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The Impacts of a Multimodal Assessment Project in General Biology I at a Southwestern Community College

Larchinee Turner

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THE IMPACTS OF A MULTIMODAL ASSESSMENT PROJECT IN GENERAL BIOLOGY I
AT A SOUTHWESTERN COMMUNITY COLLEGE

by

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ABSTRACT

This Dissertation in Practice (DiP) uses an action research (AR) methodology to answer a research question pertaining to the impacts of implementing a multimodal-based assessment project in the introductory, General Biology I (BI 114) classroom at East-State Junior College. A mixed-methods approach will be utilized to ascertain the impacts on student learning as well as student perceptions of the project. Chapter One provides a justification of the relevance and importance of the research question regarding student learning, the post-secondary science landscape, Hispanic-Serving Institutions, and the challenges of providing positive learning opportunities and experiences to those students. A concise literature review is provided on authentic (or alternative) assessments, multimodal assessments, project-based learning, and student learning impacts when implemented into the science classroom. The particular AR methodology decided for this DiP is discussed briefly, and how its use will provide data-driven insight into the problem of practice and research questions which will drive future curriculum and instructional decisions within the introductory biology course. Ethical considerations pertaining to the study are discussed, as well as a culminating overview describing each DiP chapter.

Keywords: authentic assessment, community college, introductory biology, multimodal learning, project-based learning

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LIST OF ABBREVIATIONS

AR.....	Action Research
BI 114.....	General Biology I (course)
DiP	Dissertation in Practice
ESJC.....	East-State Junior College
ESL	English as Second Language
HSI.....	Hispanic-Serving Institution
NMPED.....	New Mexico Public Education Department
PjBL	Project-Based Learning

CHAPTER ONE

INTRODUCTION

"Sound educational experience involves, above all, continuity and interaction between the learner and what is learned" (Dewey, 1938, p. 10). Rooted in constructive and progressive theory, Dewey (1938) believed that it was not enough to provide rote, generalized information to students and expect positive learning experiences to result. He felt it was important to consider the varied experiences of the learners and create positive learning experiences that allow students to create meaning from and through experiences, perceptions and reflection.

As a biology instructor at East-State Junior College (ESJC) I am interested in methods to increase content understanding within my introductory biology courses. Biology, as a "hard science," consists of difficult concepts that are traditionally conveyed in a conventional teacher-centered methodology, although research on science assessments in post-secondary education indicates that this dynamic is changing (Goubeaud, 2009; Drake, 2014). In addition, students entering ESJC and community colleges in general are often grossly under-prepared for college-level coursework. "Sixty percent of incoming students are referred to at least one developmental course" (Bailey, 2009, p. 12). This leads to placement in developmental (or remedial) courses or multiple course attempts to increase academic preparedness or succeed in their intended college major (NCPPE, 2010; Bailey, 2009). Consequentially, community college faculty members often take on the hard but necessary task of meeting students where they are

and helping to move them to the next academic level (Goldrick-Rab, 2010). Since ESJC does not offer remedial biology courses, non-major students directly enter General Biology I (BI 114) as their initial post-secondary biology course.

Students within the introductory biology courses often struggle gauging and understanding the complex biological concepts presented, and as a result many are unsuccessful or withdraw from the course. This contributes to multiple BI 114 course attempts, and/or lowered program completion rates (ESJC, 2017). Aligning with Dewey's (1938) progressive and constructivist views on education, I attempt in this action research DiP to further investigate a three-pronged inquiry approach to improve teaching and learning in my introductory biology courses: (1) to bridge the individual experiences and backgrounds of the introductory biology students by utilizing a multimodal pedagogy (2) to craft project-based learning experiences that will allow them to increase understanding and create meaningful and lasting connections with what they are learning; and (3) improve ongoing assessment of student learning through implementation of authentic assessment. Evaluating these classroom instructional and assessment methodologies will allow greater reflection by me, the teacher-researcher, on how to increase student understanding. Doing so can, in turn, also affect how students navigate their post-secondary educational journeys.

Problem of Practice

East-State Junior College (ESJC) students often have difficulty learning departmental concepts in the General Biology I course. This educational experience affects student learning outcomes (SLO) achievement and course success rates due to withdrawals or course failure. There is known to be a ~65% BI 114 course success rate

each semester, according to college data (ESJC, 2017). Engagement is also affected when students struggle with understanding course content (Kuh, Cruce, Shoup, Kinzie, & Gonyea, 2008). Longitudinally, student program completion is affected as students are unsuccessful in a gateway course to their program majors, such as nursing.

Another confounding factor in the student learning process concerns the high number of English as Second Language (ESL) students that are found at the institution. East-State Junior College is designated as a Hispanic-Serving Institution, as are many colleges found along border states (Torres & Zerquera, 2012). The presence of many ESL students also compounds the difficulties generally found in post-secondary (science) education.

Each individual varies in background knowledge, readiness, language, preferences in learning, and interests (Dana & Yendol-Hoppey, 2014), and consequently, a traditional, one-size fits all approach is ineffective in terms of both instruction and assessment. Rather, a more effective approach maximizes the teacher's knowledge of different learning potentials in students, the learning opportunities must be active and crafted to student's interests and capabilities, and experiences must simultaneously allow the student and teacher to observe, reflect, and evaluate their learning.

Research Question

The teacher-researcher posed the following question to guide the conceptual and methodological planning and implementation of a mixed-methods, pre-experimental, one group pretest-posttest action research study.

Exam data or performance will also be compared between the treatment group and the Fall 2017 non-treatment group, to garner further insight pertaining to the following research question: What is the impact of implementing a multimodal project on students' academic achievement regarding course-specific objectives mastery?

Purpose Statement

The purpose of this research is to investigate the efficacy of a multimodal assessment project on student learning within the introductory, General Biology I (BI 114) course in a community college setting (ESJC). Multimodality is a learning theory developed by Gunther Kress (2009), which considers the many different means (or modes) by which people use to communicate with each other and convey information. A mode is generally defined as a communication channel that a culture recognizes (Kress, 2009; Schweppe, Eitel, & Rummer, 2015), such as speech, text, and diagrams. For this study, learning is to be operationalized as course-specific student learning outcomes (SLOs) performance. Learning outcomes describe what students can demonstrate in terms of knowledge, skills, and values upon completion of a course, a span of several courses, or a program (Tiu & Osters, 2015). Student Learning Outcomes (SLOs) for the BI 114 course at ESJC consist of a broader, departmental set and a course-specific set that is rooted in content objectives.

Understanding the student impacts of this integrated assessment and project-based approach that utilizes a multimodal design on multimodal learning will inform further methods of course implementation, to benefit the varied learners present. "The most important benefactors of taking an inquiry stance towards teaching and actualizing that stance through action research are the students you teach" (Dana & Yendol-Hoppey,

2014, p. 8). Students will also gain insight into *how* they can learn material in the course, and develop methods of empowering their own learning processes.

Significance of the Study

Social Justice

Action research is a form of self-reflective inquiry undertaken by participants in social situations to improve the rationality and justice of their own practices, their understanding of these practices, and the situation in which the practices are conducted (Carr & Kemmis, 1986). This definition incorporates personal and political dimensions. It reflects attention to one's practice in the classroom, and ways in which this practice may reflect wider societal inequities or may seek to address them. Regarding the learner:

Action research is designed to improve the research subjects' capacity to solve problems, develop skills (including professional skills), increase their chances of self-determination, and have more influence on the function and decision-making processes of organizations. (Boog, 2016, p. 6)

In educational contexts, action research is a special form of research that may be carried out by teachers who are not only interested in understanding, but in changing their teaching to align it more with their values (Arhar & Buck, 2000; Mertler, 2014). Action research projects can focus on ways in which the routines and procedures of the classroom and/or school may maintain injustices for certain groups of students. For example, a project might consider ways in which students are not given a voice in their learning, which potentially perpetuates a cycle of disinterest and lack of academic achievement (Dana & Yendol-Hoppey, 2014).

Community colleges are centers of educational opportunity. “They are an American invention that put publicly funded higher education at close-to-home facilities, beginning [more than] 100 years ago with Joliet Junior College” (Kasworm, Rose, & Ross-Gordon, 2010, p. 244). Since then, community colleges have been inclusive institutions that welcome all who desire to learn, regardless of wealth, heritage, or previous academic experience. It is often that students see opportunities in community colleges to obtain diplomas, certificates, and degrees to change/improve their unique situations.

Community colleges have a greater proportion of students with various risk factors when compared to all higher education (Mullin, 2012). It is not uncommon for students entering community colleges to place into developmental or remedial courses, due to a lack of academic preparedness or inadequate scores on admissions placement tests.

About 60 percent of incoming community college students are referred to at least one developmental course (NCPPE, 2010), including entering students at East-State Junior College. Developmental, or underprepared students face tremendous barriers.

Less than one quarter of community college students who enroll in developmental education complete a degree or certificate within eight years of enrollment. In comparison, almost 40 percent of community college students who do not enroll in any developmental education course complete college in the same time period. (Bailey & Cho, 2008, p. 4)

Research also indicates that older students, African-American and Hispanic students, part-time students, and students in vocational programs are less likely to progress through their full developmental sequences (Bailey, Jeong, & Cho, 2008; NCPPHE, 2010). This contingent makes up a large proportion of community college students. Community colleges provide access to nearly half of all minority undergraduate students and more than 40 percent of undergraduate students living in poverty (Mullin, 2012). Close to half of all community college students leave before obtaining their stated goals (Goldrich-Rab, 2010; Sandoval-Lucero, Maes, & Klingsmith, 2014). Barrington (2004) believes this is becoming an increasingly alarming issue because post-secondary institutions (in the West particularly) still privilege certain ways of knowing and focus on a narrow view of the intellect that does not always allow for socio-cultural differences.

An epistemology of experiential education and constructivism is that individuals, or learners, come to educational experiences with their own narratives (life stories) and perceptions, and interpret these experiences based on those narratives (Dewey, 1938; Allison & Pomeroy, 2000). Learning can also be positive or negative for the student (Dewey, 1938). When researching or making curricular decisions, one must consider, value, and build on the diverse prior learning experiences of students to promote positive learning experiences. “A constructivist epistemology typically utilizes research approaches such as ethnography, case studies, biographies, and phenomenology in order to develop understanding of experiences” (Allison & Pomeroy, 2000, p. 96). These experiences are subjective and belong to the individual and the collective group.

The conceptual history of action research includes social justice empowerment through self-actualization, self-determination and emancipation from social, economic, and personal restraints (Helskog, 2014).

Addressing the needs of academically underprepared students is arguably the most difficult and important problem facing community colleges (Bailey & Cho, 2008). Researching instruction and assessment implementation can lead to changes that not only improve success rates within an introductory course or program, but also can improve the outcomes of the students beyond. The Commission on Access, Admissions, and Success in Higher Education states that a goal for college completion is to, “increase the number of American adults who hold a college degree or certificate to at least 55 percent by 2025” (Sandoval-Lucero, Maes, Klingsmith, 2014, p. 522). Improving educational efficacy not only contributes to improving national completion goals, but at the local level it also seeks to fulfill the community college mission of providing opportunity and access to higher education. There is a possibility to close post-secondary achievement (and SES) gaps by providing quality instruction to those that are underprepared and/or diversified in backgrounds and experiences.

Theoretical Framework

Progressivism

Progressivist educational theory is a primary work of John Dewey and his colleagues. According to Dewey (1938), education is rooted in individual experiences. In order to provide the most effective (and positive) learning opportunities, pedagogy should consider the nature of their student body. Progressive education is often described in contrast with what are considered traditional or essentialist-based educational methods.

According to Dewey (1938), in traditional education subject-matter as well as standards of conduct are handed down from the past, where the attitude of students must generally be one of subjugation, receptivity, and obedience. Textbooks represent the chief ideals and wisdom of the past, while teachers are the primary means through which students are brought to understand the material. Therefore, teachers are the agents through which knowledge and skills are communicated. Dewey (1938) posited that since learning experiences can be either positive or negative, the more subdued learning environment experienced in a traditional classroom can contribute to negative learning habits that stifle future growth.

Prior experience of the learner provides the background for all future learning, and progressive education utilizes a student-centered methodology to effect positive learning. For educators, it is important to consider student-teacher dynamics in progressive pedagogy and to treat students as participants versus spectators (Dewey, 1938). Alternative, project-based, and differentiated assessments are examples of progressive pedagogy utilized in this particular AR study.

Dewey (1938) also noted the importance of reflective thought in the educational process and claims that through active investigations, learners find solutions to complex problems. Mertler (2014) describes reflection as “the act of critically exploring what you are doing, why you decided to do it, and what its effects have been” (p.14). When teachers present their classes with relatable problems and guide their students towards problem-solving, active reflection and individual understanding is promoted (Solomon, 2013).

In addition to the notions of individualism, experiential learning and reflection, progressive educators and theorists claim that education holds the potential to solve social problems, and an educated and socially responsible population strengthens democratic institutions.

Conceptual Framework

The conceptual framework supporting my AR study is grounded in multimodal pedagogical/learning strategies and alternative assessments, to include project-based learning. Chapter Two will provide a thorough exploration of these pedagogies through a review of related literature.

Constructivist Teaching Pedagogies

Constructivist-based research on student learning, in opposition to traditional, lecture-based instruction has included both differentiated and multimodal pedagogies. Differentiated instruction is rooted in the notion that the uniqueness of students requires distinct or individualized presentation of material, to effect learning. Multimodal instruction is rooted in the integrated means by which people communicate and interact with each other, using not just one mode such as writing, but also through the convergence of audio, kinesthetic, and visual forms (or modes).

Differentiated Instruction. One means to differentiate student instruction is by determining individual student learning profiles, or preferences. An example of learning profile includes Kolb's four learning styles: 1) concrete experience, 2) reflective observation, 3) abstract conceptualization, and 4) active experimentation (Kolb and Kolb, 2005). It is also possible to possess multiple learning preferences, which is considered

multimodal in nature. Once a student's learning style is ascertained, instruction and/or assessments are then crafted to meet their unique needs.

While popular within educational circles as a student-centered pedagogical tactic (Willingham, Hughes, & Dobolyi, 2015), the concept of learning styles/preferences and their associated assessment models have not been met without criticism. Validity of the Kolb's learning style model, as well as others have been questioned extensively. For instance, with regards to content validity: "Despite the various refinements of Kolb's theory, however, the instrument still appears to possess several weaknesses which limit its use, including low reliability, questionable validity, and low predictive powers" (Manolis, Burns, Assundani, & Chinta, 2013, p. 44).

In addition, the forced-response nature of the inventories/scales is seen to limit their psychometric power (Henson & Hwang, 2002; Manolis, Burns, Assundani, & Chinta, 2013; Willingham, Hughes, & Dobolyi, 2015). Manolis et al. (2013) warn that "pigeonholing students into a single learning style without appreciating the "strength" of that style or that other less dominant styles may unnecessarily curtail student learning is problematic" (p. 51). As educators are classroom leaders, effective leadership calls for an ability to adjust to the student population at hand and use different styles at a particular time, when needed.

Multimodal Instruction. Multimodality is a learning theory which considers the many different modes that people use to interact with each other and express themselves. A mode is generally considered to be a communication channel such as speech, text, videos and diagrams (Kress, 2009; Schweppe, Eitel, & Rummer, 2015).

While many of these modes have always existed, they have not always been recognized as a legitimate or culturally accepted form of communication or expression (Kress, 2009; Blikstein & Worsley, 2016).

Multimodal instructional pedagogies involve the practice of multiple representation or re-representing concepts through different outlets (Tang, Delgado, & Birr Moje, 2014). It also considers how learners integrate the various components of a representation, for example, via the senses to produce meaning. Connecting with Vygotsky's (1986) sociocognitive theory, representations are broadly understood as symbolic tools that mediate social learning and human cognition. Using and transforming several tables, diagrams, or graphs from one form to another, are forms of multiple representation. Multiple representations also relate to the multimedia effect, which posits that learning with text and pictures is a benefit from combined representations as compared to text only (Schweppe, Eitel, & Rummer, 2015; Sankey, Birch, & Gardiner, 2013).

Innovations in the use of educational technologies provides higher education institutions greater opportunities to design media-enhanced, interactive, more inclusive and engaging multimodal courses (Sankey, Birch & Gardiner, 2010). In addition, "with the rapid move to more online, off-campus study, traditional print-based materials are being converted into more multimodal, interactive, technology-mediated e-learning formats" (Sankey, Birch & Gardiner, 2010, p. 852). Henceforth, the use of multimodal instruction is also useful in promoting 21st century skills associated with a technological world.

Multimodal education provides unique opportunities that enhance and stimulate learning for all students. According to Drake and Pawlina (2013), “educational programs designed to help the visual, auditory, and kinesthetic learner should be the current goal of course and curricular design” (p. 1). Each student is unique, and a one-size-fits all approach to instruction and learning may not maximize their educational experience. Being conscious of student needs and classroom dynamics can assist teachers in creating equitable learning opportunities for all students. “Alternative and authentic assessment, multiple intelligences theory, differentiated instruction, and inclusionary practices all have the goal of improving learning for each and every student” (Waters, Smeaton, & Burns, 2004, p. 90). Considering the pros and cons associated with a differentiated pedagogy, a more integrative pedagogy will be considered for this action research DiP study. I seek to utilize an instructional approach rooted in multimodalities and authentic course products to ascertain its efficacy in practice, and potentially increase student learning opportunities.

Authentic or Alternative Assessments in Science

Authentic assessments are referred to as performance-based or alternative assessments. These types of assessments require students to apply their knowledge and skills to real-world settings to measure what they know and are able to do (Chapman & King, 2012; Dorsch & Zion, 2014). These assessments are generally graded with performance rubrics. Authentic tasks not only serve as assessments in the traditional sense, but also as vehicles of learning as each student constructs meaning as part of the assessment process.

Authentic assessments utilize a variety of tasks that reflect the learning differences present in the class and allow opportunities for all learners to demonstrate their knowledge. Some examples of authentic assessments include models, demonstrations, projects, performances such as with dance, journals, etc. For my AR study, I will employ the use of projects as an alternative assessment, in an effort to encourage interactive, project-based learning. Project-based learning is a comprehensive approach to classroom teaching and learning that is designed to engage students in investigation of authentic problems (Blumenfeld et al., 1991). When designing alternative assessments choice is key, as students take more responsibility for their learning (Mullen, 2016). All of these types of assessment are based in constructivist views of learning that seeks to incorporate unique experiences as a counter to traditional lecture-based classroom structures.

Methodology

Teacher-Researcher

“Action research is participative, since educators are integral members- not disinterested outsiders- of the research process” (Mertler, 2014, p. 21). As a primary lecture and lab instructor for the BI 114 course, I am involved in curriculum and learning outcome management, as well as teaching the course each semester. Generally, I teach between 1-2 lecture sections and 4 lab sections, with up to 200 combined students per semester. It is through instruction of the course at ESJC and comparable courses at other community college institutions that I have garnered most of the observations that led to culminating my problem of practice and research questions.

For instance, I have observed that while biology courses often have an interactive lab component, students may not necessarily connect their actions to the lecture or retain the information (Stuckey, et al., 2013).

As a former nursing program advisor and physical therapy assistant advisor, I have also observed longitudinal student progression relating to a community college, introductory biology course. Through regular collaboration with fellow ESJC biology instructors, being a current associate degree advisor, and review of college publications, I have gained further insight to support the basis of my AR project.

As the main purpose of promoting research is to sharpen and maintain teachers' insight and curiosity (Lu, Shin, & Overton, 2016), improvement of the classroom environment and student learning are the main goals associated with this research study. The course is presented in a face-to-face, web-enhanced or completely online format, containing departmentally and regionally-based standards associated with general and cellular biology. Web enhanced is operationally defined to consist of traditional lecture/lab periods with added resources found on the online course platform, Canvas. Some specific topics include basic chemistry, cell structure and function, photosynthesis, cell respiration, cell division, genetics and protein synthesis. It has been observed that students entering an introductory biology course often feel overwhelmed, which can be exacerbated by low performance. In turn, students' course success can suffer.

It is important for educators to reflect upon their classroom practices for improvement. "This sometimes requires a shift in the way we think about and approach our own classroom practice" (Mertler, 2014, p. 24). As an instructor for the course, it is important for me to utilize various methods of expressing the course content to the

students, whether through videos, animated PowerPoints, group work, etc. But it is also important to consider other means of providing learning opportunities within the classroom. For this teacher-research the insight gained by this AR project on the effects of a multimodal assessment project can only provide data to better understand and improve the classroom environment for students.

Student-Participants and Research Setting

The city of Hobbs was founded in 1907 when the James Hobbs family established a homestead and named the settlement. Hobbs is the largest municipality in Lea County, the southeastern-most county of New Mexico's 33 counties, and situated on the far western edge of the Llano Estacado. The Hobbs area exhibits a multicultural heritage of Native American and cowboy influences, farming traditions and Hispanic culture. As of 2011 there were 33,405 people, 10,040 households, and 7,369 families residing in the city (Hobbs Chamber of Commerce, 2017). In addition to the city of Hobbs, Lea County also consists of the cities of Eunice, Jal, and Lovington, as well as the town of Tatum.

Major economic highlights of the area revolve around the oil industry, with companies such as Hess, Halliburton, and Oxy establishing operating locations. Other businesses include retail and food operations. Comparative to much larger cities in the Llano Estacado region such as Midland-Odessa and Lubbock, Texas, Hobbs has a slower economy. Many residents enroll in local colleges seeking to improve their economic outcomes and specialized job skills through education.

