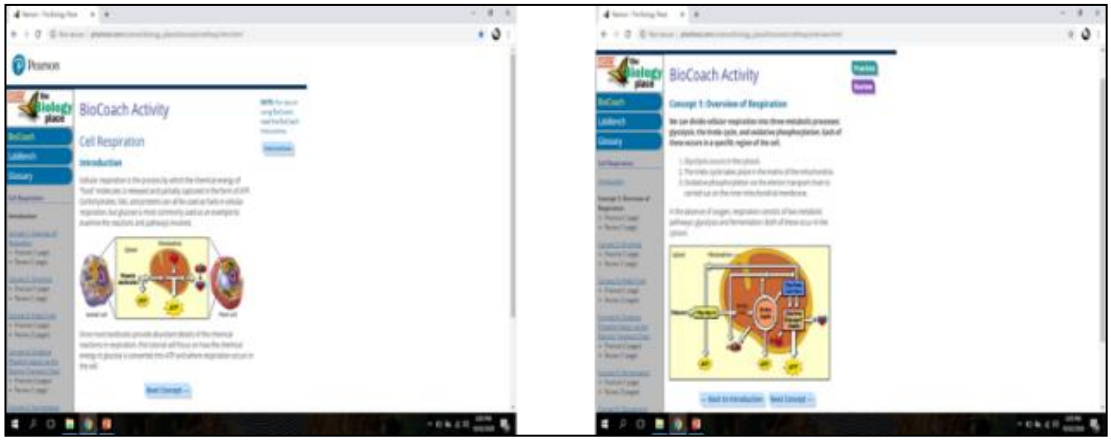

Fig. 7. Lesson 6 CAI Package

Lesson 7 presents the specific learning outcome that is attainable by the students, that the students will enumerate then describe the important stages involved in glycolysis and illustrate the sequential events in glycolysis. In the Explore part, the students are tasked to answer the action entitled "The Concept of Glycolysis" using the C.A.I. application. Figure 8 presents the actual C.A.I. application in doing the activity entitled "The Concept of Glycolysis." The students navigate only in every taskbar presented in the figure by following the procedures stated in action. It helps them understand more by clicking animations showing the flow of materials or input to make products.

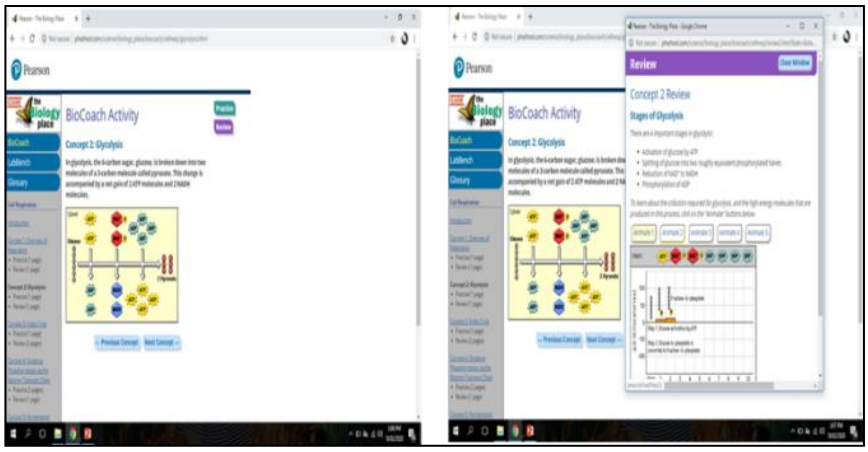

Fig. 8. Lesson 7 CAI Package

Lesson 8 presents the specific learning outcomes wherein the students were able to discuss and describe the citric acid cycle and list down the steps involved in the cycle and its corresponding output or products being produced. Figure 9 shows the C.A.I. application on the concept of Kreb's cycle. The BioCoach activity provides the students detailed steps in doing their activity. In the left portion of the application, as the students click the concept 3 Kreb's cycle, they can navigate the step-by-step conceptual presentations that helped them understand Kreb's cycle.