Area High School Demographics. A large portion of students at ESJC are graduates of local high schools. According to the New Mexico Public Education Department (2017), Local Education Authorities (LEAs) made of area K-12 schools

receive an annual comprehensive report of their achievement, accountability, teacher qualifications, and post-secondary success. A demographic profile is also provided, to better understand the nature of the local student population. Another goal of the NMPED annual comprehensive report is to provide transparency with public education outcomes, to include the sciences.

New Mexico state’s 2016-2017 achievement proficiencies in 11th grade science are as follows: 35% proficient, 65% non-proficient (NMPED, 2017). The previous academic year’s proficiencies were: 39% proficient, 61% non-proficient. The 11th grade science proficiencies for Eunice’s LEA during the 2016-2017 academic year, for local comparison are: 25% proficient, 75% non-proficient. According to the New Mexico Public Education Department (2017), the proficiency assessments were developed to measure grade-level standards that New Mexico educators and the public determined are important for the students to master. Table 1.1 provides statewide 11th grade proficiency levels, based on demographic subgroup.

Table 1.1: Data on 2016-2017 New Mexico state achievement proficiencies in 11th grade science, based on demographic subgroups.

Demographic Subgroup	Proficient (%)	Non-Proficient (%)
Caucasian	61	39
African-American	37	63
Hispanic	34	66
Asian	66	34
American Indian	22	78
Economically Disadvantaged	32	68
English Language Learners (ELLs)	16	84

Accountability is described as consisting of school grade summaries, cohort graduation rates (4, 5 and 6 year), and status of non-graduates (NMPED, 2017). Eunice

High and Hobbs High in Lea County have an overall school grade of C and B, respectively. New Mexico state's four-year, high school graduation rates in 2016 consisted of 75% of the total student population, and Eunice High's four-year graduation rate was 79% (NMPED, 2017).

The local and state demographics reported align with research on the academic preparedness of students entering college (Bailey & Cho, 2008; NCPPHE, 2010; Sandoval-Lucero, Maes, & Klingsmith, 2014). While there is a litany of contributing factors, as a community college educator, I am provided objective insight into the educational backgrounds of the students within my classroom. In addition, I am encouraged to further reflect on how to meet my students' varied academic needs in science, while fostering growth and progression. The local and state data supports the basis of my action research DiP, which seeks to implement a student-centered, multimodal assessment project in an effort to enhance content learning and achievement (proficiency).

East-State Community College Dynamics. ESJC is a comprehensive community college; the ESJC mission is to: "Promote success through learning" (NMJC, 2017, para 1). East State Junior College first opened its doors to students in the fall of 1966. Since then it has grown to be one of the major community colleges in the "Land of Enchantment", with a current enrollment of ~3,300. In addition to a range of academic/career pathways, athletic teams and student dormitories are offered as part of the student experience. ESJC is the flagship community college of Lea County, and primarily serves its local population, in addition to regional and out-of-state students.

ESJC offers associate degrees in science, applied science, and arts; in addition, several certificate programs in vocational trade areas. There are over 640 courses of study offered annually through ESJC's two instructional sectors: Arts and Sciences and Business and Technology. It is also designated as a Hispanic-Serving Institution (HSI), because of the large number of Hispanic students attending the college. According to the Hispanic Association of Colleges and Universities (2018), a minimum of 25% of the total school enrollment must be Hispanic for this classification. This designation is common for many colleges located in Mexican border states (Torres & Zerquera, 2012).

ESJC students generally enter remedial courses due to admissions placement test scores. Remedial (also designated as transitional) courses are offered in both English and math. As there are no longer remedial biology courses offered at the college, ESJC has opted to place those students into BI 114 as the introductory biology course, which is also geared towards non-science majors.

The General Biology I and II courses are the largest offered in the biology department and has chronically lower success rates (~65% on average) compared to many science courses/departments, due to failing grades or attrition (ESJC, 2016). In the Fall 2017 semester, five lecture sections were offered of BI 114 and two of BI 124 (General Biology II) with an average of 60 students in each. Instructor and advisor observations indicate that many entering students are academically underprepared within the classroom. It is also important to note that many ESJC students have families, full-time jobs, and various sociocultural factors (such as English as a Second Language challenges) affecting them in addition to academics. This dynamic is common in community college settings (Mullin, 2012).

The BI 114 course serves as both a course option for an AA/AS major, as well as a prerequisite option for students entering an Allied Health field such as nursing and need higher-level science courses such as Anatomy and Physiology. Most students entering the BI 114 course are seeking to complete requirements for a two-year degree and/or transfer to a four-year institution. Students that are unsuccessful in the first course attempt must take the course again to proceed into more rigorous courses in their program or complete their program requirements to graduate.

Ethical Considerations

Ethical decisions should be made to ensure that classroom inquiries take place within a set of agreed rules. As action research consists of an educator or educators studying a particular educational context, there is inevitable personal involvement with the research subjects which can be different from traditional research methods (Dana & Yendol-Hoppey, 2014). Some ethical considerations as a teacher-researcher include ascertaining a need to gain informed consent from the participants, protecting student privacy and health, and following the local policies where the research occurs.

Gaining the voluntary, informed consent of participants is a major ethical consideration. It is important for research subjects (the BI 114 students in this case), to be aware of what they are involved with, and how the information will be utilized. “No one- adults or children- should ever feel coerced or compelled to participate” (Mertler, 2014, p. 103). It is important to disclose the objectives of the research, including making known any predictable detriment which may occur because of research participation, and taking steps to minimize risk of any detriment (Dana & Yendol-Hoppey, 2014; Trager, 2016).

As consent and participation is voluntary, it is important to allow for the students to remove themselves as participants from the study if they choose.

As an educator, I have access to personal information of students, and therefore must consider participant privacy, including confidentiality and anonymity during the research process. “The basic idea of getting permission for conducting action research and collecting data on students is to protect the privacy of students and their families” (Mertler, 2014, p. 103). Family Education Rights and Privacy act (FERPA) states that schools must have written permission from the parent or the eligible student to release any information from a student’s educational record. This can be accomplished by having students sign an informed consent form or parental consent form for minors, which details the purpose of the study and student involvement. Per the University of South Carolina Institutional Review Board, as the BI 114 students at ESJC are interacting with the study as part of their embedded course curriculum, students would not be required to sign an informed consent form (L.M. Johnson, personal communication, December 5, 2017). For protection of identity during data reporting, individual names should be removed, or pseudonyms provided as an alternative.

There are additional ethical considerations to be made when working in educational contexts. In addition to seeking advice on the implications of school-specific policies relating to classroom-based inquiry, additional ethical considerations should be considered for “inquiries which involve work with children, young people and vulnerable adults” (Trager, 2016, p. 5). As a researcher, one must also consider their own subjectivity during the research process. “Since one cannot be a fly on the wall in their own classroom, a teacher-researcher must deal with emotional and interpersonal

responses as part of the data” (Zeni, 1998, p. 14). A study may consist of individuals with vastly different life experiences, SES, etc., than the researcher. It is important to consider and reflect on personal bias in how data is collected and interpreted, as this can also affect outcomes.

Will your study attempt to read and interpret the experience of people who differ from you in race, class, gender, ethnicity, sexual orientation or other cultural dimensions? How have you prepared yourself to share the perspective of the ‘other’ (coursework, experiences, other sources of insight)? (Zeni, 1998, p. 13)

Once data are collected, it should not be tampered with, altered, or suppressed in any way. As the teacher-researcher, I must take care to collect and interpret student data with as little bias as possible, to maintain integrity of the study and results.

Definition of Terms

Action research: any systematic inquiry conducted by teachers, administrators, counselors, or others with a vested interest in the teaching or learning process for the purpose of gathering information about how their particular schools operate, how they teach, or how students learn (Mertler, 2014, p. 4)

Authentic assessment: a meaningful performance task the learner applies to demonstrate knowledge, skill, strengths, and needs in a realistic manner (Chapman & King, 2012, p. 3)

Constructivism: a theory of education that suggests that learners create (construct) knowledge based on their individual experiences (Dewey, 1938; Chapman & King, 2012)

Developmental course: refers to classes taken on a college campus that are below college-level, and is often used interchangeably with “remedial” and “transitional” (Bailey, 2009, p. 12)

Differentiation: a philosophy that enables teachers to plan strategically in order to reach the needs of the diverse learners in classrooms today to achieve targeted standards (Chapman & King, 2012, p. 4)

Differentiated assessment. An ongoing process through which teachers gather data before, during, and after instruction using multiple formative and summative tools (Chapman & King, 2012, p. 1)

Engagement. The tendency to be behaviorally, emotionally, and cognitively involved in academic activities (Thijs & Verkuyten, 2009, p. 268)

Experiential education. Philosophy of education that describes the process that occurs between a teacher and student that infuses direct (individual) experience with the learning environment and content (Dewey, 1938)

Web-enhanced courses. Refers to courses that are presented with a traditional, in-class components with online or external resources to satisfy contact hours for credits (Jaggers, 2014)

Learning preferences (or style). Refers to the ways that individuals want to take-in and present information (Chapman, 2012). For example, visual, aural, read/write, and kinesthetic methods.

Multimodality. Multimodality is a theory which focuses on the multiple ways people communicate and interact with each other, not just through writing (one mode) but also through the convergence of speaking, gesture, gaze, and visual forms (many modes).

(Tang, Delgado, & Birr Moje, 2014)

Novelty. Anything new, different, or unique that captures the mind's attention (Chapman & King, 2012, p. 19)

Progressivism. Philosophy of education that centers around the idea that education should foster a relationship between the student and society, especially focusing on the democratic process, and learning as exploration that is rooted in experience (Dewey, 1938)

Project-based learning: A teaching method in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging and complex question, problem, or challenge (Chapman & King, 2012)

Summative assessment. Evaluation of student work occurring at the end of a unit or period of study (Chapman & King, 2012, p. 5)

Traditional education. A teacher-centered delivery of instruction to classes of students who are the more passive receivers of information (Dewey, 1938)

Potential Weaknesses of Study

Action research by nature has limitations or weaknesses, while used as an appropriate methodology for enacting local educational change. There is some assumed bias and subjectivity present as a teacher-researcher, as they are not removed from the research setting or participants. Care must be taken to reflect on any potential biases during the research process and triangulate data for reliability.

“Triangulation is a process of relating multiple sources of data in order to establish their trustworthiness or verification of the consistency of facts while trying to account for their inherent biases” (Mertler, 2014, p. 12).

Action research is usually not generalized to a larger population, as the sampling is nonrandom, and the research questions pertain to a specific educational setting. Since a pre-experimental, one-group pretest-posttest design is used to answer my research question, I must consider that there are external, confounding factors that may account for improvement, or decline in performance on learning outcomes that are not directly measured by the research design (Mertler, 2014). To increase the reliability of inferences made pertaining to student gains and performance, exam data from the Fall 2017, traditionally-taught BI 114 course will be compared to that of the Summer 2018 treatment group, to ascertain any significant differences between the two. Nonetheless, as the students are varied in their experiences and backgrounds, a weakness in educational research is found in confounding factors that could contribute to the research results. Examples of confounding factors to consider in this study are previous college or course experience, access to resources/technology and student time availability outside of class.

Summary and Conclusion

This action research DiP attempts to answer the following research question pertaining to a local problem at East-State Junior College: What is the impact of implementing a multimodal project on students' academic achievement regarding course-specific objectives mastery?

The status and progression of the community college student is one that warrants intervention and improvement. Most students attending community colleges are of lower

academic preparedness, SES, and minorities, improving the educational experiences of this group also improves social outcomes for the community through improved course success and program progression (Westheimer & Kahne, 2004; Helskog, 2014).

Traditional education negatively impacts those that require instructional interactivity and real-world understandings. It also rejects the concepts of student empowerment and individuality that is valued in a progressive society. One must challenge these traditional educational roles in non-traditional education settings such as community colleges, to provide opportunities for learning and societal progression to all that strive to improve themselves.

The insight gained from the data collected will be used to ascertain (1) if there was an improvement in student performance on departmental SLOs, and (2) student-based perceptions of both the multimodal project design and efficacy. The results will be used to make more informed decisions pertaining to curriculum implementation and instruction within the introductory biology course. Short-term goals of the DiP would be to increase performance on student learning outcomes for a difficult BI 114 topic, designated as photosynthesis. I also hope to challenge the students to learn more about their learning needs and to gain empowerment in *how* to study material. A long-term goal of the DiP is to provide positive learning experiences to introductory biology students that would improve their course and program outcomes at the college.

CHAPTER TWO

LITERATURE REVIEW

The purpose of this literature review is to provide an evidence-based framework pertaining to my AR study, pertaining to multimodal assessments in an introductory biology course. The topics surrounding my local problem of practice and research question concern:

- 1) The community college landscape, and Hispanic-Serving Institutions.
- 2) The nature of science and biology education.
- 3) Authentic assessments, such as multimodal and project-based.
- 4) Authentic assessments in post-secondary STEM courses, and its effects of student learning and/or engagement.

The literature review methodology primarily consists of online database searches of Educational Source and ERIC, as provided by the University of South Carolina library system. Additional resources are provided by previous and current course materials, textbooks, and physical journal articles. In analyzing a diverse array of primary and secondary sources regarding the above topics, I seek to provide support, context, and background understanding for the development of the following research question pertaining to a local problem at East State Junior College: What is the impact of implementing a multimodal project on students' academic achievement regarding course-specific objectives mastery?

The progression of the literature review begins with a historical overview, characteristics and comparisons of the major associated theories, constructivism and progressivism. Next, a description of the community college landscape, Hispanic-Serving Institutions (HSIs) and nature of science education describes the educational backgrounds pertaining to the student population at ESTC and BI 114 course. Lastly, descriptions of authentic assessments, multimodalities, project-based learning and associated considerations are provided to lend strength and credibility to its use in this AR study.

The History of Constructivism and Progressivism

As the topics of authentic, student-centered assessments pertain to activities that influence the individual learner, their theoretical underpinnings are rooted in constructivist and progressivist philosophies. Prior to the development and growth of each philosophy, educational assumptions (such as the behavioral and cognitive theories) were primarily objectivistic in nature. The world is real, external to the learner, and the goal of education was to map the structure of the world onto the learner (Ertmer & Newby, 1993).

Constructivist roots can be found in classical antiquity, in using Socrates's dialogues with his followers, where directed questions were asked that led his students to analyze themselves and identify weaknesses in their thinking (Butler, 1997). It was through these interactions where personal understanding could be constructed. In the 1900s, Jean Piaget and John Dewey developed theories of childhood development and education that led to the evolution of constructivist and progressivist theories (Driscoll, 2005; Ultanir, 2012). Lev Vygotsky (1978) is also credited with contributing to the social aspect of constructivism, also termed social constructivism.

Piaget (1971) believed that humans learn through the construction of one logical structure after another. The intelligence develops through adapting and organizing. Adaptation is a process of assimilation and accommodation, where external events are assimilated into existing understanding. Unfamiliar events, which do not fit with existing knowledge are accommodated into the mind, thereby changing its organization. He also concluded that the logic of children and their modes of thinking are initially entirely different from those of adults (and therefore require different instructional considerations). This concept is important in designing effective instruction for community college students.

The Progressive education philosophy was established from the mid-1920s through the mid-1950s. Dewey was its primary proponent (Schon, 1992; Ultanir, 2012). One of his beliefs was that the school should improve society through experiencing freedom and democracy in schools (Dewey, 1938). Education is to be grounded in real-world experience, and the notion of traditional schooling is rejected, where students were expected to be passive receptacles of foreign information. Inquiry is a key part of constructivist learning. Dewey (1938) posited that, "if you have doubts about how learning happens, engage in sustained inquiry: study, ponder, consider alternative possibilities and arrive at your belief grounded in evidence" (p. 24). Education depends on action, and the learner is the constructor of knowledge. Knowledge and ideas are gained when learners have experiences of meaning and importance to them. Dewey argued that human thought is practical problem solving, and these problem-solving experiences occur in a social context, such as a classroom, where students join together to manipulate materials and observe outcomes.

Lev Vygotsky's relevance to constructivism derives from his theories about social interactions and how they mediate one's learning. Vygotsky (1978) believed that a child gradually internalizes external and interactive activities with more competent others. Although social speech is internalized and becomes thinking in adults, Vygotsky contended that it still preserves its collaborative essence.

In his experiments, Vygotsky studied the difference between the child's reasoning when working independently versus reasoning when working with a more competent person. He formulated the *zone of proximal development* to reflect on the potential of this difference of achievement or effective problem-solving without and with help from others. Vygotsky's (1978) findings suggested that learning environments should involve guided or scaffolded interactions that permit children to reflect on inconsistency and to change their conceptions via communication.

The history of constructivism and progressivism is heavily focused on the individual learner, and how individuals create different meanings based on unique, prior experiences. Dewey (1938) and Vygotsky (1978) also acknowledge that human learning is a social endeavor, both in gaining knowledge and applying it to society-at-large. The two philosophies shifted conceptualizations of learning from an objective to a subjective nature, and set the foundation for many modern, student-centered educational techniques such as: problem-based, project-based, multimodal, and authentic learning.

Characteristics of constructivism. The presence of prior knowledge is a characteristic of constructivist thought, and impacts the learning process (Ertmer & Newby, 1993; Bachtold, 2013). In trying to solve novel problems, awareness of similarities between existing knowledge and a new problem can assist in channeling what

is already known. Information that is provided but not connected to an individual's prior knowledge is not effectively retained. As opposed to behaviorist and cognitivist theories, "humans create meaning as opposed to acquiring it" (Ertmer & Newby, 1993, p. 55).

Constructivist learning is based on the active participation of learners in problem-solving and critical thinking, using real-world, authentic problems (Driscoll, 2005; Ultanir, 2012). As students pursue and answer questions, they discover new and more complex questions to be investigated. Curriculum consists of a process of further exploring major concepts, rather than presenting a breadth of coverage (Ultanir, 2012).

The teacher's role in a constructivist classroom is to be a facilitator who can guide students into adopting cognitive strategies such as articulating understanding, asking probing questions, self-analysis and reflection (Ertmer & Newby, 1993; Dorsch & Zidon, 2014). Another role of the teacher in constructivist classrooms is to organize information around big ideas that engage the students' interest, to assist students in developing new insights, and to connect them with their previous learning (Ultanir, 2012; Dana & Yendol-Hoppey, 2014). The activities are student-centered, and students are encouraged to ask their own questions, carry out their own experiments, create their own analogies, and come to their own conclusions.

Characteristics of progressivism. In the progressivist philosophy, learners are active participants, problem-solvers, and planners. Learning is rooted in the questions of learners that arise through experiencing the world. It is an active process, not passive. The learner is a problem-solver and thinker who makes meaning through his or her individual experience in the physical and cultural context (Dewey, 1938). Skills are related to content and are viewed as functional tools.

As the community (social aspects) is viewed as part of the learning process, students are encouraged to collaboratively work on activities (Muller, 2014).

As with constructivism, teachers are facilitators who foster critical thinking. Intelligence is perceived as being variable and is measured in authentic problem-solving. Learner interests should be addressed and developed through: (1) direct and indirect contact with the world, and experiences gained; (2) application of knowledge gained, and relationships built between subjects; (3) the consciousness (ex: self-satisfaction) of achievement (Ultanir, 2012).

Cons of constructivism and progressivism. The biggest disadvantage of both philosophies is its perceived lack of structure (Driscoll, 2005). Some students require highly structured environments to excel. Constructivism calls for the teacher to discard standardized curriculum in favor of a more personalized course of study, based on what the student's prior experience. This could lead to a classroom where some students fall behind others. Also, increased time investments are required of teachers for more individualized preparation, and certain instructional tools may not be available for active learning exercises (Driscoll, 2005).

As constructivism calls for a removal of summative grading in the traditional sense and instead places more value on students evaluating or organizing their own progress, educators may not know that the student is struggling. Since learners are believed to create knowledge by integrating new information with that from their prior experiences, students may struggle forming relationships between the knowledge they already have and the knowledge they are trying to gain (Driscoll, 2005). Since there is a lack of evaluation in the most traditional sense, the student may not be creating

knowledge as the theory asserts but are merely imitating others. These aspects also highlight an importance in involved teacher scaffolding during the learning process.

Especially as a community college, students enter the BI 114 classroom at ESJC with various backgrounds and educational experiences. To create a student-centered environment that caters to these differences, constructivism and progressivism posits that I, as an educator, am responsible for creating a transformative environment as a facilitator of knowledge. In researching the effects of a multimodal course project on student achievement (as an indicator of learning), I am better able to understand how to provide positive and authentic learning experiences to an array of students.

The Community College Landscape

With its founding in 1901, Joliet Junior College in Illinois is the oldest existing public two-year college (AACC, 2017). In the early years, the colleges focused on general liberal arts studies. During the Depression of the 1930s, community colleges began offering job-training programs as a way of easing widespread unemployment (Kasworm, Rose, & Ross-Gordon, 2010). After World War II, the shift from military industries to consumer goods created new, skilled jobs in the economy. This transformation along with the GI (interpreted as General Issue, Government Issue, or Galvanized Iron) Bill created an environment that needed more higher education options (Kasworm, Rose, & Ross-Gordon, 2010; Mullin, 2012). In response, the Truman Commission suggested the creation of a network of public, community-based colleges in 1948 to serve local needs.

The number of community colleges has steadily grown since the 1960s. Currently, there are over 1,100 community colleges in the United States (AACC,

2017). Because of its affordability and range of educational opportunities for all seekers, more than half the nation's undergraduates attend community colleges, and since 1901 at least 100 million people have attended (Kasworm, Rose, & Ross-Gordon, 2010). Each community college is a distinct institution but shares with others a comprehensive mission of access and educational opportunity. Community colleges provide many benefits in terms of selection of programs, career/academic pathways, and increased earning potential (Sandoval-Lucero, Maes, Klingsmith, 2014).

Student population. As centers of access and opportunity, community colleges serve a wide range of student demographics. According to Columbia University's Community College Resource Center (CCRC) (2017):

In Fall 2015, nearly 6.3 million students were enrolled in public, two-year colleges. About 2.3 million were full-time students and nearly 4 million were part-time. About 6.9 million students were enrolled in all two-year and less-than-two-year colleges, public and private. (para. 1)

Of all full-time undergraduates in 2015, 24%, or roughly one-fourth attended community colleges.

Community colleges have been centers of access for those that have been traditionally underrepresented in or excluded from higher education. According to a longitudinal community study by Shapiro et al. (2017), 44% of low-income students (those with family incomes of less than \$25,000 per year) attended community colleges first after high school. In contrast, only 15% of high-income students enrolled in community colleges initially.

Similarly, 38% of students whose parents did not graduate from college choose community colleges as their first institution, compared with 20% of students with college-graduate parents.

In addition to being centers of opportunity for lower income and first-generation individuals, community colleges also provide access to large proportions of minority groups. According to the AACC (2016), 62% of Native American undergraduates were enrolled in community colleges in 2014, 57% percent of Hispanic undergraduates, 52% of African American undergraduates, and 43% of Asian/Pacific Islander undergraduates.

In 2016, 60% of students enrolled for credit hours, and 40% enrolled for non-credit or continuing education (AACC, 2016). Many students enter community colleges for additional workplace training or lifelong learning opportunities. Without the flexibility and availability of community colleges, many people would not have reasonable access to higher education opportunities.

As centers of educational opportunity and access, community colleges also include those with higher risk factors than traditional four-year institutions (Bailey, Jeong, & Cho, 2008; CCRC, 2017). A high degree of variance requires consideration of how to best meet those educational needs of the student body, in this case as an educator and teacher-researcher. “Programs designed to promote retention of diverse students attending community colleges need to take into account the students’ unique learning needs and work-life balance issues” (Sandoval-Lucero, Maes, Klingsmith, 2014, p. 523). Studies of community college success often use persistence, degree attainment, or transfer as metrics of success, but learning is a less commonly studied outcome (Mullin, 2012; Sandoval-Lucero, Maes, Klingsmith, 2014).

Hispanic-Serving Institutions. Hispanic-Serving Institutions, or HSIs are defined in federal law as accredited and degree-granting public or private nonprofit institutions of higher education with “25 percent or more total undergraduate Hispanic full-time equivalent (FTE) student enrollment” (Excelencia in Education, 2014, p. 1). The HSI designation was adopted by the federal government in 1992, through the advocacy of the Hispanic Association of Colleges and Universities (Torres & Zerquera, 2012). As opposed to Historically Black Colleges and Universities and Tribal Colleges, whose designations stem from their founding missions, HSIs are named because of their enrollment profile.

“Latinos now make up 16.3% of the U.S. population, with growth over the past decade rising from 19.2% to 24.6% in New York and New Mexico to as high as 144.5 and 147.9% in Alabama and South Carolina” (Torres & Zerquera, 2012, p. 260).

Forsnacht and Nailos (2016) posit that over the next ten years, Latina/o high school graduates will increase over 40%, with many attending college afterwards. Hispanic-Serving Institutions (HSIs) enroll about 60% of Latina/o undergraduates, with over 50% of the student population receiving financial aid (Torres & Zerquera, 2012; Excelencia in Education, 2014). Because of this, HSIs are critical to the educational progression and attainment of Latinas/os.

The majority of HSIs consist of two-year institutions, that are located in regions that possess a high concentration of Latina/os and are typically found in states that border Mexico, aside from Florida and Puerto Rico (Forsnacht & Nailos, 2016). In addition, HSIs tend to have more open admissions policies, lower graduation rates, and offer fewer terminal degree programs than what are non-minority serving institutions (or non-MSIs)

(Forsnacht & Nailos, 2016). The Latino/a students attending HSIs tend to be female, of a lower SES, and older than non-MSI peers. Culturally, students that attended HSIs also tended to value attending college closer to home (Nunez & Bowers, 2011).

“Culture is one factor that needs to be considered in retention models for students of color at community colleges” (Sandoval-Lucero, Maes, Klingsmith, 2014, p. 524). For instance, research indicates that a close association exists between students' cultural background and preferred learning styles (Ladson-Billings, 2009; Edmin, 2016).

Students' individual learning are typically accompanied by culturally determined tools that influence the way they process information and, depending on the fit between teaching and learning styles, facilitate or hinder their educational achievement (Sanchez, 2000; Sandoval-Lucero, Maes, Klingsmith, 2014). Sanchez (2000) cited two concurrent studies examining the impact of culture on the learning preferences of Hispanic and Native American college students in the southwestern United States. In comparison to Caucasian counterparts, both Hispanic and Native American students exhibited a high propensity for participation in active, concrete learning experiences, cooperative situations, and elaborative processing (Sanchez, 2000; Palma-Riveras, 2000; Musoba, Collazo & Placide, 2013). Similarly, African-American students' achievement appears to be positively related to oral experiences and interpersonal relationships (Palma-Rivas, 2000; Edmin, 2016). While culture may not routinely be a first or singular consideration in educational pedagogy, it undoubtedly influences the personal academic experience.

According to Forsnacht and Nailos (2016) and Musabo, Collazo and Placide (2013), students' learning and development is a product of the time and effort spent purposefully engaged in educationally beneficial activities. Engagement and learning is a

joint duty shared between the student and the institution. Not only is a student responsible for putting forth effort into their learning experience, but institutions should also provide an environment that encourages and expects their student body to become involved in beneficial educational endeavors (Forsnacht & Nailos, 2016). These duties apply to both K-12 and post-secondary science education.

The Nature of Post-Secondary Science Education

To better understand the local problem of practice, the background to science as a field of education and inquiry requires discussion. What are believed to be important for a student to learn within a science classroom and relevant classroom pedagogies are also presented. Differences in implementation and perspective can consequently impact individual learning environments.

Background. Science as a field is related to empirical thought. Empiricism is a theory of knowledge which emphasizes a close relationship to experience, especially as gained through experimental analysis (Matthews, 1992, Muller, 2014). Although present in ancient societies, empiricism gained footing in Europe during the Scientific Revolution, when scholars began conducting systematic experiments and observations of the world and discovered that the planet revolves around the Sun, for example. Empiricism and the scientific method posit that all hypotheses and theories must be tested against observations of the natural world, rather than resting solely on “unjustified” reasoning, intuition, or revelation. It is suggested that the best way to gain knowledge is to see, hear, touch, or otherwise sense things directly. A commonality between constructivists and empiricists is that knowledge is based, first and foremost, on observing and interacting with our world (Matthews, 1992).

The nature of science (NOS) refers to science as a way of knowing (an epistemology), or the beliefs underlying the discovery and transmission of scientific information (Lederman, 1998). Some foundational ideas, or tenets, of the NOS include:

- 1) Scientific knowledge is tentative, or subject to change.
- 2) Facts are inherently different from hypotheses and theories.
- 3) The use of a logical methodology (scientific method) to uncover solutions to issues.
- 4) The differences between an observation and a judgement.
- 5) Science is a human endeavor and prone to mistakes. (National Academy of Sciences, 1998)

Aside from assisting to understand content-specific aspects of scientific knowledge, such as understanding the functions and processes of photosynthesis, the tenets of the NOS are also considered valuable transferrable knowledge skills to society-at-large (Edruran & Zagher, 2014).

Individuals have possessed questions about the NOS and scientific processes since historical times, such as: What causes the difference between night and day? In *Vision and change in undergraduate biology education: A call to action*, the American Association for the Advancement of Science (2011) recommended that students know and understand evolution; structure and function; information flow, exchange, and storage; pathways and transformations of energy and matter; and systems as representing the interconnectedness of life at different levels of biological organization. The report also recommended that students be able to apply the process of science, use quantitative reasoning, use models and/or simulations, engage with other disciplines to address

complex questions, communicate and collaborate, and understand the dynamic relationship between biology and society openly while managing a growing body of knowledge (AAAS, 2011). Since the transmission of the NOS and scientific concepts is an educative process, debates in transmission methods have arisen as well.

Science in the classroom. Traditionally, post-secondary science education particularly is associated with the teacher-centered classroom (Waldrop, 2015). The experience is behaviorist-oriented and tends to promote passive receptivity by the student. The teacher's role is seen as the "sage on the stage" or transmitter of knowledge, which students are expected to retain and demonstrate competency in, primarily via exam-based classroom assessments. As one may argue that use of the scientific method and laboratory experiments contribute to an active environment, Waldrop (2015) posits that:

Undergraduate students have always had discussion sessions to ask about the course material, and laboratory classes in which they would carry out experiments. But if you look more closely, these are often just 'cookbook' exercises. The typical approach is 'read that and be prepared to talk about these questions', or 'follow that procedure and you'll get this result'. In an active-learning class, the students take charge of their own education. They are framing the questions themselves. (p. 273)

Action does not necessarily constitute learning, and thoughtful, directed curriculum planning is needed to positively affect student learning outcomes (Dewey, 1938; Tomlinson, 2013; Freeman et al., 2014).

Stuckey et al. (2013) posits that science education is often seen as being irrelevant for the learners involved, and the goal should be to make science education relevant both personally and societally. This is an important undertaking, as much of modern society revolves around scientific information, articles, and advertisements. An ability to distinguish good science from parodies and pseudoscience depends on a grasp of the NOS, and “the art of the teacher is to judge the sophistication of his or her students, and present aspects of the nature of science that are intelligible to them without being overwhelming” (McComas, Clomas, & Almazroa, 2002, p xviii). Using the constructivist platform, an immersion in active experiences seeks to provide meaningful or relevant scientific learning opportunities and transferrable skills (Stuckey et al., 2013).

As educators, one cannot teach what they do not understand. To be able to convey adequate science conceptions to students, teachers should themselves possess informed conceptions of science. Research on the translation of teachers' conceptions into classroom practice indicates that even though teachers' perceptions of NOS can be thought of as a necessary condition for learning, these conceptions, nevertheless, should not be considered sufficient (Lederman, 1998). Efforts should also be used to translate these understandings into classroom practice. Nonetheless, effective translation is also affected by a complex set of situational variables such as: institutional support, student body, and curriculum needs (Lederman, 1998).

Authentic Assessments

Authentic assessments, also known as alternative or performance assessments are a form of assessment in which students are asked to perform real-world tasks that demonstrate meaningful application of knowledge and skills (Kilpatrick, 1918; Chapman

& King, 2012; Stuckey, et al., 2013). In the classroom, a task for students to perform is assigned and a rubric is provided by which their performance on the task will be evaluated. Some defining characteristics of authentic assessments include: task performance, real-world scenarios, construction and application of content, student-centered focuses, and direct (applied) evidence (Stuckey et al., 2013). Examples of performance tasks are designing and conducting an experiment or debate, creating an artifact such as a website or project, building task portfolios and self-assessments. In interacting with the task, proponents of authentic assessments believe that students practice higher-order thinking skills and self-reflection/analysis (Chapman & King, 2012).

When completing a traditional assessment, objectives a student will demonstrate has been carefully structured by the person(s) who developed the test. The student's attention will be focused on and limited to the test content (Waldorf, 2015). In contrast, authentic assessments allow more student choice in determining what is presented as evidence of proficiency (Mullen, 2015). Even when students cannot choose their own topics or formats, there are usually multiple accepted routes towards constructing a product or performance. An example in science would be the creation of a 3-D diorama of the solar system or creating and conducting an experiment highlighting the process of photosynthesis. Nonetheless, an educator does not have to necessarily choose between traditional and authentic assessments. It is possible that a mixture of the two will meet specific needs (Tanner, 2013). Authentic assessments are related to constructivism and progressivism in that knowledge is rooted in individual experiences, and active, real-world interactions with material helps to create meaning (Stuckey et al., 2013).

Research on authentic (or alternative) assessments. “The role of assessment in higher education is gaining importance as accountability requirements intensify and as assessments are increasingly recognized as having potential to improve teaching and learning” (Goubeaud, 2009, p. 237). Goubeaud (2009) researched 2 and 4-year college biology, chemistry, and physics grading practices, to understand the assessment landscape within college science courses. It was found that biology courses used a greater spread of assessment types, which could be more helpful to student learning. Some examples included multiple drafts of written work and the use of open-ended questions.

When using alternative or open-ended assessments, students have the opportunity to express their learning in an authentic form that parallels the “context of use” in real life. Consequently, assessments no longer function purely as an evaluative tool. “A variety, rather than a narrow repertoire of assessments, is necessary to be able to assess the skills, knowledge, and competencies that students should demonstrate in college science” (Goubeaud, 2009, p. 239). While no array of assessments can perfectly measure student understanding, using a wider variety of assessment tools can bring educators closer to this goal.

Freeman et al. (2014) tested the hypothesis that active lecturing maximizes learning and course performance, using a meta-analysis of two hundred and fifty-five studies that reported data on examination scores or failure rates. Active learning was defined as “engaging students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work” (Freeman et al., 2014, p. 8413). Student performance in undergraduate science, technology, engineering, and mathematics

(STEM) courses under traditional lecturing versus active learning were compared and analyzed. Active learning consisted of a wide variety of activities to include group work, projects, and case-study analysis. “The results indicate that average examination scores improved by about 6% in active learning sections, and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning” (Freeman et al., 2014, p. 8410). It was also discovered that active learning increases scores on concept inventories more than on course examinations, and that active learning appears effective across all class sizes, with the greatest effects in smaller classes (of less than 50 students).

Harackiewicz et al. (2014) conducted a study to assess and ameliorate first-generation college student achievement gaps in introductory biology. Undergraduate minorities, women, and first-generation students are more likely to possess achievement gaps in the sciences (Bailey, Jeong, Cho, 2008; Harackiewicz et al., 2014). “First-generation (FG) college students are those for whom neither parent received a 4-year college degree, and they comprise roughly 15–20% of students in American universities” (Harackiewicz et al., 2014, p. 376). A values affirmation (VA) writing treatment was implemented in a university, introductory biology sequence with 798 students to assess student belief systems and attempt to lessen stereotypes of self or group (stereotype threats) that can influence or impede achievement.

Formative, weekly writing exercises were assigned for the VA treatment to promote critical thinking skills and increase interpersonal interactions/connectedness within the course. The writing prompts were not related to content matter, but to identification and expression of values or strengths. Responses were then analyzed in

conjunction with first-generation and continuing-generation (CG) course grades, persistence and end-of-semester GPA. It was found that in courses where the VA treatment was implemented there was a significant closure of the achievement gap between the FG and CG groups with regards to course grades and GPA (Harackiewicz et al., 2014). A higher persistence rate into the second semester for FG students was also found.

The use of the VA treatment as an alternative assessment sought to identify student differences within the classroom based on value affirmation and turn this information into individualized opportunities to promote a sense of belonging within the course, which subsequently increased achievement and persistence rates (Harackiewicz et al., 2014). The study serves as a reminder that to improve learning opportunities, it is also important to view students as emotional creatures with various mindsets and needs.

Cavanaugh et al. (2016) studied 245 students' buy-in to active learning, and its effect on engagement and performance in an undergraduate, introductory biology (anatomy and physiology) course. Buy-in is described as feelings an individual has in relation to a new way of thinking or behaving (Cavanaugh et al. 2016). Active learning was described as the inclusion of collaborative experiences, critical thinking activities, formative assessment, and discussions of learning goals. Buy-in was measured using an online survey to garner student responses to a selection of active learning activities implemented in the course based on content relevance. Student learning outcomes were measured using end-of-semester grades.

Using statistical analyses of student responses and grades, buy-in to active learning was found to be positively associated with engagement in self-regulated learning and course performance (Cavanaugh et al. 2016). Students who reported more substantial buy-in to active learning were more likely to engage in the types of self-regulated (or self-motivated) learning behaviors that often lead to academic success (Cavanaugh et al. 2016). These results provide an understanding of *student perceptions* regarding current active-learning practices within undergraduate STEM classrooms.

Student experiences in science courses are important in impacting scientific thinking (as related to the NOS) and career decisions, among other outcomes (Wang and Degol, 2013; Brownell et al., 2015). Poor course experiences may impact the choice of one's major, the likelihood of graduating, and the decision to pursue further training (Cavanaugh et al. 2016; Harackiewicz et al., 2014). Post-secondary STEM courses consist of students with a wide variety of backgrounds and needs. Understanding authentic, alternative methods of assessment to best meet their learning needs and potentially impact achievement at ESJC is a goal of this AR study.

Characteristics of multimodal learning. Multimodal learning environments are constructivist-based and allow instructional elements to be presented (or represented) in more than one sensory mode, to include visual, aural, and written (Cisco, 2008).

Representations are artifacts that symbolize an idea or concept in science (e.g., force, energy, chemical bonding) and can take the form of analogies, verbal explanations, written texts, diagrams, graphs, and simulations. As such, they are an integral part of the language of science. (Tang, Delgado, Birr Moje, 2014, p. 306)

In turn, materials that are presented in a variety of presentation modes or representations may lead learners to perceive it as easier to learn, leading to improved attention and performance.

According to Kelly (2010), general characteristics of a multimodal design include:

- 1) Adjusting the activity every 15-20 minutes, to prevent monotony.
- 2) Repeating/presenting the lesson through multiple outlets to reinforce the lesson.
- 3) Creating supplemental activities as needed, as learners may not grasp the content immediately.

Cisco (2008) also posits that multimodal learning can have both an interactive and non-interactive design. Interactive multimodal learning “includes simulations, modeling, and real-world experiences; typically includes collaboration with peers, but could be an individual interacting with resources” (p.13). Non-interactive multimodal learning includes text with illustrations, watching and listening to animations, listening to lecture with graphics devices such as whiteboards, and typically involves individual learning, or whole-group work focused on listening, observing and/or reading (Cisco, 2008).

Research in neuroscience has found that significant learning increases can be accomplished through visual and verbal multimodal learning (Cisco; 2008; Fadel, 2008). Multimedia outlets can also be used to represent the content knowledge in ways that appeal to different modal preferences (Sanky, Birch & Gardiner, 2010; Birch & Sankey, 2008; Moreno & Mayer, 2007).

Technological innovations have provided many opportunities to present multiple representations of content (text, video, audio, images, interactive elements) to cater more effectively to the different modal preferences of an increasingly diverse student body.

Similar to the general multimodal design characteristics described by Kelly (2010), Sankey, Birch and Gardiner (2010) also cite a number of benefits to including visualizations particularly within learning environments, such as: (1) promoting learning by providing an external representation of the information; (2) deeper understanding; and (3) maintaining learner attention by making the information more attractive, making complex information easier to comprehend.

A multimodal project is one that uses more than one modality to achieve its intended purpose (Tang, Delgado, Birr Moje, 2014). The idea behind multimodal projects is that, since educators are asking their students to create artifacts in a new media age, they should be allowed and encouraged to explore all of the available means of persuasion. By integrating various modes of presentation and representation, multimodal education provides unique opportunities that enhance and stimulate learning for all students. As “educational programs designed to help the visual, auditory, and kinesthetic learner should be the current goal of course and curricular design” (Drake & Pawlina, 2013, p. 1), I attempt in this DiP to design and implement a multimodal learning project for my post-secondary BI 114 students, to encourage understanding and achievement.

Research on multimodal science education. The following research studies pertain to authentic and multimodal assessments relevant to the problem of practice, and research question of the dissertation in practice.

Post-Secondary Multimodality Implementation. Shahril, Wan Dali, and Lin Lua (2013) used a cluster randomized control design to evaluate the effectiveness of implementing multimodal nutritional education interventions (NEI) in a college-level nutrition course to improve dietary intake among students. A total of 417 students aged 18-24, in 16 classes were recruited for the longitudinal study, spanning the course of five months. During the 10-week instructional period, the treatment group received multimodal intervention using three modes (conventional lecture, brochures, and text messages) while those placed within the control group did not receive any intervention. Dietary intake was assessed pre- and post-intervention, and outcomes were reported as nutrient intakes and average daily servings of food intake. Students also completed a demographics form, prior to study implementation to ascertain the classroom composition.

The intervention itself was based on 13 out of 14 key points from the latest Malaysian Dietary Guidelines, and all points were delivered through three modes: (1) conventional lecture, (2) brochures, and (3) text messaging. The intended use of brochures was to provide visual, take-home messages to increase content retention/understanding. Thirteen text messages were designed and sent to students once every five days, also in an effort to increase content retention. Analysis of covariance (ANCOVA), a means of measuring the fluctuations of multiple variables, was utilized to examine the changes in dietary intakes for both groups, from pre-intervention to 10 weeks after intervention with potentially confounding factors (weight, waist, hip, and baseline readings) included as covariates. Groups' sociodemographic characteristics were analyzed, to minimize confounding factors. Results showed that participants in the intervention group significantly improved their dietary intake by increasing their energy

intake, carbohydrate, calcium, vitamin C and thiamine, fruits and 100% fruit juice, fish, egg, milk, and dairy products while at the same time significantly decreasing their processed food intake (Shahril, Wan Dali, & Lin Lua, 2013). The percentage of carbohydrate, protein, and fat contribution to energy was unaffected after 10 weeks of intervention in this study, “as the predicted interaction between time and group was not significant” (Shahril, Wan Dali, & Lin Lua, 2013, p. 4).