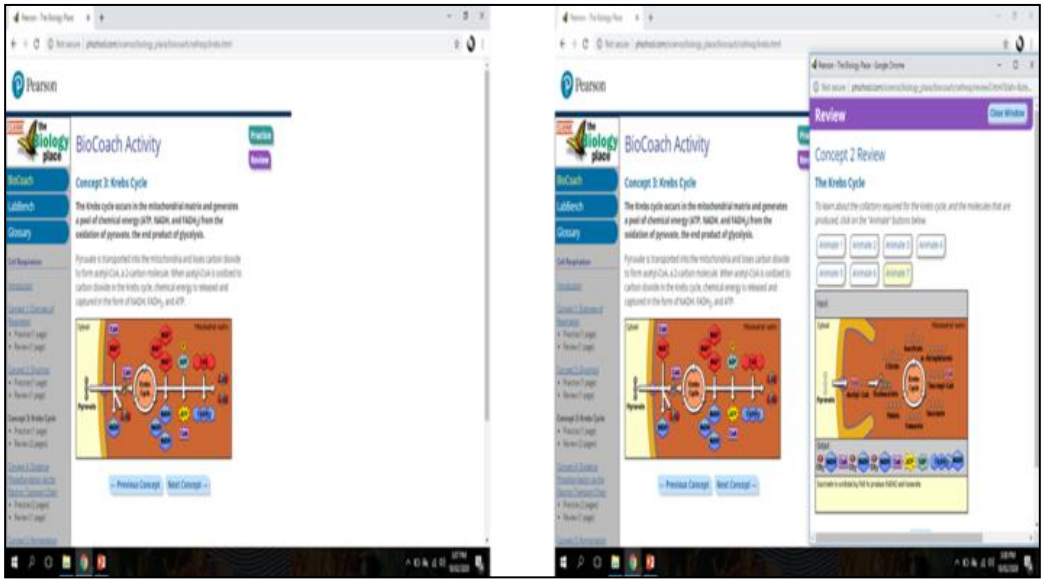

Fig. 9. Lesson 8 CAI Package

Lesson 9 focuses on learning the outcomes that the students could discuss the electron transport chain and identify the relationship between photosynthesis and cellular respiration. Figure 10 shows the detailed conceptual presentation of oxidative phosphorylation via the electron transport chain. It presents the actual C.A.I. application that the students navigated by clicking the Animation button from 1 to 8. These animations allow the students to enrich the flow of molecules in and out of the membrane presented during the whole process.

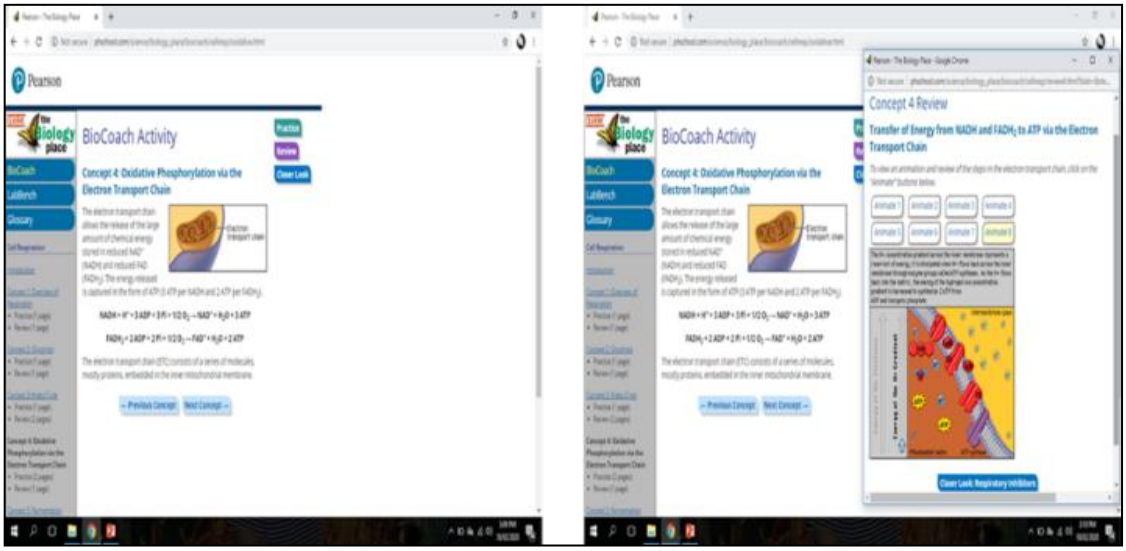

Fig. 10. Lesson 9 CAI Package

Assessment of Lesson Plan

The developed lesson plans are excellent (weighted mean=4.69) when it comes to the lesson objectives, learning experiences that involve the interactive learning activities that the students are engaged in, assessment of learning outcomes are multi-sensorial that caters to the students' capabilities in doing the tasks assigned in every lesson. The features of computer-aided instruction integrated into the lesson are appropriate to magnify and improve the student's conceptual understanding, which is an input to mastery of the learning competencies.