Bennett (2011) sought to investigate the science literacy of freshman-level, non-major genetics students at the University of Iowa, who were given a modified, multimodal curriculum to address specific teaching and learning challenges from previous classes. A mixed-methods correlational design to investigate the relationship that existed between students’ writing assignment experiences connected to multimodal representations and their academic performance in classroom assessments (exams in this case). A core focus was the interconnectedness between the use of multiple representations and adequate expression of scientific knowledge and concepts. According to Bennett (2011):

The principle component of the fundamental sense of science literacy investigated in this study is the students’ ability to read, interpret, and implement multimodal representation found in the scientific literature and in their own writing assignments. The multiple modes of representation are the extra-textual components of science literature such as diagrams, graphs, and mathematical equations which allow scientists to communicate their results and ideas effectively. (p. 2)

The reading and writing components of class assignments was modified by making at least one multimodal representation a required component of their homework. The results showed that there were significant positive correlations between student multimodal representations and quiz scores, but not exam scores. Bennett (2011) posited that this may be due to major differences in design between the assigned homework tasks, and that provided on the exam. Being an educational intervention, it is also possible that differences were also the result of confounding factors inherent to the student population/study design. Through this study it is also suggested that students' development of science literacy through multimodal representation knowledge requires *experience* with multiple modes of representation, to effectively build competency (Prain & Waldrip, 2006; Bennett, 2011).

Greater understanding is needed on the two areas of multiple representations and multimodal integration. More particularly, how the two interact to effect learning (Yore & Treagust, 2006; Tang, Delgado, Birr Moje, 2014). Within the science community, the use of multimodal learning has not been completely ignored (Drake & Pawlina, 2013). "We [science educators] have been using multimodal approaches to learning for many years (particularly in laboratories), and we just need to expand our current offerings to be at the forefront of this pedagogical change" (Drake & Pawlina, 2013, p. 1). Some suggestions for improvement include the inclusion of active versus passive learning, enhanced exposure to images, and learning in context.

Reception to multimodal instruction. Tomlinson (2013) asserts that there are three approaches that schools and teachers can use to “address academic diversity: (1) to place students in heterogeneous settings and do little to attend to student differences; (2) to track or group the students homogeneously by ability; and (3) to create heterogeneous classrooms designed to attend to learner variance” (p. 30). Tomlinson (2013) reported that teachers see the need for multimodality in classrooms but find change and direction a daunting task and are therefore prone to “sticking with what they know”. For instance, some teachers perceive classroom innovation as a distraction from curricular standards and preparations for standardized testing. In science, Drake (2014) also states that educators clash about inquiry-based approaches versus direct instruction of formulas and principles.

Santangelo and Tomlinson (2012) conducted a study to explore university educators' perceptions and use of alternative instruction practices, and found that in relation to learner characteristics, teacher educators recognized the importance of readiness. Teacher educators highly value and prioritize creating a positive learning environment. To realize this goal, they reported using a variety of strategies, such as developing a sense of community in the classroom, making themselves available to candidates, and ensuring equitable participation (Santangelo & Tomlinson, 2012). Teacher educators reported using a variety of strategies that support multiple expressions of content, process, and product. For instance, they frequently present course content in a variety of ways, use candidates' feedback to help shape content and activities, use multiple forms of assessment, and use different grouping formats to promote understanding of content.

Blikstein and Worsley (2016) posit that an important goal of learning analytics is to equalize the classroom playing field by developing methods that examine and quantify non-standardized or alternative forms of learning. Especially given the increasing demand for assessable project-based, interest-driven learning and student-centered pedagogies. Both K–12 and university-level engineering education demand higher-level, complex problem-solving as opposed to performance in routine cognitive tasks (Blikstein & Worsley, 2016; Kirschner, Sweller, & Clark, 2006). The teachers that embraced changes learned to be more responsive to the students they teach, and positive student outcomes encouraged continued teacher development.

These findings lend strength to the purpose statement and DiP, that organized research and application of alternative, multimodally-based assessment should be conducted to promote a cyclic and comprehensive classroom environment.

Characteristics of project-based learning (PjBL). Project-based learning is a comprehensive approach to classroom teaching and learning that is designed to engage students in investigation of authentic problems (Blumenfeld et al., 1991). Project-based learning can be described as involving both vertical learning (ex: subject matter knowledge) and horizontal learning (ex: generic skills). When designing alternative assessments choice is a key component, as students take more responsibility for their learning (Chapman & King, 2012; Mullen, 2015).

Some recurring themes in project-based learning are 1) promoting active engagement, 2) providing students enough time for completion and 3) a sense of personal decision-making in the process (Grant, 2002; Chapman & King, 2012). The ability to work in groups and collaborate is also important (Springer, Stanne, & Donovan, 1999).

Connecting educational theory to classroom practice is a challenge identified with its implementation (Springer, Stanne, & Donovan, 1999). To effectively implement a PjBL activity/assessment, some practical classroom recommendations include:

- 1) Focusing on a task or guiding/driving question.
- 2) Developing a process or investigation that results in the creation of one or more sharable artifacts.
- 3) Scaffolding, such as teacher conferences to provide feedback and help learners assess their progress and project templates (Grant, 2002; Hill, 2014).

Focusing on a specific task or driving question related to the content anchors the assignment and provides students with expectations on the purpose/outcomes. For example, illustrating how solar energy is transformed to carbohydrates during the two stages of photosynthesis is a specific content-based task through which to orient a project, as opposed to the broader concept of producer (plants) contributions to consumers (animals). As the process commences, students may generate their own questions outside of those provided by the teacher that are still related to the topic. Establishing this also ameliorates the challenge of trying to follow content in a syllabus in a project-based learning environment (Grant, 2002, Tomlinson, 2013).

Developing a process that yields one or more shareable artifacts is the outcome of the project-based learning process (Tanner, 2013). During the process of creating an artifact, students gain higher-level insight into content through critical-thinking and hands-on activity (Wurdinger & Qureshi, 2015). Providing choices in the artifact created is emphasized in project-based learning, whether it be a diorama, poster board, or recording (Mullen, 2015).

Using the photosynthesis example above, a student could ultimately design and conduct an experiment examining various levels of sunlight (or water) exposure and its effects on plant growth or oxygen production.

Examples of project-based learning in university-level science. Barab, et al. (2000) examined the effects of project-based learning of introductory college astronomy and analyzed learning impacts. Ten students taking the 16-week pilot course used three-dimensional modeling technology to build virtual solar systems, over the course of two projects. Some student choice was allotted in the visual presentation of their models. Students exposed to the PBL environment were found to perform better than students of the previous year (with the traditional format) on course assessments based on qualitative instructor observations. Barab et al. (2000) posited that implementing inquiry and project-based learning has been difficult in the past due to the abstract nature of the subject, but computer-based innovations and technologies have improved opportunities for use while improving digital literacy. The availability of resources has been identified in this study as an essential feature to support a participatory learning environment.

Springer, Stanne, and Donovan (1999) conducted a meta-analysis of the effects of small-group, project-based learning on STEM undergraduate course attitudes, academic achievement, and student course persistence. A favorable (.55) effect was found on student attitudes. Also, based on “49 independent samples, from 37 studies encompassing 116 separate findings, students who learned in small groups for their projects demonstrated greater achievement ($d = 0.51$) than students who were not exposed to cooperative or collaborative grouping” (Springer, Stanne, & Donovan, 1999, p. 29).

Lastly, a 22% difference was reported in student attrition rates between the alternative and traditional courses. Investigations showed that the effect was greater at four-year institutions versus two-year institutions.

Pros and cons of multimodality and project-based learning. Providing student choice in a course product and encouraging multimodality taps into students' individuality and allows them to process information accordingly to learn (Chapman & King, 2012). In order to reduce anxiety during the process, it may be useful to provide some examples of artifacts or types to create. As any learning process takes time, addressing the challenge of providing enough time to successfully navigate or complete an artifact is essential (Springer, Stanne, & Donovan, 1999; Hill, 2014). The case studies reviewed showed that longer implementation periods, those taking at least half a semester corresponded to greater effect sizes (Springer, Stanne, & Donovan, 1999). Depending on the course structure, this time investment may not be possible. It is therefore recommended to review a specific course schedule/syllabus and use a calendar or organizer to plan enough time around various course objectives for feedback and completion of a project (three weeks in a 16-week semester, for example) (Hill, 2014).

Scaffolding is an important part of the multimodal and project-based learning process, as it solidifies the role of the teacher as facilitator (versus lecturer). Allowing for weekly or twice-weekly feedback on the progress of a student/group project maintains focus, engagement, and enthusiasm (Springer, Stanne, & Donovan, 1999; Dorsch & Zidon, 2014). Through instructor scaffolding, students are able to ascertain their standing with regard to their progress and identify strengths or weaknesses to focus on for enhanced learning. For educators, specific content areas or skills (such as calculating

solution percentages) that may require additional classroom reinforcement can be identified. For example, scaffolding is imperative to prepare students to effectively use and interpret multimedia, visual representations. “Many authors speculate that unless students have been trained to interpret visuals [ex: a graph], the impact of multimedia will be minimal” (Cisco, 2008, p. 14). Instructor feedback can be provided in many forms: through face-to-face meetings, virtual draft reviews, mediating peer-reviews, or holding group question-and-answer sessions with students (Grant, 2011).

As Springer, Stanne, and Donovan (1999) noted, the effects of project-based learning were more pronounced at four-year institutions versus two-year institutions. Additional research is needed to determine the effects of multimodality and/or PjBL at two-year institutions, as these schools possess a different student dynamic. Doing so may provide additional insight or strategies to reach more students with varied backgrounds.

Conclusion

Constructivism and progressivism seek to create active, student-centered environments that challenge both the students and the teacher. Encouraging passive receptivity undervalues the students and what can be accomplished by igniting their flames. Dewey (1938) posited that education meets the needs of society as well as the individual. As people do not create a homogenous society, our educational systems should not. Research has shown that while there are many practical aspects to consider in implementing alternative and multimodal assessment strategies that are part of an authentic learning environment, the pros outweigh the cons and stimulates achievement, persistence and growth (Tomlinson, 2013; Harackiewicz et al., 2014, Freeman et al., 2014).

Ensuring that students receive such an undergraduate education requires that we be able to assess their level of achievement of essential learning goals and, by extension, how well colleges, universities, and other “providers” of higher education enable this kind of learning. In order to meet current societal needs and expectations, the implementation of authentic assessments alone is not enough to ensure a quality post-secondary education, it is also critical that faculty practices change within the classroom to better teach not only the content matter but transferrable, 21st century skills as well (Sullivan & McConnell, 2017).

These changes must include assessment processes that privilege faculty judgment while focusing on student learning. Students in community colleges have a wide range of ability, backgrounds, experiences, and needs. Designing, introducing, and evaluating authentic, project-based assignments meant to help students improve their higher-order learning skills, disciplinary learning and success in biology is a goal of my research study at ESJC.

CHAPTER THREE

ACTION RESEARCH METHODOLOGY

This chapter will outline in detail the research methodology I employed to answer my research question. The purpose of this action research study is to investigate the efficacy of a multimodal assessment project on student learning within the General Biology I (BI 114) course, in a community college setting (ESJC). The research question investigated in this study is as follows: What is the impact of implementing a multimodal project on students' academic achievement regarding course-specific objectives mastery?

My dissertation in practice (DiP) sought to determine if a project-based, multimodal learning treatment benefits students in my introductory biology classroom, and an AR methodology provided the most appropriate framework to investigate these research questions.

Action Research versus Traditional Research

Action research, according to Mertler (2014), is "research that is done by teachers for themselves" (p.4). As teacher-practitioners are responsible for planning and conducting the educational research, data is gathered that can effect change within local educational environments. The subjects of action research are found within one's own classroom. Examining instructional effectiveness and curriculum implementation for reflection and practical improvement of practice is the foundation of action research. "When teachers are reflective and critical of their own practice, they use the information they collect and phenomena they observe as a means of facilitating informed, practical

decision making" (Mertler, 2014, p. 24). Action research involves a collaborative effort, with educators working together to improve practices. Results and actions are focused on specific institutional settings and are not focused on generalizing to populations at large.

Traditional research shares some similarities with action research, but also differs in structure and function. Both are methods utilized to gather data that will inform decision-making processes. Traditional research tends to involve researchers that are not directly involved with the participants and seeks to gather data that can be generalized to large-scale populations (Mertler, 2014). While useful for developing educational principles and theories, educators may find that the results lack practicality for their local situations.

A criticism of action research is that it lacks the rigor of traditional research. Mertler (2014) soundly posits that since action research does not focus on generalizable results, researchers should focus on maintaining construct validity and instrumentation reliability during research design and experimentation. Therefore, teacher-researchers are still challenged to maintain standards of research for the data collected to be valid and useful. Goals of both traditional and action research are to reduce bias and maintain rigor as much as possible, although there are different methods used to achieve this. As I wished to conduct research to better understand the student learning dynamics at my particular college and instructional settings, an action research methodology was an appropriate experimental design for my study.

Research Design

According to Mertler (2014), the four stages of the cyclic action research process are: (1) planning, (2) acting, (3) developing, and (4) reflecting. Using this four-stage model of action research, I designed my study to answer my research questions.

Planning

Mertler (2014) describes the planning phase as brainstorming and reconnaissance activities performed prior to the implementation to the project.

This stage can be further divided into:

- 1) Identifying and limiting a topic.
- 2) Gathering information in your particular setting.
- 3) Reviewing related literature for insight.
- 4) Developing a research plan.

Identifying a Topic of Interest. During this stage of the AR process, I initially reflected on past experiences of students within my biology courses, in order to identify key issues that could be explored. As I have instructed a range of biology courses, this reflection allowed me to narrow my topic of interest to a specific course. Next, I collaborated with fellow introductory biology instructors over time, to gain further insight into instructional pedagogy, student learning, success rates, and program progression. I was then able to determine that the learning and performance of students within the BI 114 course was a crucial topic to further explore and improve through data-driven research.

Gathering Information in Particular Research Setting. After identifying a topic of research, I performed a literature review of related topics in general (introductory) biology and post-secondary science-based courses to gain further conceptual insight into my decided topic for study. Reflection and identification of a key topic for research required that I analyze my role as a science educator within my institution. Biology, identified as a “hard science”, consists of difficult concepts that are traditionally conveyed in a teacher-centered methodology, although research on science assessments in post-secondary education indicates that this dynamic is changing (Goubeaud, 2009). Reflecting on personal experiences with both learning and teaching biology caused me to evaluate how I could further contribute to the positive learning experiences of those that I teach.

Literature review of educational research and institutional documents indicated that students entering ESJC and community colleges in general are often grossly under-prepared for college-level coursework. "Sixty percent of incoming students are referred to at least one developmental course" (Bailey, 2009, p. 12). This leads to placement in remedial (or transitional) courses in an attempt to increase academic preparedness for their intended college major (NCPPE, 2010; Bailey, 2009). As is the case with the biology courses at ESJC, when a remedial course is not offered in the subject (biology, for instance), they are placed into introductory-level, transferrable courses in lieu of. Additional insight was gained regarding the use of alternative assessments in post-secondary science classrooms to increase student understanding (Goubeaud, 2009; McConnell, 2006; Mullin, 2012).

It is from this reconnaissance work that I was able to further understand the nature of my proposed topic of research, and then continue literature review to build a conceptual framework regarding multimodal and alternative assessments.

Developing a Research Plan. After identifying a problem of practice, research question, and conducting a literature review, a research plan should be developed. In developing a research plan to answer my proposed research question, I initially studied the types of educational research and forms of data collection. Quantitative research methodologies focus on the collection and analysis of numerical data and uses deductive reasoning when seeking to answer research questions (Mertler, 2014; Fraenkel & Wallen, 2015). Starting with theories, hypotheses then seek to confirm or deny them through the experimental process. Qualitative research methodologies inversely use inductive reasoning to answer research questions. Specific observations or patterns are noted by the researcher, and further analyzed to formulate hypotheses or theories to explain or better understand the phenomena.

In addition to the analysis of pretest and posttest data for significant differences, I also sought to understand the student-perceived impacts of the multimodal assessment. Through research of quantitative and qualitative designs, I identified the use of both a Likert scale and open-ended response survey (or interview) to provide this insight. “The advantages of surveys and rating scales include the fact that they are very effective at gathering data concerning students’ attitudes, perceptions, or opinions (Mertler, 2014, p.150). To best answer my particular AR question, a three-pronged, mixed-method methodology was chosen.

General Research Design. To answer the research question, student performance on SLOs before and after the multimodal project treatment were measured using a one group, pretest-posttest design. The use of a pretest in research design is an improvement over the pre-experimental one-shot case study, as “the teacher will, at a *minimum*, know if some sort of change has taken place” (Mertler, 2014, p. 104). As I usually am assigned two-three sections of the BI 114 course each semester, each section taught will be assigned as a separate treatment group for the study.

In pre-experimental designs, the independent “variable” does not vary, largely because of the fact that there is only one group- since all participants in the study belong to the same group, there can be no “group” comparisons. (Mertler, 2014, p. 102)

Each BI 114 section consists of its own unique student body, as is common in educational research, although there are various background factors that they share such as placement test performance. Therefore, it was best to design an experiment that allows for appropriate inferences to be made about each specific class environment.

Mean scores on an identical pretest and posttest were analyzed using a repeated-measures t-test for any significant differences. If no significant differences were found in one or more groups, I would have reason to believe that external factors to the study had a greater effect on scores than the treatment.

To increase reliability and broaden understanding of student achievement between a traditionally-taught versus experimental group, Exam 2 achievement scores (See Appendix D for exam questions) were also compared and analyzed between the Fall 2017 (traditional) and Summer 2018 (experimental) semesters using an independent-measures t-test for any significant performance differences pre- and post-implementation pertaining to the content of photosynthesis.

Student Learning Outcomes. Learning outcomes describe what students can demonstrate in terms of knowledge, skills, and values upon completion of a course, a span of several courses, or a program (Tiu & Osters, 2015). Student Learning Outcomes (SLOs) for the BI 114 course at ESJC consist of a departmental set and a course specific set. The departmental learning outcomes are presented below, and are more generalized in nature, consisting of broad concepts students are expected to gain from any science-based course at ESJC.

1. Describe the process of scientific inquiry.
2. Solve problems scientifically.
3. Communicate scientific information.
4. Apply quantitative analysis to scientific problems.
5. Apply scientific thinking to real world problems.

The course-specific SLOs serve as more specific content goals for students to gain while taking BI 114. They also served as the basis for development of the pretest-posttest, the multimodal assessment project, and analysis of Exam 2 responses between the traditionally-taught BI 114 group (in Fall 2017) and treatment groups (in Summer/Fall

2018). For the purpose of this action research DiP, the following course-specific learning outcomes used focused on the topic of photosynthesis.

1. Draw a chloroplast and label its structures. State the function of chloroplasts.
2. Write the chemical formula for photosynthesis & state examples of organisms capable of this process.
3. Compare and contrast the light-dependent and Calvin cycle reactions that are associated with photosynthesis.
4. Briefly explain the three stages of the Calvin cycle.

Pretest-Posttest Development. The standardized course-specific student learning outcomes (SLOs) for the BI 114 course served as the basis for creating an identical pretest and posttest of 10 questions to administer to the students (see Appendix A for pretest-posttest format). The course-specific SLOs are major, departmentally-decided biology concepts to achieve and demonstrate proficiency to progress into future coursework at the college and beyond. Using standardized SLOs as a guide in assessment development also sought to improve evidence for validity based on instrument content (Tiu & Osters, 2015), which Mertler (2014) describes as being “based on the relationship between the content addressed on a or on another instrument used for data collection and the underlying characteristic it is trying to measure” (p.155). Both the pretest and posttest were administered in a multiple-choice format, to garner data objectively and efficiently. In developing a research plan, I reviewed previous end-of-semester outcome performance for various topics covered in the course. I also collaborated with additional instructors to understand challenging topics as well as topics that are reiterated in students’ subsequent

coursework. The interrelated topics of chloroplasts and photosynthesis was then identified as a topic and outcome focus for my AR study.

Multimodal Project Design. In addition to course-specific SLOs, the work of Mullen (2015) and Chapman and King (2012) served as guides in creating the multimodal project for assessment. As an authentic assessment, students created products to demonstrate their working knowledge of the course content. “For example, to demonstrate understanding of the food chain, some students may create a three-dimensional diagram, while others create a PowerPoint presentation” (Chapman & King, 2014, p. 184) (See Appendix B for project design).

An identified method of establishing expectations for this project was through the use of learning contracts (see Appendix B). Learning contracts begin with an agreement between the teacher and the student. The teacher specifies the necessary skills expected to be learned by the student and the required components of the assignment, while the student identifies methods for completing the tasks. This strategy (1) allows students to work at an appropriate pace; (2) can target learning needs/expectations; and (3) helps students work independently and learn planning skills (Chapman & King, 2012). To encourage opportunities for interaction between students and include those that desired collaboration, students could work with a partner or individually to complete the project. SLOs served as content guides to cover in students’ project, while a choice was provided in how the project was created based on their specific methods of expressing multimodalities. The development of a rubric (see Appendix B for rubric design) established a more objective grading process (Green & Johnson, 2009).

One BI 114 summer course consisting of 24 students was assigned as the treatment group for the initial cycle of the AR study. The designated treatment group participated in the multimodal assessment project pertaining to photosynthetic processes for approximately one week, or four instructional days. As summer courses maintain the same set of students for both lecture and lab, a two-hour lab period was devoted to the project during this period to allow for students to plan /implement their projects, collaborate and ask questions if needed. The independent variable in the experiment was the multimodal assessment project. The dependent variable was student achievement on SLOs (as measured by posttest performance). During each of the four days of the study implementation process, observation notes were recorded in order to document student actions such as distress or increased engagement, questions asked, and teacher-student interactions (See Appendix F for observation format). In order to ascertain whether the students met learning outcomes, or whether learning outcome achievement was a result of the multimodal aspect of the study, the teacher-researcher used field notes to document how students implemented various modes to complete the objectives of their final projects and which were used.

Post-Treatment Survey Design. As research has indicated that interactive, alternative assessment projects have increased student performance in science courses (Barab et al., 2000; Bennett, 2011; Mullen, 2015), I also sought to understand the perspective of students in my specific educational setting. I chose to employ a mixed-methods methodology in creating a 10-question survey (see Appendix C for survey format) regarding student perceptions of the impacts of the multimodal project on student achievement in the BI 114 course.

A Likert-scale post-treatment survey instrument consisting of seven questions was created. Likert-scales are a type of rating scale that begins with a statement and asks individuals to respond using a 5-point continuum (Mertler, 2014; Chapman & King, 2012). Response options and scoring ranged as follows: strongly disagree=1, disagree=2, undecided=3, agree=4, and strongly agree=5. As reference models for the survey, I made use of the science-specific achievement research of Barab et al. (2000), Bennett (2011), and Mullen (2015).

To provide additional qualitative insight into the research question and student perspectives, an open-ended student response portion was included within the post-treatment survey for analysis (see Appendix C for survey format). The goal was to allow students to state in their own words their perspective of the impacts of the treatment on learning the material. It also allowed the teacher-researcher to further ascertain specific benefits of the multimodal aspect of the project on their course experiences. Students were able to provide detailed insight into what could be improved or positive aspects of the treatment project, for reflection and future improvements. For the open-ended portion of the student survey, I asked three interview questions pertaining to:

- 1) Efficacy of multimodality and project-based assessment on learning content.
- 2) Positive aspects of treatment design.
- 3) Areas of treatment design for improvement.

Mertler (2014) posits that open-ended questions are more qualitative in nature, although they could be used for quantitative insight. To maintain a mixed-methods organization, this portion of the survey was sorted into categories to identify major themes and specific student responses will be recorded.

To further enrich the data, I also sought to employ the use of educator field notes documenting both class observations and focused recorded observations on six diverse students.

Acting

After an action research plan has been developed, the researcher will implement the plan and analyze subsequent data (Mertler, 2014; Dana & Yendol-Hoppey, 2014). It was during this phase of the AR process where I uncovered answers and insight into my research question. As my research design was mixed-methods in nature, data analysis occurred both during and after the data collection process has concluded. Descriptive and inferential analyses was used to determine the efficacy of the multimodal project on SLO performance. Descriptive statistics using the Likert-scale and open-ended survey data also provided insight into student perceptions of the treatment.

Sampling. As action research is different from traditional methods in terms of focus and involvement, this influenced the design of my study. Traditional research tends to use randomized sampling with a focus on generalizability, but as I sought to answer questions pertaining to my particular educational institution at East-State Junior College in Hobbs, NM, a random sampling of students was not only impossible but ineffective. Therefore, I used convenience sampling for my AR study, which was based on the number of BI 114 lecture sections assigned to teach, and the number of students that registered for these courses. Each lecture section can contain a maximum of 65 students, and each lecture section I was assigned constituted a treatment group(s). All sections of students were enrolled in a 16-week course, except for the summer semester which was 8 weeks in duration. For the initial cycle of my AR study, the treatment group consisted of

one summer BI 114 course, 5 weeks in duration and containing 24 enrolled students. The second cycle of my AR study consisted of one fall BI 114 online course, 16-weeks in duration, with 28 enrolled students.

Summer BI 114 Student Demographics. Prior to implementation of the AR project, an online demographic survey was provided to the BI 114 summer students via Google Forms. Twenty-three students out of twenty-four provided responses. Via this survey the teacher-researcher sought to obtain: 1) an objective insight into the student composition of the course, 2) an understanding of past and present experiences that may affect the navigation of a post-secondary biology course, and 3) background information that would allow for further design, implementation, and observations related to the multimodal course project.

A majority of students (thirteen, or 56.5%) stated that they were in their first year at ESJC. Close to a third (seven, or 30.4%) stated that they were in their second year, while three (8.7%) stated they were in their third year, and 4.3% responded that they were beyond their third year. Nineteen students (82.6%) were found to be in their first BI 114 course attempt at the college. The remaining four students (17.4%) took the course at least once prior.

When asked about students' age groups and employment, a range of responses were provided. Fifteen students described themselves as being within the 18-22 age group, five within the 23-27 age group, and three above the age of 27. Twelve students (52.2%) responded as being unemployed at the moment, seven (30.4%) were employed part-time, and four students (17.4%) were employed full-time.

Nineteen (82.6%) students responded that they attended secondary schools in Lea County, local to ESJC. This information, combined with the Lea County high school demographic/achievement data provided insight into their academic preparation prior to entering post-secondary education. Three students (13%) did not attend secondary school locally, and one (4.3%) attended regionally in Texas.

Twenty-two (95.7%) students did not complete a degree prior to enrolling in the BI 114 course, while one student (4.3%) had. Twelve (52.2%) of students considered themselves to be first-generation college students. This data is similar to that provided by the AACC (2016) and indicated to teacher-researcher that most students may be entering the course lacking a strong prior working knowledge of the post-secondary process or culture.

Ethnically, 12 (52.2%) students stated that they were Hispanic or Latino/a. Five (21.7%) stated they were white/Caucasian, 4 (17.4%) were two or more races, 1 (4.3%) identified as Asian/Pacific Islander, and 1 (4.3%) as black/African-American. The majority Hispanic or Latino/a composition of the course is in-line with the ethnic composition of both the Southwestern, border-state regions of the United States and educational institutions with an HSI designation (Torres & Zerquera, 2012; Excelencia in Education, 2014). The teacher-researcher used the survey responses to focus on a select, varied group of six participants within the course for further in-depth observations and analysis during project implementation.

Fall BI 114 Student Demographics. In preparation for the implementation of cycle two for the AR project, an online demographic survey was again provided to the online BI 114 students at the beginning of the semester using Google Forms. Twenty-one students out of twenty-eight provided responses. Similarly to cycle one during the summer, the teacher-researcher sought to obtain from the student survey: 1) an objective insight into the student composition of the course, 2) an understanding of past and present experiences that may affect the navigation of a post-secondary biology course, and 3) background information that would allow for further design, implementation, and observations related to the multimodal course project.

As compared to the face-to-face course, the online students exhibited a broader range of demographic responses. Thirty-eight percent of students (eight) stated that they were in their first year at ESJC. Seven (33.3%) stated that they were in their second year, while two (9.5%) stated they were in their third year, and four (19%) responded that they were beyond their third year. Most students (19 or 81%) were found to be in their first BI 114 course attempt at the college. Three students (14.3%) took the course at least once prior at ESJC, while one student (4.8%) took a comparable course prior at another institution.

When asked about students' age groups and employment, a shift towards an older, working student demographic was shown as compared to the summer group. Seven students described themselves as being within the 18-22 age group, six within the 23-27 age group, and eight above the age of 27. Thirteen students (61.9%) responded as being full-time, three (14.3%) were employed part-time, and five students (23.8%) were unemployed at the moment.

Sixteen (76.2%) students responded that they attended secondary schools in Lea County, local to ESJC. This information, combined with the Lea County high school demographic/achievement data provided insight into their academic preparation prior to entering post-secondary education. Three students (14.3%) did not attend secondary school locally, and two (9.5%) attended regionally in Texas.

All students (100%) indicated that they did not complete a degree prior to enrolling in the BI 114 course. Thirteen (61.9%) of students considered themselves to be first-generation college students. These responses are similar to both the summer students and that provided by the AACC (2016), continuing to indicate to the teacher-researcher that most students may be entering the course lacking a strong prior working knowledge of the post-secondary process or culture.

Ethnically, 11 (52.4%) students stated that they were Hispanic or Latino/a. Six (28.6%) stated they were white/Caucasian, two (9.5%) were two or more races, one (4.3%) identified as American Indian or Alaskan Native, and one (4.3%) as black/African-American. The majority Hispanic or Latino/a composition of the course is still consistent with the ethnic composition of both the Southwestern, border-state regions of the United States and HSIs (Torres & Zerquera, 2012; Excelencia in Education, 2014). The teacher-researcher used the survey responses to focus on a select, varied group of five participants within the fall BI 114 online course for further in-depth observations and analysis during the project implementation period.

Data Collection Process. Once a pretest model was created based on standardized course-specific SLOs, the treatment group was provided the pretest prior to engaging in the AR topic in order to determine baseline performance. After instruction of

content to each section and implementation of the treatment project, an identical posttest was administered to the students to gather post-treatment data and course-specific SLO performance. Standardizing instruction and pretest-posttests between and within treatment sections sought to increase internal validity of the study. According to Fraenkel & Wallen (2015), a study has internal validity when observed differences in the dependent variable are attributed to the independent variable and not an extraneous factor.

Using this data, I performed statistical analyses within experimental groups to answer my research question. The secondary Likert-scale and open-ended survey was also administered to students post-treatment. The survey was provided in a paper-based format, with the students first using a Scantron, then directly recording their written responses. Once this data was collected, further analysis of data within each treatment group provided additional insight into my research question and future project implementation.

Classroom Implementation Procedures

Summer Group. Each BI 114 class period during the four days of the study period was four hours long. Two hours were allotted for lecture, and two hours were allotted for lab each day. During this time, lesson plans were implemented (See Table 3.1) and field notes taken while observing students. Prior to the two-hour lab period dedicated to project construction and submission on Day 3, scaffolding and discussions primarily occurred in 15-20 minute increments during lecture (See Table 3.1).

Table 3.1: Daily Implementation Schedule for the Cycle 1 Project Week

Prior to the Study	<ol style="list-style-type: none"> 1. The students complete a demographic survey via Google Forms the first week of classes.
Day 1- lecture (June 4)	<ol style="list-style-type: none"> 1. Discuss Unit 2 plans for the week with the students. 2. Students complete the (paper-based) pretest for photosynthesis. 3. The multimodal project instructions are distributed to students. 4. Project parameters are discussed. What is considered multimodal? What outcomes are expected to be met? What choices do students have in creating their project? Students are told they could work alone or in pairs. 5. Due date provided of Wednesday, June 6th for project submission. 6. Chapter 4 (Cell Structure/Function) covered after. (PPT, videos, discussions)
Day 1- lab	<ol style="list-style-type: none"> 1. Lab 5 (Cell Structure and Function) conducted; complete lab handout
Day 2- lecture (June 5 th)	<ol style="list-style-type: none"> 1. Chapter 5 (Enzymes and Cell Transport) discussed. (PPT, videos, discussions) 2. Students were then provided a period of 20 minutes at the end of class to ask questions about their project, plan, identify partners, supplies, etc. 3. Students were reminded of the two-hour lab period dedicated to completing and submitting the project the next day. Any supply requests were due by 5:00 pm.
Day 2- lab	<ol style="list-style-type: none"> 1. Lab 6 (How Enzymes Function) conducted; complete lab handout
Day 3- lecture (June 6 th)	<ol style="list-style-type: none"> 1. Chapter 6 (Photosynthesis) discussed. (PPT, videos, discussions) 2. Students are shown the interactive Photosynthesis learning PPT and where to access it in Canvas, as both

Day 3- lab	<p>a project design reference and for learning support of content</p> <ol style="list-style-type: none"> Supplies brought out such as laptops, poster-boards, colored pencils, paint/paintbrushes. Extra copies of the project instructions are made if needed. Two-hour period lab dedicated to student project implementation, then submission before leaving for the day. Asking questions and interactions between partners or classmates during this time encouraged. Students are to submit physical projects to me in lab, and computer-based projects are to be e-mailed to me via Canvas.
Day 4- lecture (June 7 th)	<ol style="list-style-type: none"> Students take Exam 2 (Chpts. 4-6) during their specified time slots
Day 5 (lecture) – The following week	<ol style="list-style-type: none"> Students complete their (paper-based) photosynthesis posttest and student perception surveys at the beginning of class. Chapter 7 (Cellular Respiration) discussed. (PPT, videos, discussions)

Fall Group. As the Fall BI 114 course is completely delivered via an asynchronous distance education format, students had one week (seven days) to view a video lecture, create notes, and complete a lab assignment and quiz. During this instructional week lesson plans were implemented (See Table 3.2) and field notes taken while observing students. The multimodal course project was presented as a group lab assignment using the discussion board area of Canvas (see Appendix I for project design). Over the study week, each group was to plan, complete and submit their project by Sunday night (by 11:59 pm) via their group's Organic Chem Master project discussion board.

In the week prior to the study implementation period, a 15-minute instructional video was provided for the project which discussed the project parameters, multimodality, and group expectations for early scaffolding and organizing opportunities (See Table 3.2).

Table 3.2: Daily Implementation Schedule for the Cycle 2 Project Week

<p>Prior to the Study (Aug. 20-23)</p> <p>(Aug. 24)</p> <p>(Aug. 27)</p>	<ol style="list-style-type: none"> 1. The students complete a demographic survey and pretest via Google Forms the first week of classes. 1. Record ~15 min. video overview of project expectations, discussion board setup, etc. Project parameters discussed. What is considered multimodal? What outcomes are expected to be met? What choices do students have in creating their project? Students will work in groups of three (to simulate cooperative laboratory environment). 1. Post course announcement in Canvas with video overview. Discuss project due date (Sept. 9th by 11:59 pm) and encourage students to start interacting with other group members to formulate plans for project.
<p>Day 1 (Sept. 3)</p>	<ol style="list-style-type: none"> 1. Discuss Week 3 plans for the week with the students via e-mail and course Announcement post.
<p>Days 1-7</p>	<ol style="list-style-type: none"> 1. Students are to watch the Chapter 3 lecture video (~45 mins) and complete their notes/outline. 2. Students are to complete their multimodal projects on organic molecules (in assigned groups of 2-3) during the week, using the discussion board area of Canvas to communicate/submit project. -Project is designated as Lab 4 Assignment in Canvas 3. Students are to complete Quiz 4 on organic molecules

	<p>-Quiz 4 designed to function as the post-assessment</p> <p>4. Both the Lab 4 Assignment (project) and Quiz 4 are due Sunday, Sept. 9th by 11:59 pm.</p>
Post-Treatment (due Sept. 12 by 11:59 pm)	<p>4. Students are assigned the student perception survey to complete via Google Forms to complete</p>

Statistical Analysis. For the quantitative aspect of my study, I employed both descriptive and inferential statistics in order to analyze my data. Descriptive statistics serve to summarize, simplify, and organize large amounts of numerical data (Mertler, 2014; Fraenkel & Wallen, 2015). Three main categories of descriptive statistics are measures of central tendency, measures of dispersion, and measures of relationship. The use of measures of central tendency such as calculating the mean, median, and mode was useful during my research and provided information on “what is typical or standard about a group of individuals” (Mertler, 2014, p. 169).

As my two BI 114 lecture/lab sections were diverse and consisted of 24-28 students, measures of central tendency such as the mean provided data for performance on pretest-posttests, and when additional sections were involved, comparisons of where each generally stood in relation to one another. If strong outliers are present in a group, then a more accurate analysis of scores would use the median or a measure of dispersion known as the standard deviation. Mertler (2014) advises against the use of the mean when measuring the central tendency of a Likert-scale survey and attempting to determine the *extent* of something. In this case, as with outliers, use of the median is recommended and was henceforth employed in this research study.

“Inferential statistics are typically used as the means of analysis for research designs that focus on group comparisons” (Mertler, 2014, p. 169). Examples of

inferential statistics analyses would be the use of a repeated-measures t-test or independent-measures t-test. After researching various types of inferential statistics analyses, it was decided that a repeated-measures t-test would be appropriate to analyze differences between the pretest-posttest means of each treatment group (See Appendix E). A repeated-measures t-test analysis “compares two measures taken on the same individuals” (Mertler, 2014, p. 171). To understand whether the treatment had a significant effect on performance within my treatment group, the differences in mean scores on pretests and posttests were measured to ascertain if they were statistically significant. Statistically significant usually compares a p-value to an alpha level, usually set at 0.05 in educational research. An alpha level of 0.05 means that only 5% of the time would the resulting differences would be due to chance. Therefore, my group p-values obtained through the repeated-measures t-tests were used to ascertain with a fair degree of certainty whether differences in each group’s calculated means were due to chance. If differences in scores within one treatment group pretest-posttests means were significant and insignificant in a second group, then I insight was gained into the presence of extraneous factors to the study that could also be responsible for the change in student performance.

When comparing Exam 2 performance data between the Fall 2017 and Summer 2018 student groups (See Appendix D for analysis questions), an independent-measures t-test was deemed more appropriate to use, as it allows researchers to evaluate the mean difference between two populations using the data from two separate samples (Mertler, 2014). As with a repeated-measures t-test, the general purpose of the independent-measures t-test is to determine whether the sample mean difference obtained in a research

study indicates a real mean difference between the two populations or whether the obtained difference is simply the result of sampling error. It is used when groups are independent, and all people take only one test (such as an exam or post-test). If a significant performance difference was found between the two independent groups, one being traditionally taught, there would be reason to believe that this was possibly due to implementation of the multimodal assessment project. Insight gained from this analysis was used to further improve its long-term use and efficacy.

Open-ended survey items allow for respondents to freely express an answer to a question prompt (Mertler, 2014). For the open-ended response portion of the survey, I analyzed responses to identify key themes/categories and tally the occurrence of each, to gain a more holistic view of the impacts of the multimodal project. Identifying themes with open-ended question responses allows for efficient organization of large amounts of data provided (Mertler, 2014). Identifying major themes allowed me to identify shared student perceptions, from which I then focused on more individualized responses.

Developing

The third stage in the action research process is the development phase, where “revisions, changes, or improvements arise and future actions (or an action plan) are developed” (Mertler, 2014, p. 36). Once collected and analyzed my data, I was able to ascertain whether the multimodal project was successful in improving student achievement, and which improvements to make to the assessment or future implementation process. Undoubtedly, there were aspects of the study and instruction to improve upon. Based on my results, I devised a plan to continually assist in the student learning process. For example, more complex AR studies could be developed and

implemented to further understand student impacts of multimodal pedagogies. Future effectiveness of the treatment must be monitored, evaluated, and revised as needed. As I consider my work as an educator to be perpetual in nature, this cyclical aspect of action research is welcomed.

Modifications and Improvements for Cycle 2 with Fall Group. For the second cycle of the AR study, certain modifications of the project implementation process were required as the teacher-researcher was assigned a fully online BI 114 lecture/lab to teach as opposed to a face-to-face format. To align the project as closely to that of the Summer BI 114 group, teacher-researcher again decided to implement the study again as a laboratory assignment, but formatted within Canvas using a discussion board format (see Appendix I). In an attempt to mimic the interpersonal aspect of a face-to-face laboratory environment, students were assigned into groups of 2 or 3 for the project. Embedding the project instructions within group discussion boards allowed the students to interact with one another in an asynchronous space and also allowed the teacher-researcher to be able to observe and track student interactions (using discussion board posts).

“Even while working across data points that include online conversations, patterns of interactions or activities, interviews, and screenshots, themes can unify and identify groups of codes that belong together as parts of a pattern of recurring or common experiences” (Gerber et al., 2016, p. 169). The teacher-researcher used the work of Gerber et al. (2016) as a guide when tracking student interactions or conducting online field notes and observations. A modified online observation protocol tracked the types of student interactions, the number of posts, and number of students posting within each group’s discussion board (see Appendix K for format). “Through the use of field notes or

checklists, researchers can immediately take screenshots, note time stamps, and describe the interactions, texts, and tools evident within the space” (Gerber et al., 2016, p. 146). To assist with daily field notes and student interpretations, screenshots were also taken of each group’s posts to be able to further analyze meanings.

As the online BI 114 course is taught in one-week instructional units over a 16-week semester, the students were provided seven days to be able to complete and submit their projects versus four days for the Summer BI 114 group. While students were still provided the same choices and options regarding how to complete their project, students submitting computer-based projects such as a PowerPoint or Prezi submitted their projects via their respective group discussion boards. Local students choosing a physical project to complete had the option of delivering the project to the teacher-researcher’s office before the due date. As opposed to the initial cycle of the AR study, there was an opportunity to provide past student exemplars as a visual guide in creating their projects.

Reflection

As reflection is an important component of learning (Dewey, 1938), the fourth stage of the action research process requires the teacher-researcher to reflect on their study. Reflection is seen as “a critical examination of one’s own practice” (Dana & Yendol-Hoppey, 2014, p. 6), and making changes based on new understandings gained from the research process. In doing so, I am furthering the field of education and instructional pedagogy and am also improving myself as an educator. As Dewey (1938) posited that experience is a vehicle for learning, and past experience provides the basis for future learning experiences, reflecting on my action research allowed me to mesh the two and experience authentic, positive learning. I am able to effectively implement

authentic learning experiences by critical reflection and adjustment of my own practices.