Table 2. Lesson Plan Components

Indicators	Mean Scores	Descriptive Interpretation
Congruency of Lesson Objectives	4.80	Excellent
Learning Experiences	4.76	Excellent
Assessment of Learning Outcomes	4.79	Excellent
Features of Computer-Aided Instruction	4.39	Excellent
Average Weighted Mean	**4.69**	**Excellent**

Congruency of Lesson Objectives

Table 2 presents the result of the assessed lesson plan, which is anchored to the established indicators in developing a lesson plan considering the creation of lesson objectives. Ambrose, S., Bridges, M., Lovett, M., DiPietro, M., & Norman, M. (2010) asserts that tasks must be clearly stated in designing a lesson objective. The focus is on the importance of learning goals, and they must be achievable.

Congruency of lesson objectives obtained the mean scores of 4.80, which are interpreted as excellent. This means that the goals made in these nine lessons are achievable. Statements are brief, clear, and specific, allowing the learners to do it at the end of the lesson. The result

of students' activities, teaching, and learning process has taken place. The nine lessons developed are all excellent for the assessment of experts supported by the mean scores obtained. One of the factors observed in the conduct of the lessons is that students are interested and well engaged when it comes to the activity that involves the manipulation of computers. Students are always eager to do the activity in a day to day instruction.

Learning Experiences

The assessment results in the learning experiences involved in nine lesson plans obtained mean scores of 4.76, which is verbally interpreted as excellent. These lessons integrated the identified learning activities used: problem-solving, group discussion, gamification, reflective journal, project-based, one-to-one discussion, computer-aided activities, and video demonstration. These learning activities allow the students in a well-engaged manner to develop the skills and knowledge in every concept required to demonstrate an affecting learning achievement in the lesson.

It was revealed in this study when the lesson reaches the exploratory part wherein the students are highly engaged in a virtual environment using computer-aided instruction. The mean scores result of 4.76, which the experts assessed as excellent, shows that these learning activities are efficient and effective.

Assessment of Learning Outcomes

The assessment of learning outcomes of every lesson is excellent resulted in a mean score of 4.79. The study identified activities used in the summative assessment to articulate and actualize the lesson objectives presented. These assessments of learning outcomes are: compare and contrast, data display, journal, drawing, graphic design, fact sheet, creative output, musical piece, poetry, diagram, flow chart, and fill in the blanks. The students accomplished the activities present in the lessons' evaluation part. The validation of the students' output was through the use of a scoring rubric.

Features of Computer-Aided Instruction

The study revealed that a computer-aided instruction package is excellent used in these lessons. It was supported with the mean scores obtained of 4.39, indicating that all the lessons integrated a C.A.I. package that helped the students enrich their conceptual understanding in every topic discussed in a day.

The computer-aided instruction packages used in these lessons are available in open-access online. The resulting interpretations for Lesson 1, 2, 3, 4, and 5 is excellent with i's obtain mean scores. This means that the experts were highly satisfied in assessing the package's features used in the lesson. The study viewed that as the students are called upon to respond to the program frequently prompts, students are remained mentally engaged in performing a broad range of cognitive operations. In lesson 6, with a mean score of 3.83, which was interpreted as very good, slightly affected the result of the experts' assessment. Eventually, revealed in this study that the features of computer-aided instruction are highly recommended to use in the lessons, especially in a context where the students find it challenging to understand the science concepts.

Conceptual Understanding in Life Science

Learning Gain Score (LGS) of 3.18 indicates that the higher positive LGS increases the students' conceptual understanding. Table 3 presents the effect of computer-aided instruction on students' conceptual understanding of life science.

In this study, the LGS was computed by simply subtracting pre-test mean scores from post-test mean scores. This represents the students' conceptual understanding before and after the classroom discussion with the integration of computer-aided instruction in the lesson. As shown in Table 3, the post-test got a higher mean score of 6.48, the pre-test got a mean score of 3.30, and the learning gained a score of 3.18. The integration of computer-aided instruction enhanced the students' learning gain in each topic, comparing the pre-test and post-test mean scores. This suggests that learning competencies in the subject were enriched more throughout the lesson's discussion using the C.A.I. packages.