Some questions that I sought to answer during the critical reflection of my research were:

- 1) Did I successfully obtain my research objectives?
- 2) Did I effectively implement my study and treatment?
- 3) How could I improve my instructional process for the future benefit of students?
- 4) Could this treatment be expanded upon in this course or implemented in others?
- 5) How could this insight be shared with others, for collaborative benefit?

Collaboration

Action research by nature is a means to improve schools and empower educators (Mertler, 2014). Although action research does not seek to generalize results to a large population, the results can still be useful to others, especially within my particular college. It is through initial collaboration with other faculty science instructors that I realized that although the individuals in our courses may be different, the department contains a similar student dynamic. Therefore, information that I found useful or effective from this study could help others in the department improve educational practice and student learning. Collaboration can lead to future directions of study that I alone would not have uncovered. As opportunities arise, I would like to share results with the college at large, and other educational institutions.

Summary and Conclusion

Action research seeks to answer questions pertaining to particular educational institutions and instructional settings. This is in contrast to traditional research, in which

researchers are removed from research settings in an effort and focus to generalize results. Focusing on the state of introductory, community college students within the science department at East-State Junior College in Hobbs, NM led me to therefore employ an AR methodology of study.

The purpose of this AR study is to investigate the efficacy of a multimodal assessment project on student learning within the BI 114 course at ESJC. The research question investigated in this study is as follows: What is the impact of implementing a multimodal project on students' academic achievement regarding course-specific objectives mastery?

The AR methodology employed in this study consisted of the four cyclic stages of planning, acting, developing, and reflecting. During stage one, I was able to identify a topic of interest and associated research design through collaboration, reflection, and literature review. In the acting stage, I implemented my initial AR study and analyzed the resulting data to answer my research question. Afterwards, I designed plans for improvement of the study based on my results during the development stage and implemented a second cycle during the Fall 2018 semester. Reflecting involves a continual, critical review of my practices to authentically learn from the experience, and a collaborative sharing of data with other educators.

CHAPTER FOUR

FINDINGS FROM DATA ANALYSIS

This mixed-methods action research study seeks to ascertain the impacts of a multimodal learning project on student performance pertaining to photosynthesis. Photosynthesis, as described within an introductory biology course, appears as a highly abstract and in-depth concept to students. Stuckey et al. (2013) posits that science education is often seen as being irrelevant for the learners involved, and the goal should be to make science education relevant both societally and personally. Across institutions, the teacher-researcher has employed various pedagogical strategies to teach the concepts of photosynthesis to students. Nonetheless, it has been observed that many students within the introductory biology course struggle with learning and applying the concepts of photosynthesis.

Student difficulties with understanding concepts (operationalized as SLOs) was identified as a problem of practice, which formed the basis of this AR study. The teacher-researcher then considered whether the implementation of an active learning project catering to students' various needs via a multimodal structure would impact and improve their content experiences. In designing an AR study, Sagor (2000) posits: "Observing a phenomenon through multiple "windows" can help a single researcher compare and contrast what is being seen through a variety of lenses" (para. 9). This three-pronged, triangulated study focused on observing students' understanding of photosynthesis SLOs through a pretest-posttest, student perception survey, and comparison of exam results

between the treatment group and a previous, traditionally-taught group. Teacher-researcher observation notes provided an additional, qualitative narrative to the impacts of the project.

Research Question

The teacher-researcher of this study sought to answer the following question: What is the impact of implementing a multimodal project on students' academic achievement regarding course-specific objectives mastery?

Purpose Statement

The purpose of this research is to investigate the efficacy of a multimodal assessment project on student learning within the introductory, General Biology I (BI 114) course at ESJC.

Findings of the Study

According to Sagor (2000), the information gained from implementation of an action research study will seek to answer two primary questions: 1) What is the story told by the data? and 2) Why did the story play out this way? As the data unfolds, a voice is given to the students, which may not have been uncovered previously. The findings of this AR study are presented as a narrative with the intention of understanding the impacts of the multimodal project on student learning and perceptions pertaining to the content of photosynthesis and organic molecules.

The data analysis in this chapter is separated into three major themes, based on major aspects of the implementation design: 1) student assessment performance, 2) student perceptions of the project design/structure, and 3) student perceptions of the project's impact on learning.

To enrich the narrative and breadth of the results/impacts, teacher-researcher observations recorded during the study period are provided within each major component.

Cycle 1: Student Performance – Pretest-Posttest Results

Prior to the unit on photosynthesis and implementing the multimodal project, the teacher-researcher administered a 10-question pretest (see Appendix A) to gauge students' prior knowledge of major concepts pertaining to photosynthesis. A total of twenty-four students (out of twenty-five enrolled) completed the pretest. Student names were replaced with pseudonyms for purposes of maintaining anonymity of results.

Table 4.1: Pretest-Posttest Performance Comparisons for BI 114 treatment group (Summer 2018)

Pretest	Raw Missed	% Missed	PostTest	Raw Missed	% Missed
Q1	1	4	Q1	1	4
Q2	7	29	Q2	2	8
Q3	11	46	Q3	14	58
Q4	9	38	Q4	7	29
Q5	7	29	Q5	7	29
Q6	10	42	Q6	7	29
Q7	12	50	Q7	6	25
Q8	17	71	Q8	8	33
Q9	21	88	Q9	12	50
Q10	18	75	Q10	11	46
Avg Score	5.2	53	Avg Score	6.8	69
# Tests	24	24	# Tests	24	24
Mean	11.3	47.2		7.5	31.1

In analyzing the pretest responses, both the raw number of students that missed a question and the percentage of the class were observed. The teacher-researcher observed the highest number/percentage of students missed questions 9, 10, and 8 respectively.

Each of these questions not only represented a higher-degree of knowledge pertaining to

the two stages of photosynthesis known as the Light Dependent and Light Independent reactions, but also the abstract, critical thinking involved as compared to other questions. Regarding the raw number of students that missed questions, the mean number of students that missed questions #1-10 on the pretest were 11.3 out of 24. The mean percentage of the class that missed questions #1-10 on the pretest was 47.2%.

After instruction on the unit on photosynthesis, and implementation of the multimodal project over the course of one week (four instructional days) within the 5-week summer semester, students were administered an identical posttest to complete (see Appendix A). Twenty-four students completed the posttest. In addition to generally improved results, the teacher-researcher observed that while questions #9 and 10 remained among the three highest missed, the number of students which missed these questions decreased significantly. For question #9 on the significance of the Light Independent reactions, 12 students missed the question versus 21 on the pretest. For question #10 on oxidation-reduction reactions, 11 students missed the question versus 18 on the pretest. Question #8 on the significance of the Light Dependent reactions was no longer considered one of the three most missed questions from the posttest. Eight students missed question #8 versus 17 on the pretest. The mean number that missed #1-10 on the posttest were 7.5. The mean percentage of the class that missed questions #1-10 on the posttest was 31.1%.

In order to ascertain whether or not any observed differences between the pretest and posttest were deemed significant, the teacher-researcher used a repeated measures t-test to compare collective means for the raw number of students that missed questions and the percentage of students that missed. The results of a repeated-measures t-test comparing the means for the raw number missed showed a p value of .008145, which is significant at a 95% confidence interval ($p \leq 0.05$). The results of a repeated-measures t-test comparing the means for the percentage missed showed a p value of .007512, which is also significant at a 95% confidence interval ($p \leq 0.05$). For the teacher-researcher, this indicates that there were generally positive impacts that occurred over the course of the photosynthesis unit. As the unit was instructed as similarly as possible to a traditional BI 114 course with exception of the multimodal assessment project, the teacher-researcher ascertains that at least part of the positive impacts found from the pretest-posttest differentials can be attributed to that of the treatment.

Additional classroom observations. Recorded teacher-researcher observations on day four noted that students appeared more confident and at-ease in responding to the posttest questions versus the pretest questions. Rhonda, a typically vocal student-athlete at the ESJC with multiple BI 114 course attempts, stated upon turning in her pretest: “Some of these questions were difficult. Will we be expected to know these for a test?” Upon turning in her posttest, Rhonda additionally stated: “I felt more confident in answering these questions this time. I think I did much better.” Students were documented during the posttest as appearing to shuffle less in their seats, expressing less overt anxiety during the process.

It was also observed that students generally took less time responding to the posttest questions, as students cumulatively finished within 12 minutes as compared to 20 minutes with the pretest.

Conflicting pretest-posttest question results. While the students generally improved in their performance on the posttest, there were also some observed inconsistencies. For question #3 regarding the contributions of producers and consumers to one another, there was a cumulative increase in incorrect responses on the posttest. Whereas 11 students (46%) answered incorrectly on the pretest, 14 answered (58%) incorrectly on the posttest. The teacher-researcher noticed individual improvements in 5 out of the 11 students from the pretest, Rhonda, Justin, Kaylee, Andrea, and Rachel. Rhonda is a student-athlete, Justin is a 12-year Navy veteran having last taken biology 15 years ago, and Andrea is a first-generation high school graduate and college attendee. Both Kaylee and Rachel are dual-enrollment students.

A cumulative regression in incorrect responses may be attributed to a confounding factor such as situational stress or could indicate a focus on the connections between producers and consumers more within the project or unit. For question #5 which scientifically described a chloroplast, there was no cumulative difference in performance between the pretest and posttest, with seven students, 29% of the class, answering incorrectly although some individual improvements in response were noted for three students, Rhonda, Justin, and Andrea in the class. Regarding the cumulative inconsistencies noted between the pretest-posttest results, the teacher-researcher believes that additional improvement and implementation of the action research project at later dates will provide further insight and guidance.

Cycle 1: Student Performance - Exam Comparison Analysis

To ascertain a wider range of impacts from the multimodal assessment project and to further triangulate data, a comparison of mean exam performance/scores between the Summer 2018 treatment group and a Fall 2017 non-treatment group was performed on questions pertaining to the instructional unit of photosynthesis. A total of seventeen questions (when multiple parts questions #10 and #11 were considered) were identified by the teacher-researcher from the students' second exam in the course for analysis (see Appendix D). The teacher-researcher began with a cumulative performance comparison between the two courses, then reviewed individual question performances between the two groups to ascertain additional content-specific insight.

Cumulative performance comparisons. For cumulative student performance comparisons, a mean percentage of correct student responses for the 17 exam questions was calculated using the means of each individual question (see Table 4.2).

Table 4.2: Fall 2017 and Summer 2018 group performance comparisons

Question	Fall 2017 (% correct)	Sum 2018 (% correct)
1	81	84
2	71	90
3	14	6
4	33	47
5	61	75
6	76	95
7	52	50
8	63	58
9	91	88
10A	93	73
10B	59	55
10C	59	57
10D	86	73
10E	59	45
10F	74	79
11A	55	64
11B	68	68
Mean	64.4	65.11

The mean percentage of the Fall 2017 students that answered the photosynthesis questions correct on Exam 2 was 64.4%. The mean percentage of the Summer 2018 students that answered the photosynthesis questions correct was 65.11%. Once calculated, an independent-measured t-test was used to infer whether the differences between the two, separate group's means were statistically significant. With a calculated p-value of .460995, the differences between the two means were not deemed significantly different from one another at a 95% confidence interval. These results are in line with Bennet (2011) whose research on the effects of multimodal assessment activities in post-secondary genetics courses found there to be positive correlations between the assessments and quiz scores, but not exam scores. Upon reflection of these observations, the teacher-researcher noted that there may be additional confounding factors that affect the efficacy of the project-based assessment on performance *over the long-term*. Cisco (2008) posits: "Given the multiplicity of opportunity for social networking, collaborations, and student-student, student-instructor, and student-response interactions, the complexities of the research need to become more specific and fine-grained" (p. 14). For instance, students are also tested on concepts not related to photosynthesis that can impact the direct effects of the project. Additionally, factors such as study time and test anxiety can affect student outcomes on an exam. It is also important to note that as comparisons were made between two differing groups of students, enrollment numbers and unique student dynamics are also potential confounding factors to consider.

Individual question analysis. Upon analysis of individual question performances between the Fall 2017 and Summer 2018 groups (see Table 4.2), the teacher-researcher did not immediately notice consistent differences in performance between the two groups. Questions #2, #4, #5, and #6 showed a significant difference in performance between the comparison and treatment groups. The teacher-researcher did observe that these questions were primarily identification or definition-based questions, which are lower on the Bloom's Taxonomy scale. The remaining questions exhibited either a similar or regressive performance between the two groups. There are a variety of formats such as identification, analysis, and evaluative identified for these questions. As with cumulative performance results between the two groups, the teacher-researcher believes that confounding factors may contribute to these results, and later research may provide additional clarity.

Cycle 1: Student Performance: Project Grading

As the multimodal project was integrated into the unit as an alternative assessment, an analytic grading rubric was developed (see Appendix B) and used to standardize the grading process. The majority of student submissions (19 out of 24) received a 30 out of 30 overall score based on the rubric's grading criteria. The six remaining students received no less than a 25 out of 30 overall score. The teacher-researcher identified criterion #2, "Student project is based on a multimodal nature" as the primary reason points were deducted from the project. An analysis of student survey responses showed that two students that received a lower score, Lisa and May expressed a need for greater clarity in the instructions for what is required of a multimodal project in the open-response portion of the student survey.

As Cisco (2008) identified a similar need for directional clarity within a previous study of the impacts of a multimodal project on student performance, the teacher-researcher believes that further development the project instructions and increased teacher-student scaffolding will be beneficial in future implementation cycles.

Student Examples. Submissions included a variety of choice, form, and expression while creating their photosynthesis project. While most students chose to submit a multimodal, computer-based presentation via Microsoft PowerPoint (See Appendix G for examples), other physical projects consisted of illustrated/narrated poster boards, and an interactive photosynthesis game (See Figures 4.1-4.4 below). Shari, an ESL student from Nepal created a 3-D tactile effect using paper, plastic balls, etc. Lisa’s project, while highly visual in nature did not illustrate as much detail in the Light Dependent/Independent reactions as the Figure 4.1 or 4.2. Some students chose to work in pairs for added interactivity, while others chose to work alone or interact via informal discussions with classmates only.

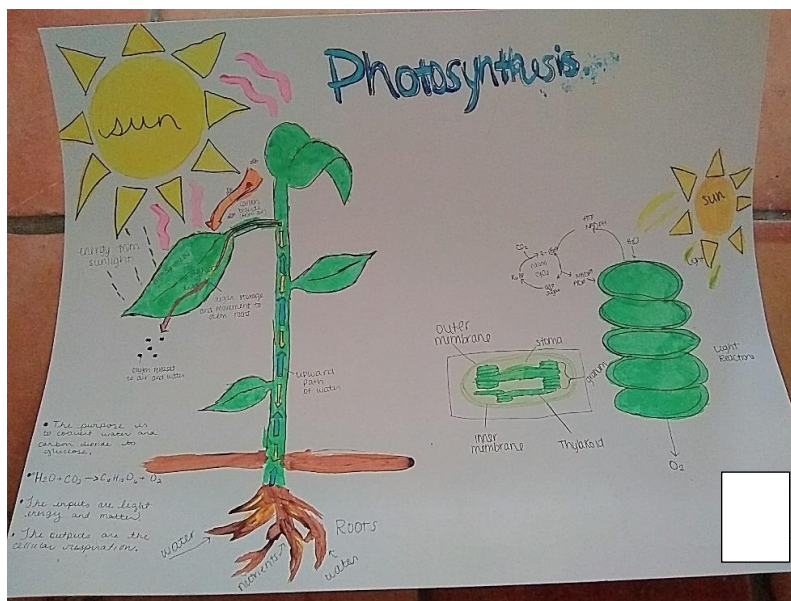


Figure 4.1: Briana and Jocelyn’s posterboard presentation using ink and watercolors

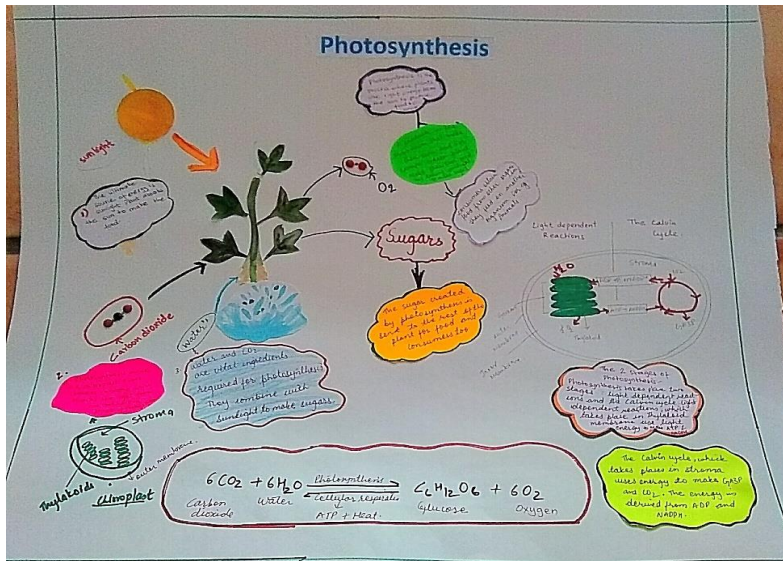


Figure 4.2: Shari's posterboard presentation using ink, watercolor paints, markers

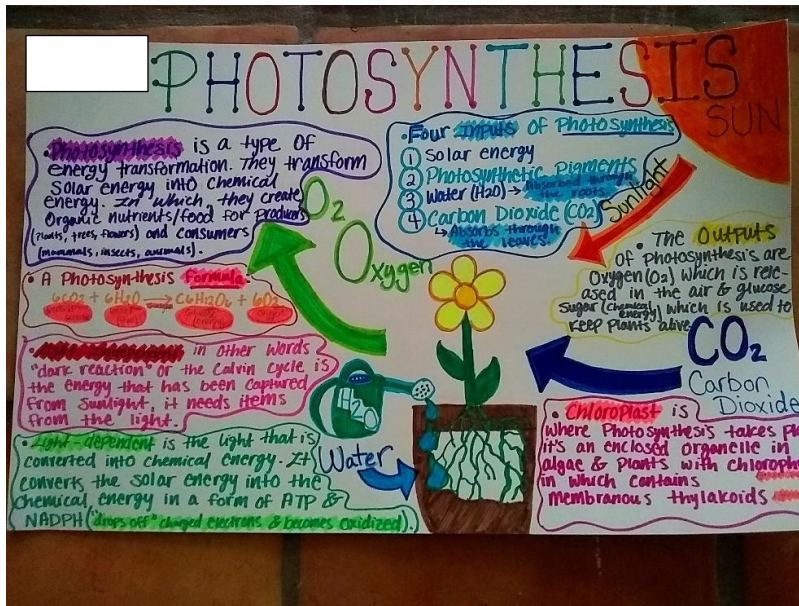


Figure 4.3: Lisa's posterboard presentation using highlighters

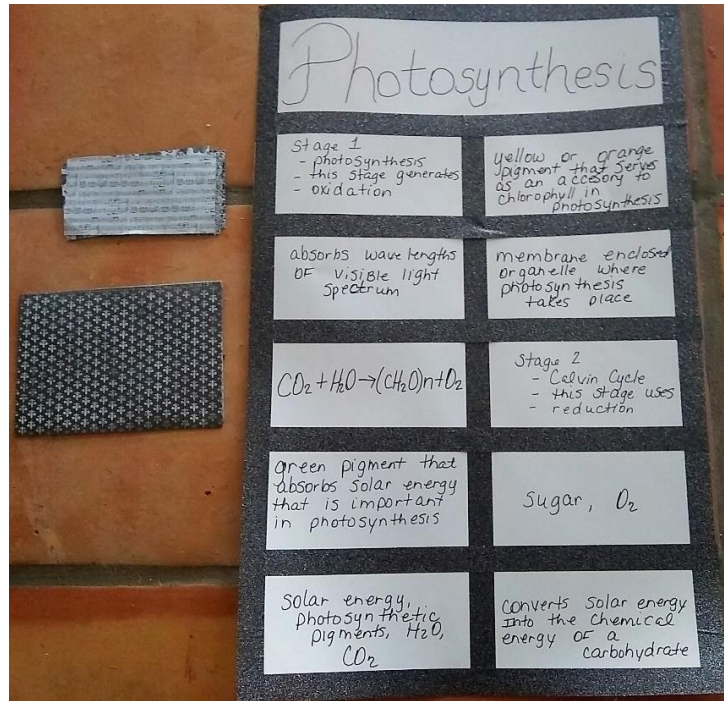


Figure 4.4: Patsy and Amanda's photosynthesis game, like Bingo

Cycle 1: Student Project Perceptions

Providing student choice in their learning process not only encourages interactivity and responsibility, but also allows for self-discovery as learners (Weimer, 2011; Chapman and King, 2012). As learning is a unique and personal experience for students, the teacher-researcher was interested in their perceptions of the multimodal project for reflection and future growth. To achieve this, a two-part student survey was distributed to each student at the end of the photosynthesis unit. Twenty-four students completed a 10-question survey regarding their perceptions of the multimodal assessment project. Student pseudonyms were used to maintain anonymity. The survey used a mixed-methods design, with questions #1-7 employing the use of a five-point Likert-scale, and questions #8-10 employing the use of open-ended response questions (see Appendix C). The Likert-scale ranged from a score of one (strongly agree) to five (strongly disagree), with three being "undecided". The teacher-researcher chose to provide an undecided

option, as she did not want to force students into an opinion they may not have readily held. It was the teacher-researcher's desire to gather a more holistic insight from the students by providing an open-ended response portion of the survey. Students were encouraged to answer openly and honestly regarding their experiences with the project. Two themes were addressed from the survey: 1) student perceptions of the project's implementation/design, and 2) student perceptions of the project's impact on learning.

Student perceptions of project implementation/design. Table 4.3 displays the cumulative response means to the Likert-scale portion of the student survey.

Table 4.3: Median responses for Q1-Q7 of Summer BI 114 student survey

Questions	Response Median
Q1	2
Q2	2
Q3	2
Q4	2
Q5	2
Q6	2
Q7	1
n	23

Questions #3, #4, and #7 on the Likert-scale portion of the survey specifically addressed the project's design and implementation during the first cycle of this AR study (see Appendix C). For question #3, "The (photosynthesis) content objectives of the multimodal project were reasonable to complete", a cumulative median response of 2 was calculated. For question #4, "There was enough time allotted to complete the project", a cumulative median response of 2 was also calculated. Question #7, "I understood the project instructions" presented a 1 cumulative response score. Median scores for Questions #2-6 most closely correspond to an "agree" response for the class, while Questions #7 most closely responds to a "strongly agree".

For the open-ended response portion of the study, various themes in student responses were identified from questions #8, #9, and #10. For question #8, “What were positive aspects of the multimodal course project?”, two major themes emerged: 1) increased content understanding and 2) increased engagement motivation. Five out of the 23 students that completed the survey directly identified increased understanding of photosynthesis as a positive aspect of the project. Andrea stated: “It helped me better understand the concepts of the material. Very useful.” Pasty, an older, non-traditional student stated: “It allowed me to apply the information I learned in class in everyday life.” Some students perceived that having an opportunity to explore material for themselves in order to create a project helped to increase their understanding. For instance, Monique stated: “Making a review for your own self helped to understand photosynthesis more.” The teacher-researcher has observed that while there were significant student increases between the pretest-posttest scores for photosynthesis, there were no significant cumulative differences in Exam 2 scores between the traditionally-taught and treatment groups. Future directions may focus on a more long-range project or ascertaining the long-term impacts of the photosynthesis project.

Four out of 23 students directly expressed an increase an engagement from the project. Three directly mentioned the project as being “fun” to complete. For instance, Justin stated: “It [the multimodal project] was a fun way to learn, and I got to be really creative.” For Shari, the project was “encouraging” and “one of the most effective projects I’ve had.” Cisco (2008) connects student engagement/interest and multimodal learning to the Germane aspect of cognitive load theory (CLT), which is “the degree of learner effort in construction of schemas [concepts], influenced by motivation,

engagement and interest” (p. 15). Henceforth learner effort, when associated with the transfer of working to long-term knowledge, is identified as a major retention aspect to consider in addition to content alignment and project design.

For question #9, “What were aspects of the project that could be improved?” the most apparent theme identified as a need for improvement was regarding time constraints for the project. Out of the 23 students that completed the survey, seven identified concerns with the four-day span of time to prepare and complete the project. For instance, Justin states: “With the time allotted, I was not able to go into as much detail as I wanted.” Andrea also stated: “This course is a summer course, so time was an issue. I feel if there was more time to go over the project and material I would have understood better. But overall the project was a great aspect.” The remaining students did not address time as a constraint or positioned their perspective of time in terms of the accelerated summer semester. For instance, Rhonda stated: “I feel everything was reasonable for this being a summer course.”

Teacher-researcher observation notes over the course of the project implementation period also noted that some students felt pressured under the time constraints of a 5-week summer period to complete the project. For instance, an ESL student named Laura stated during the two-hour lab period allotted in class for the project: “I wish we had more time to complete the project in class”. Although this was not possible due to the structure of the 5-week summer course and syllabus, the teacher-researcher believes that additional time in class is an important factor to consider and implement for future project cycles (Springer, Stanne, & Donovan, 1999; Hill, 2014), especially when considering potential ESL student needs.

The teacher-researcher identified a second concern pertaining to the details of the project's instructions, from six students. Lisa stated: "Instructions for the project could have been stated differently in what exactly was required." May also expressed that "some directions were hard to understand". Teacher-researcher observations from project grading noted that both students created a PowerPoint presentation to address the SLOs, but lacked multimodality in terms of imagery, videos, etc. Weimer (2011) also states that in providing student choice in assessments, "the biggest challenge involves getting students to examine the criteria they use to select assignments" (para. 4). To address these concerns, in future cycles the teacher-researcher will provide at least one student example of the project, conduct more interactive scaffolding discussions, and attempt to provide more instruction detail regarding multimodal media expression. One student, Kyra, suggested that the project instructions be expanded to include more chapters (of material), which was identified as a potential future action research direction.

Student-Teacher Interactions. During project implementation, the teacher-researcher noted in multiple instances that while identifying and creating their projects, students became more engaged and enthused than usual. For instance, Justin was recorded as saying: "This is interesting! I'm going to find some videos to add to my project!", with Andrea in agreement. Justin and Andrea were also among many students that interacted with one another to discuss ideas, content, etc. Most students chose to create a multimodal PowerPoint presentation, while others created a range of products such as a photosynthesis matching game, poster board presentations, and a 3D diorama. Overall, the students' creativity and engagement appeared to increase during this period, as compared to normal lecture/lab periods.

The teacher-researcher also observed that students interacted with the teacher more than usual by asking questions about how their project looked, was it addressing needs properly, etc. While the students only had one solid laboratory period to work on their project in class during the five-week summer semester, the students present all submitted their projects on time and earned positive grades per the project rubric (see Appendix B). The teacher-researcher attempted to provide additional time for students to plan their project during the accelerated semester by providing and explaining the project instructions two days before implementation.

Student perceptions of project impacts on learning. For the Likert-scale portion of the student survey, questions #1, #2, #5, and #6 pertain to student perceptions of the project's impact on their learning of photosynthesis, or how its multimodal nature may influence their learning of future content. For question #1, "I believe that the multimodal project increased my understanding of photosynthesis and its processes", question #2, "The multimodal project helped me understand my individual learning needs more", question #5, "I plan to apply my multimodal project skills to additional topics or subjects", and question #6, "I believe that the photosynthesis project assigned to me was effective in delivering information in different ways", a median score of 2 was calculated for each. As with the student responses regarding perceptions of project implementation/design (with the exception of Q7), each of the above scores most closely correspond to an "agree" response for the class.

For the open-ended response portion of the survey, students exhibited generally positive perceptions of the project on their learning experiences. Question #10 asked, "How did the project assist in your understanding of your personal learning needs and

methods for learning material?” Pasty stated: “The project assisted me in understanding how the system of photosynthesis is part of our everyday life and how to look for it. Having to use multimodal methods was very useful to make connections with the content.” Shari stated: “The project helped me to understand the Light Dependent and Independent reactions [specifically], which I found to be the most difficult parts of photosynthesis because of the vocabulary and processes.” Andrea found the act of personally researching the material to prepare for the project to be effective in retention. “Looking up the answers for myself helped me understand more and build my research skills.” Other students echoed similar sentiments. Their responses relate to the positive aspects of authentic and alternative assessments in relating information to real-world and unique experiences (Chapman & King, 2012).

Upon active reflection, teacher-researcher interpreted these results as meaning that the students found positive learning benefits in both a project-based assessment and multimodal design. This is congruent with McDonald (2008), Grant (2011) and Mullen (2015), whom posited that the authentic, alternative, and interactive nature of project-based learning creates unique and impactful learning experiences. Teacher-researcher observation notes noted that students appeared to find empowerment in having a choice in the project created. For instance, Rhonda stated: “I’m glad I was able to choose a PowerPoint presentation for my project. I’m good with computers so this fits me.” Shari, also stated: “I really enjoy painting and drawing things. I’m going to use a poster board for my project.” Some students were initially concerned about the notion of having a choice in what product was created.

Once reassured that they would be able to create a product of their choice as long as it met the requirements provided in the instructions regarding learning outcomes and multimodality (see Appendix B), the students became more confident in their actions and progressed forward.

Cycle 2: Student Performance – Cumulative Pretest-Posttest Results

During the first instructional week of the Fall semester and prior to implementing the multimodal project, the teacher-researcher administered a 10-question pretest (see Appendix H for pretest-posttest format) to gauge students' prior knowledge of major concepts pertaining to organic molecules. Due to the online, asynchronous nature of the course, the pretest was administered via Google Forms over a period of four days. A total of twenty students (out of twenty-eight enrolled) completed the pretest. After instruction on the unit on organic molecules during week three of the course, and implementation of the multimodal project over the course of one week (seven instructional days) within the 16-week summer semester, students were administered an identical posttest to complete using the quiz feature in Canvas. All twenty-eight students completed the posttest. Student names were replaced with pseudonyms for purposes of maintaining anonymity of results. In contrast to the Summer BI 114 group, the teacher-researcher focused less on quantitative details of individual question performance and more on the general class or specific students' changes.

Table 4.4: Pretest-Posttest Performance Comparisons for BI 114 online treatment group (Fall 2018)

Pretest	Raw Missed	% Missed	PostTest	Raw Missed	% Missed
Q1	8	40	Q1	0	0
Q2	15	75	Q2	9	32
Q3	12	60	Q3	8	29
Q4	11	55	Q4	7	25
Q5	18	90	Q5	8	29
Q6	9	45	Q6	8	29
Q7	8	40	Q7	4	14
Q8	11	55	Q8	9	32
Q9	12	60	Q9	13	56
Q10	17	85	Q10	11	39
Avg Score	4.0	40	Avg Score	7.4	74
# Tests	20	20	# Tests	28	28
Mean	12.1	60.5		7.7	28.5

In order to ascertain whether or not any observed differences between the pretest-posttest were deemed significant, the teacher-researcher used a repeated measures t-test to compare collective means for the raw number of students that missed questions and the percentage of students that missed. The results of a repeated-measures t-test comparing the means for the raw number missed showed a p value of .001069, which is significant at a 95% confidence interval ($p \leq 0.05$). The results of a repeated-measures t-test comparing the means for the percentage missed showed a p value of $7.8E^{-05}$, which is also significant at a 95% confidence interval ($p \leq 0.05$). For the teacher-researcher, this indicates that there were generally positive impacts that occurred over the course of the organic molecules unit. As the online course is structured as similarly as possible to the face-to-face course, with some necessary modifications for the distance-education environment, the teacher-researcher ascertains that at least part of the positive impacts found from the pre-posttest differentials can be attributed to that of the treatment.

It must also be noted that as there are modifications for a distance-education environment, such as additional, written discussion board activities, there could be confounding factors affecting the pretest-posttest results.

Student Performance – Individual Pretest-Posttest Results. For cycle 2 of the study, the teacher-researcher focused on the actions and performance of five individuals from the BI 114 online group:

- 1) Charity- A traditional, full-time college student, 18-22 years of age and Caucasian, having attended a non-local high school. Currently, she is unemployed.
- 2) Nala- A part-time student, aged 23-27 and Hispanic/Latina, having attended a neighboring high school. She is currently employed full-time and has attempted to take BI 114 prior, at another institution.
- 3) Shardee- A full-time student, 23-27 years of age and African-American, having attended a Lea County high school. She is currently employed full time.
- 4) Jamie- A part-time, third-year college student, above 27 years of age and Caucasian, having attended a Lea County high school. She is currently employed full-time and has attempted BI 114 multiple times at ESJC.
- 5) George- A full-time student, 23-27 years of age and Caucasian, having attended schools long-distance from Lea County. He is currently employed full-time and is located in Florida.

All five students showed improvements in their pretest-posttest results. Charity initially missed seven questions (a 30% score) on the pretest, and missed two questions (an 80%

score) afterwards. Nala initially missed three questions (a 70% score) on the pretest, and missed one question (a 90% score) on the posttest. Sharee initially missed five questions on the pretest (a score of 50%) and missed one on the posttest (a score of 90%). Jamie showed the most marked improvement, initially missing seven (a score of 30%) on her pretest, and missing zero questions (a score of 100%) on the posttest. George showed the smallest range of improvement between the two tests, with initially missing six questions on the pretest (a score of 40%) and missing five questions on the posttest (a score of 50%).

Additional classroom observations. With the online course, the teacher-researcher had less opportunity to “observe physical interactions and expressions as with a face-to-face environment” (Gerber, et al. 2016, p. 148). Nonetheless, via teacher-researcher field notes, it was observed that more students completed the posttest online (28 versus 24) when it was formatted as a required course quiz, versus an “optional” survey. The required assignment aspect is believed to impact student participation with the online course as compared to the Summer BI 114 face-to-face students, whom all completed the pretest-posttest and student perception surveys even as optional assignments. Similarly to the students in cycle one, it was also observed that students generally took less time responding to the posttest questions, as students cumulatively finished within 11 minutes as compared to 18 minutes with the pretest.

Cycle 2: Student Performance - Exam Comparison Analysis

For cumulative student performance comparisons, a mean percentage of correct student responses for the 11 exam questions was calculated using the means of each individual question (see Table 4.5).

Table 4.5: Fall 2017 and Fall 2018 group performance comparisons

Question	Fall 2017 (% correct)	Fall 2018 (% correct)
1	64	40
2	36	36
3	64	80
4	44	54
5	59	61
6	56	58
7	63	35
8	53	33
9	80	53
10	71	46
11	35	73
mean	56.81818182	51.72727273

The mean percentage of the Fall 2017 students that answered the organic molecules questions correct on Exam 2 was 56.8%. The mean percentage of the Fall 2018 students that answered the organic molecules questions correct was 51.7%. Once calculated, an independent-measured t-test was used to infer whether the differences between the two, separate group's means were statistically significant. With a calculated p-value of .215039, the differences between the two means were not deemed significantly different from one another at a 95% confidence interval. These results are again in line with both the Cycle 1 results and Bennet (2011) whose research on the effects of multimodal assessment activities in post-secondary genetics courses found there to be positive correlations between the assessments and quiz scores, but not exam scores. Upon reflection of these observations, the teacher-researcher again noted that there may be additional confounding factors that affect the efficacy of the project-based assessment on performance *over the long-term*. Similarly to the initial AR cycle, comparisons were made between two differing groups of students, enrollment numbers and unique student dynamics are also potential confounding factors to consider.

Cycle 2: Student Performance: Project Grading

As the multimodal project was integrated into the unit as an alternative assessment, an analytic grading rubric was again used to standardize the grading process, with slight modifications to grading criteria #1 to reflect student effort and creativity (see Appendix I). The majority of group submissions (8 out of 10) received a 30 out of 30 overall score based on the rubric's grading criteria. The two remaining groups (Organic Chem Masters 2 and 3) received no less than a 28 out of 30 overall score. The teacher-researcher identified criterion #4, "Student project is organized" as the primary reason points were deducted from the project. This result varies from that found in cycle one, where #2, "Student project is based on a multimodal nature" as the primary reason points were deducted. The teacher-researcher believes this shift in criteria for deductions (as well as the number of points deducted) stems from having student submissions from the Summer BI 114 students to be able to learn from as the teacher-researcher and also share with the Fall students as an exemplar for reference. As the teacher-researcher recorded two students in the previous study as indicating a need for greater clarity in the project's instruction requirements (Cisco, 2008), having a visual exemplar to provide is believed to have been beneficial to the Fall group by providing additional scaffolding for creating their product. Bigatel (2016) also echoes this sentiment in online courses: "Providing examples or models of well-written assignments is one way to ensure students focus on the assignment's goals. Having a rubric to guide students' work helps them focus on clearly articulated expectations and helps faculty write comments directly related to the rubric" (para. 8).

Cycle 2: Student Performance: Learning Outcome Analysis

For the second cycle of this AR study, the teacher-researcher sought to analyze and connect students' finished products to how the course-specific SLO's (see Appendix I for objectives) were met. The five focus students' finished projects were reviewed more closely to ascertain the quality with which objectives were met, as well as the level of thinking exhibited by their finished projects.

- Charity: Charity's group project (see Appendix G) exhibited a high degree of multimodality and quality in expressing each SLO. For instance, for SLO #1, "Distinguish between dehydration synthesis & hydrolysis reactions.", it was stated that "It is known as Zimmer's hydrogenesis", a dehydration reaction "refers to the formation of larger molecules from smaller reactants accompanied by the loss of water molecules" and a hydrolysis reaction "Is the reaction involving the breaking of a bond in a molecule using water. It is the breakdown of polymers into monomers by using a water molecule and an enzyme." For SLO #2, "Distinguish between monomers and polymers.", the group stated for monomers that "Monomers are small molecules which may be joined together in a repeating fashion to form more complex molecules called polymers. Monomers form polymers by forming chemical bonds through a process called polymerization." For polymers, the group stated: "Polymers, which means "many monomers", are also called macromolecules. They are known as the largest biomolecules because they are constructed by linking together the same type of subunit." The teacher-researcher observed that the group went a step further by providing realistic examples and explanations for the use of polymers. For SLO #3, "Identify the

structures and functions of each major macromolecule group & give examples of each.”, the group created an overview slide for the four major macromolecule groups, then allotted two slides for each specific group, with specific characteristics and examples. For SLO #4, “Describe why **each** organic molecule group is important (and connect to real-world) examples, the group stated as an example for carbohydrates: “They are essential for energy. Your body uses food to store energy and build muscle tissue. Carbohydrates also assist your coordination by supplying your brain with fuel. (sugars)”. To multimodally express each SLO, various images were provided to support the statement/concept, and the teacher-researcher observed a high level of organization for the PowerPoint.

- Nala: Nala’s group project (see Appendix G) exhibited a high degree of multimodality and quality in expressing each SLO, albeit less organized. For example, with SLO #1 the group stated: “First of all Hydrolysis is a Greek word that means water and separation. This process as its meaning says is about the split of the bond H_2O to HO . Hydrolysis occurs when you add water and it breaks or destroys two molecules.” For dehydration synthesis: “Dehydrations means to take water out and synthesis means to build something. Dehydration is the process of bonding two molecules and taking away water.” Not only were the definitions provided, the roots of the terms were also. For SLO #2 the group stated: “Polymers are the largest biomolecules made up of subunits called Monomers. Monomers must be energized before joining to form a Polymer.” Examples were also provided for the four groups. The teacher-researcher noted that the SLO #2

slides were the last two PowerPoint slides, which affected the organization of the information as monomers and polymers are important to understand before discussing each group. For SLO #3, an overview slides of the four groups' structures and functions were also provided, with one slide describing each group. For instance, with lipids: "Lipids are important to have. They are known as fat. They are hydrophobic, and are not soluble to water. Triglycerides store energy in our bodies regulating insulation. That's why penguins can survive in degrees below zero." For SLO #5, the group meshed this information with SLO #4 for each slide, for instance with the penguins and fat insulation. Another example for nucleic acids would be: "They are genes that are responsible to reproduce every protein in our bodies." Many images were used to also convey information, although two images could not properly display within the PowerPoint.

- Sharee: Sharee's group exhibited multimodality by emphasizing differing colors, fonts and text sizes versus images (See Appendix G). For SLO #1, the teacher noted some inaccuracy in conveying the *process* of dehydration synthesis (as opposed to the definition). It was stated: "In dehydration synthesis, two hydrogen's and two oxygen's are taken out.", where one two hydrogens and one oxygen is removed. For hydrolysis it was stated: "In hydrolysis, when water is added, it separates the bond between oxygen and hydrogen and reforms into two separate hydroxyls." For SLO #2, the group used visual and written examples to express the relationship between monomers and polymers, in addition to the definitions. For instance: "Example: Glucose + Glucose + Glucose + Glucose → polysaccharide (sic)." For SLO #3, the group used an introductory slide to the four

groups, then a separate slide for functions and examples. The group used more real-world verbiage to describe the functions of each, for example: “Carbohydrates: Providing energy and regulation of blood glucose sparing the use of proteins for energy” although for lipids there were slight errors or interpretations needed from the information provided. For instance, the group stated: “Lipids: regulate membranes permeability. Serve as a source for fat soluble like A, D,A,K.” versus fat-soluble vitamins like A,D,E,K. For SLO #4, the group used one slide to describe the importance for each group, in a paragraph-like format. For instance: “Proteins are polymers of amino acids. They have the same structure, generally, but they differ by the side chain attached weight of the cells consists of proteins. Some of the main functions of proteins in animals cells are, support, metabolism, transport, defense, regulation, and motion. The shape of a protein is suited to its function. to a central carbon. The sequence of amino acids will determine the final shape of the protein. The shape determines the structure and function in the cells. As much as 50% of the dry” described proteins but was lengthy and missing the remaining sentence.

- Jamie: Jamie’s group created an interactive Prezi presentation in conjunction with images and video to meet the course-specific SLO’s. To meet SLO #1, the group opted to insert a Ricohet Science Youtube video to introduce describing dehydration synthesis versus hydrolysis. The video accurately and animatedly describes dehydration synthesis and hydrolysis, and provides examples.