Table 3. Learning Gain Score in Life Science

Topics in Bioenergetics	Mean Scores		Learning Gain Score (LGS)
	Pre-test	Post-test	
Structures and Function of Cells	3.33	8.41	5.08
Photosynthesis and Energy Flow	3.41	5.85	2.44
Utilization of Energy	3.15	5.19	2.04
Average Weighted Mean	**3.30**	**6.48**	**3.18**

This result indicates that the higher positive Learning Gain Score increases the students' conceptual understanding. This situation indicates that, in general, the students' conceptual understanding is associated with an increase in academic performance. These results agree with the results of the study of Brecht and Ogilby (2008). They found out that students who worked with computer-aided instruction performed better than those who worked with traditional lectures.

Effect of CAI on Students' Performance

A paired-samples t-test was computed to compare the performance between the pre-test and post-test of Grade 11 students in a life science subject. The paired samples t-test in table 4 shows a significant difference between the pre-test (M=9.70, SD=2.80) and post-test (M=19.56, SD=2.82) using the two-tailed hypothesis test. The study revealed an increase in the students' performance in the pre-test and post-test results connected to their conceptual understanding.

Table 4. Paired Samples Statistics for Students' Conceptual Understanding

Variables	Mean	Std. Deviation	Mean Difference	T	df	*p* (2-tailed)
Pre-test (N=27)	9.70	2.80	-9.85	-14.3**	26	0.01
Post-test (N=27)	19.56	2.82				

***Significant at 0.01*

The mean difference test between students' pre-test and post-test scores showed a significant result ($t26 = -14.30$, $p<0.01$). Hence, there is a significant difference between the students' pre-test and post-test scores that measure the effectiveness of computer-aided instruction on students' conceptual understanding in Life Science. The mean difference was -9.86, which was obtained by subtracting the post-test score from the pre-test score. The post-test scores were more significant than the pre-test scores, as indicated by the negative mean difference. Hence, sufficient evidence shows that the student's scores improved significantly after being taught in computer-aided instruction.

Conclusion and Recommendation

The study's primary goal is to determine the effectiveness of computer-aided instruction on students' conceptual understanding of life science. Specifically, it aimed to develop lesson plans, subject the lesson for validation, and implement them with the integration of C.A.I. packages to determine the students' performance in the pre-test and post-test connected to their mastery in the learning competency and conceptual understanding. The study's findings suggest that C.A.I. packages are one innovation in an interactive tool in teaching bioenergetics. It was also found out that students are more interested to learn when exposed to educational technology. However, some students are restricted with factors in learning the lesson related to intrinsic motivation, socio-economic status, and readiness to learn. As noted in the previous study, computer-aided instruction is an excellent tool to enrich the students' interests and improve their understanding of the concept. Thus, teachers are challenged to deeply extend

educational technology in remote areas to elevate the students' level of understanding.

Therefore, the developed nine daily lesson plans with computer-aided instruction packages are excellent and effective in teaching bioenergetics lessons. It is excellent in terms of congruency of lesson objectives, learning experiences, assessment of learning outcomes, and the features of computer-aided instruction packages. There is an increase in the learning gain scores related to the students' conceptual understanding as it also increases. Further, this increase is likely to improve the students' performance in the mastery of the learning competencies, which is shown in the significant difference between the performance in the pre-test and post-test of the students. This is an input to the principle of an integrative theory that students are stimulated and interested to learn the subject when educational technology and computer-aided instruction are embedded in the curriculum. This would imply that students are learning best at their own pace when guided by the activities programmed in the Computer-Aided Instruction packages.

This output shall serve as a model for the lesson development of Science Senior High School teachers. Masbate Catholic Education Association, in partnership with the Department of Education, Division of Masbate, especially the Education Program Supervisor in science, shall revisit and up-skill science teachers through forums, conferences, seminars, and workshops in preparation for the creation of lesson plan development team, which will be composed of daily lesson plan writers, demonstrator teachers, layout artist, editors, and validators in the senior high school with the integration of computer-aided instruction. The lesson plan writers shall ascertain that the components of the lesson are patterned as to congruency of objectives, learning experiences, and assessment of learning outcomes. Further, science enhancing and student-centered teaching strategies shall be applied to ascertain the students' conceptual understanding. Finally, a thorough establishment of correlational and significant results among groups of students (controlled and experimental) might be sought, and testing the effectiveness of C.A.I. might be enriched.

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