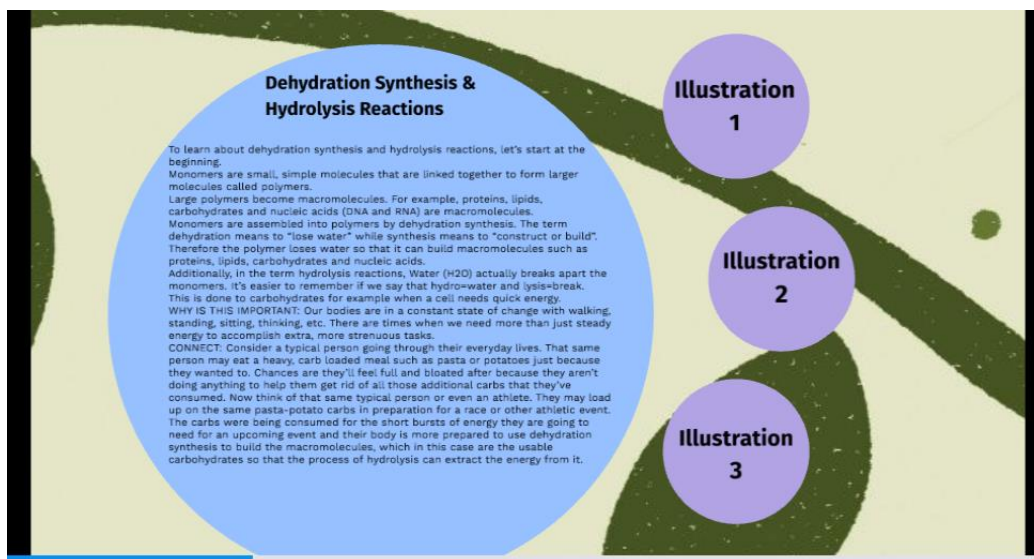


Figure 4.5: Further description of dehydration synthesis and hydrolysis by Jamie's group

Illustrations and a further description were provided in a separate area of the Prezi, which was accurate but lengthy for a presentation (See Figure 4.5). To meet SLO #2, the group presented a description of monomers and polymers along with a video, important vocabulary and a real-world example (See Figure 4.6).

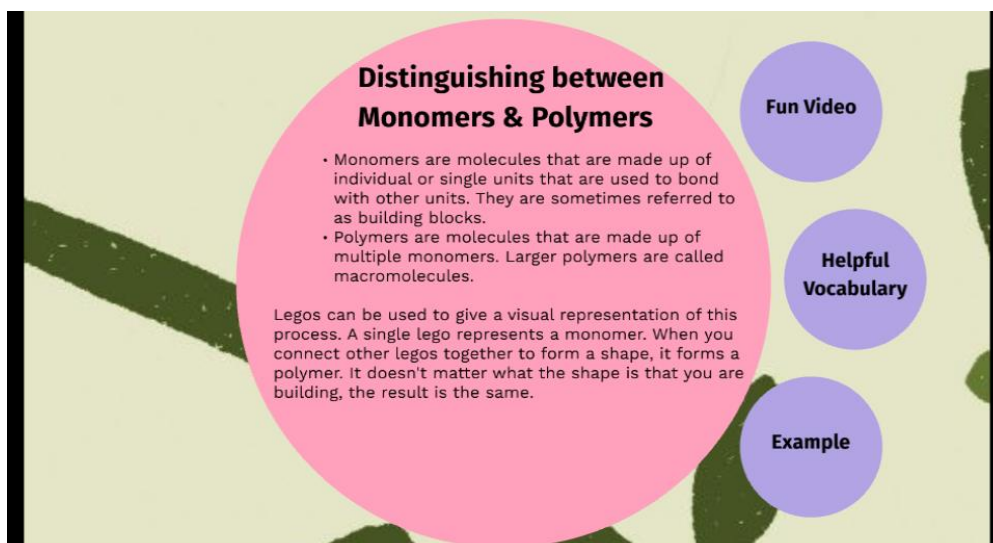


Figure 4.6: Description of monomers and polymers by Jamie's group

For SLO #4, the group used a question-answer format, along with an additional information and a video to describe the structures, functions, and importance of each group (See Figure 4.7).

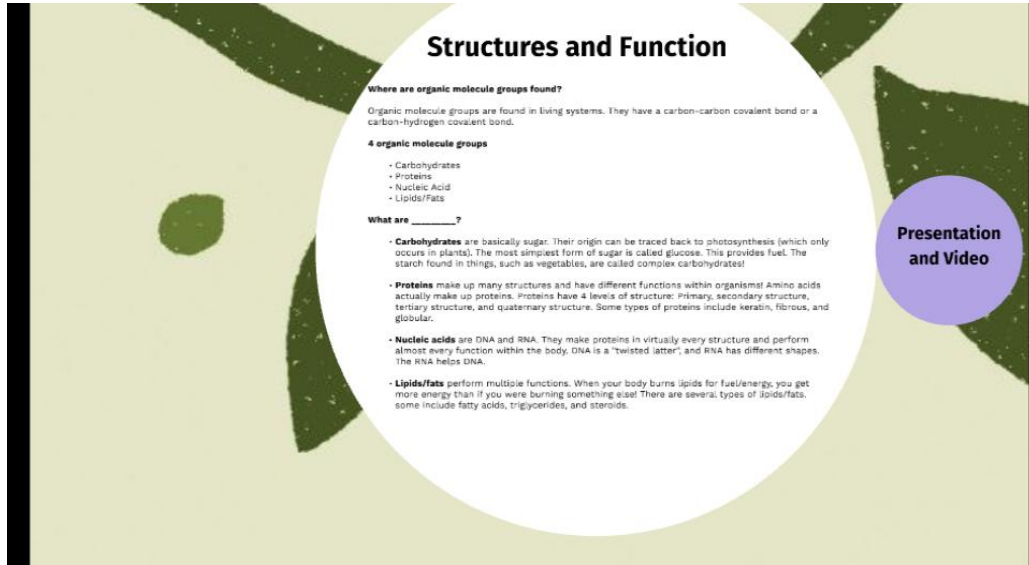


Figure 4.7: Structures and functions of organic molecules by Jamie's group
Jamie's group presentation exhibited the most dynamic and interactive project within the BI 114 group. The teacher-researcher also observed a high level of engagement and interactions from the group members within their discussion board.

- George: George's group also created an interactive Prezi presentation to address the course-specific SLOs. For SLO #1, the group used a Venn diagram and image to compare and contrast dehydration synthesis and hydrolysis (See Figure 4.8), this exhibiting a higher level of analysis for the two processes. For instance, it was stated that both reactions involve enzymes and water.

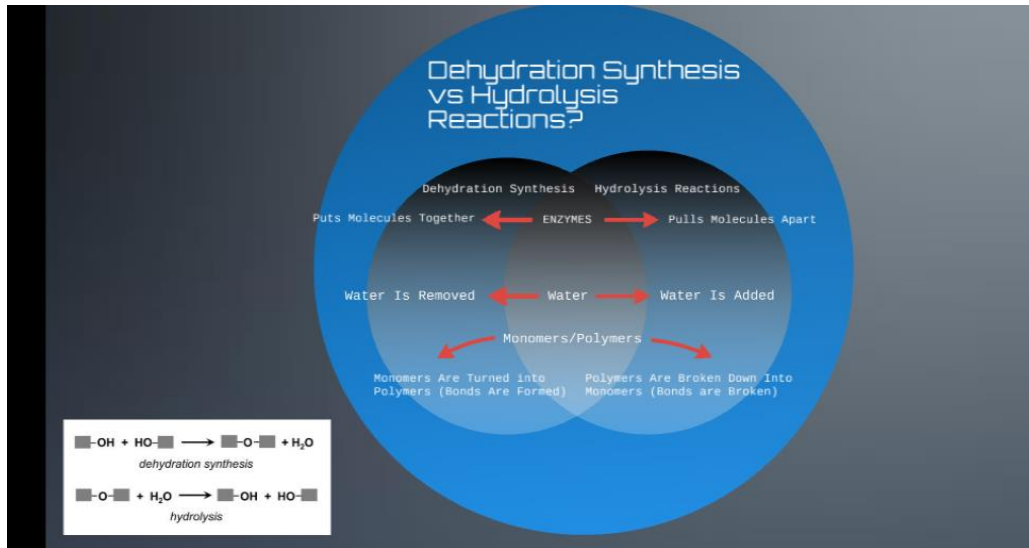


Figure 4.8: Dehydration synthesis and hydrolysis by George’s group

To meet SLO #2, the group described monomers as: “One single unit able to bond in long chains” and polymers as “chain of monomers, usually organic but sometimes can be inorganic”. An image was also provided to illustrate the difference (See Figure 4.9).

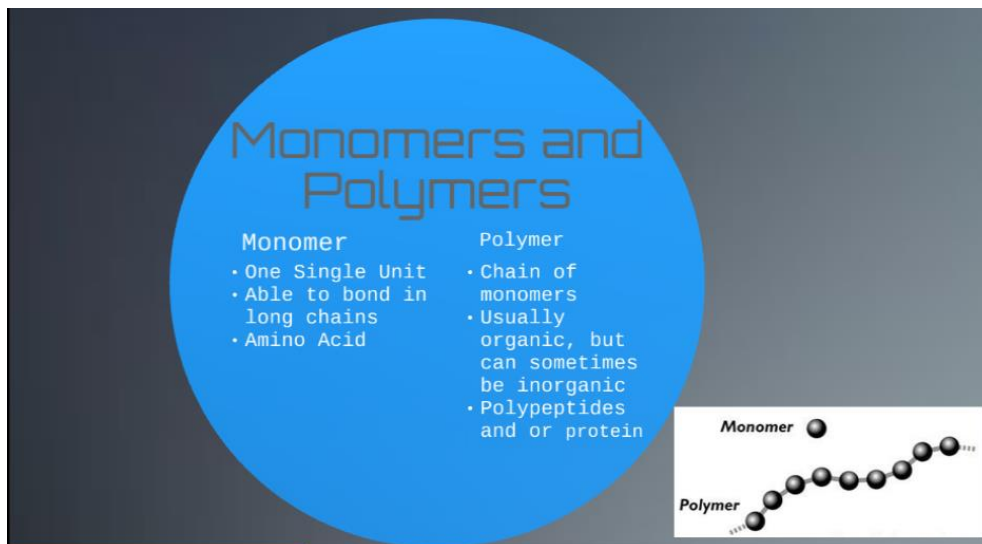


Figure 4.9: Monomers and polymers by George’s group

For SLO #3 and #4, the group provided an overview of the four major groups, an image overview, and separate areas to describe the characteristics, functions, and importance of each group (See Figure 4.10).

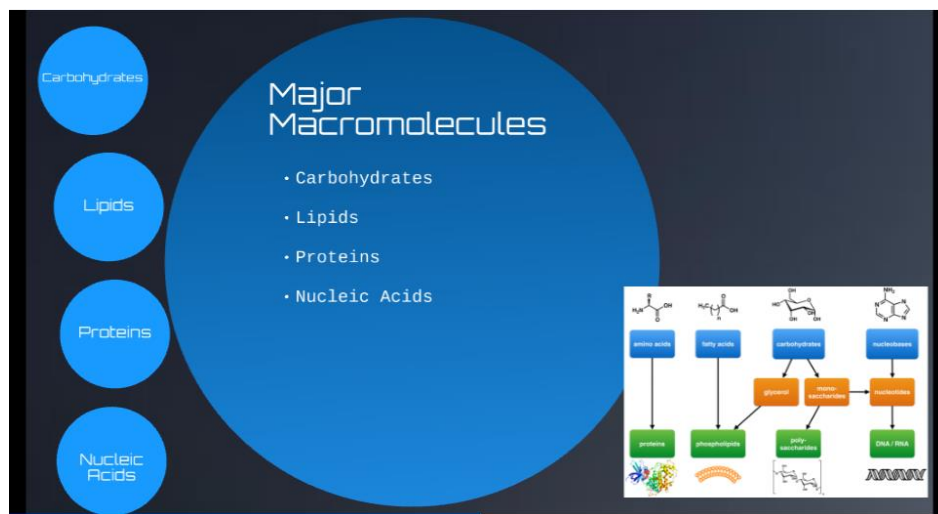


Figure 4.10: Organic molecule characteristics by George's group

Ultimately, each group created a unique, highly multimodal project to address each of the outcomes associated with the project and unit on organic molecules.

As alternative assessments provide choice and flexibility (Chapman & King, 2012), each project differed in how each outcome was expressed, yet each of the focal students' groups directly addressed them in a comprehensive and generally thorough manner.

Cycle 2: Student Project Perceptions

For the second cycle of the AR study, a two-part student survey was again distributed to each student at the end of the organic molecules unit. As an asynchronous online course, the survey was distributed via Google Forms over a period of three days. Twenty-two students completed a 10-question survey regarding their perceptions of the multimodal assessment project. Student pseudonyms were used to maintain anonymity. The survey used a mixed-methods design, with questions #1-7 employing the use of a

five-point Likert-scale, and questions #8-10 employing the use of open-ended response questions (see Appendix C for survey). Two themes were again addressed from the Fall BI 114 survey: 1) student perceptions of the project’s implementation/design, and 2) student perceptions of the project’s impact on learning.

Student perceptions of project implementation/design. Table 4.6 displays the cumulative response means to the Likert-scale portion of the student survey.

Table 4.6: Median responses for Q1-Q7 of Fall BI 114 student survey

Questions	Response Median
Q1	1.5
Q2	1.5
Q3	1.5
Q4	1
Q5	2
Q6	1
Q7	1
n	22

Questions #3, #4, and #7 on the Likert-scale portion of the survey specifically addressed the project’s design and implementation during the second cycle of this AR study (see Appendix C). For question #3, “The (organic molecules) content objectives of the multimodal project were reasonable to complete”, a cumulative median response of 1.5 was calculated. For question #4, “There was enough time allotted to complete the project”, a cumulative median response of 1 was also calculated. Question #7, “I understood the project instructions” presented a 1 cumulative response score. Median scores for Questions #2-6 most closely correspond to an “agree” or “strongly agree” response for the class, while Questions #7 most closely responds to a “strongly agree”.

For the open-ended response portion of the study, various themes in student responses were identified from questions #8, #9, and #10. For question #8, “What were positive aspects of the multimodal course project?” two major themes emerged: 1)

increased engagement/feelings of interactivity and 2) increased content understanding. Eleven of the 22 students that completed the survey directly identified increased engagement and/or interactions with other students as a positive aspect of the project. George stated: “Working with others was a nice change of pace.” Nala similarly stated: “I liked the people I worked with because we kept communication and made the task easier.” Some students also perceived that having clear instructions for the project helped ease stressors involved in creating a group project. For instance, Jamie stated: “Having all the requirements ahead of time was helpful in that my team members and I were able to discuss what to do and work on our particular pieces without additional stress.”

Five out of 23 students directly expressed an increase in content understanding/learning from the project. Sharee stated: “The project helped me understand the organic compounds and refreshed my mind on carbs and proteins.” Some students, such as Charity perceived that having an opportunity to explore the material in different ways (multimodally) in order to create a project helped to increase their understanding. She stated: “It gave verbal and visual ways of understanding the information.” Anjelica, an ESL student and ESL second-grade teacher stated, “You remember what you do. I will remember the material from this project because I researched and created it myself”. According to Gerber et al. (2016), the asynchronous, online aspect of the course may have provided positive learning opportunities from the project. “Asynchronous approaches allow respondents to participate at times convenient to themselves, to potentially engage in greater levels of reflectivity and reflexivity, and to consult external documents and sources” (Gerber et al., 2016, p. 152).

The teacher-researcher has observed that while there were significant student increases between the pretest-posttest scores for organic molecules, there were no significant cumulative differences in Exam 2 scores between the traditionally-taught and treatment groups. As with Cycle 1 of the AR study, future directions may focus on a more long-range project or ascertaining the long-term impacts of the organic molecules project.

For question #9, “What were aspects of the project that could be improved?” the highest number of respondents, 8 out of the 22, stated that nothing needed to be improved for the project. George stated: “Nothing that I can think of needs improvement.” Sharee also stated: “I think the project was well laid out. It was easy to keep in contact with my group members and it was easy for us to get our work completed.” Although there is always room for reflection and improvement, the teacher-researcher interpreted this cumulative outcome as meaning that the initial cycle with the Fall BI 114 online group was generally positive.

The most apparent theme identified as a need for improvement, from 7 respondents was group communication and/or involvement during the project. Nala posited her response in the context of interacting within an entirely distance education environment: “I just think it's difficult doing an ALL online course. Just makes communication harder.” Charity echoed a similar sentiment with an online course and suggested smaller groups: “It would have been easier if the groups were kept to just 2 people instead of more. Excess members make it difficult to align schedules to work on the project. With this being an online class, everyone's schedules and time zones will be different.” Gabriel (2004) posits that successful online collaborations and learning

communities require commitment from everyone involved. “Students who are required to work collaboratively online must commit increased time and develop new strategies to get to know each other, plan work together, and maintain effective communication in a Web-based environment” (Gabriel, 2004, p. 55). As the asynchronous and distance education nature of the course in addition to time availability, internet access, and student personality differences creates challenges within an online environment, the teacher-researcher will further reflect on methods of encouraging group interactions in future online AR cycles.

Three of the respondents stated technology as a general area of improvement from the project. Kynlee, an early college student and Lea County resident stated that “I had to pay a lot of money to use PowerPoint and Prezi. This is an added expense in addition to books and tuition.” Jamie also mentioned technology concerns in the context of individual experience and competency: “Understanding that not everyone has a Google account or knows how to work Prezi for presentations. In other words, not all online students are tech savvy.” While the students were allowed a choice in methods to complete their projects, including physical projects for local students, the teacher-researcher hopes to reflect and uncover additional methods by which to complete the projects. For instance, the “Collaborations” tab in Canvas could be specialized to provide an “in-house” and more familiar option to complete the project.

Student Interactions and Teacher Observations. Through screenshots and observation notes of student interactions (See Appendix K for online observation protocol), the teacher-researcher observed a high level of interactions between students during the project implementation period. Over the course of one week, 40 posts were

generated in the group discussion boards, by 28 students, regarding general group communications and project planning. Fifteen posts by 15 students were made regarding assignment/distribution of duties and tasks. Two posts by two students were made regarding confusion about instructions. One student, Nala, particularly posted about the helpfulness of the Youtube instructional video provided by the teacher-researcher prior to the project implementation. From Friday-Sunday of the instructional week, 10 posts by 9 students were made to turn in the project in their respective discussion boards. The teacher-researcher did not receive any late project submissions.

The teacher-researcher was unable to track some student interactions, as the group members found it more convenient to begin texting or meeting in person to plan and complete the project.

Similarly to the Summer BI 114 students, the teacher-researcher noted in multiple instances that while identifying and creating their projects, students exhibited increased engagement within their discussion posts. For example, screenshots of Nala and Jamie's group postings between August 29 and Sept 1 show that they chose to start early with distributing and researching tasks for the project. Charity also posted early to the group on August 27th to begin planning but did not receive a response from other members until later during the implementation week (Sept. 4). Both Sharee and George's group began posting during the implementation week to decide on a project format but chose to interact further via text messaging or e-mails for convenience. Although it was difficult to track Sharee and George's group interactions because of this, Sharee's group mate, Heather, stated via e-mail to the teacher-researcher after submitting their project: "I really enjoyed this group project. I got to know my group mates well, learn new material, and

ended up making new friends!” As opposed to the prior instructional week, the teacher-researcher also recorded 122 total logins to Canvas during the implementation period versus 46.

Student perceptions of project impacts on learning. For the open-ended response portion of the survey, students exhibited generally positive perceptions of the project on their learning experiences. Question #10 asked, “How did the project assist in your understanding of your personal learning needs and methods for learning material?” Similarly to the first cycle, students generally exhibited positive perceptions of the project’s impacts on their learning experiences. Charity stated: “It made me use outside sources and other photos for a more in depth, visual learning experience.” Nala exhibited positive perceptions on her learning in the context of group interactions: “I believe it helped me get a different view of the material. My teammates interpreted the material different than me. Sometimes they made more sense of it than me.” Sharee and Jamie perceived that the project helped her learn more about technology. “It helped me understand how to submit my work using different places. Via google drive, Microsoft word, and Microsoft PowerPoint.” Julie stated: “I don't know that the project material actually helped with my personal learning needs or methods for learning material but it did remind me to continue learning about technology and how to prepare for online presentations.” George provided a non-directional response, stating: “The project was pretty straight forward.”

Similar to the Summer 2018 students, the teacher-researcher interpreted these results as meaning that the students experienced positive learning and utilization of 21st century skills from a project-based assessment, with a multimodal design. This is again

congruent with McDonald (2008), Grant (2011) and Mullen (2015), whom posited that the authentic, alternative, and interactive nature of project-based learning creates unique and impactful learning experiences, even within the context of an asynchronous, online learning environment. The teacher-researcher also believes that having prior exemplars and experiences from the first cycle to both improve teacher communication about the project and provide students for some expectation of what to submit impacted the students' experiences and outcomes.

Interpretations of the Study and Further Reflections

Based on the results of the AR study, the teacher-researcher has ascertained that there is great diversity in the educational outcomes associated with the project. This is in line with Dana and Yendol-Hoppey (2014) and Cisco (2008) that label educational research as a complex and multifaceted endeavor. Generally, photosynthesis and organic molecule achievement improved over the short-term for the cumulative student body. The project-based assignment itself was met with positive reviews from the class in terms of learning impacts and interactions with the material. For non-traditional students such as Justin, Andrea and Sharee, the project appears to have impacted both learning and enthusiasm for biology. For ESL student Shari, the project increased engagement with a difficult topic and vocabulary and allowed for creative expression. Nala, another ESL student found positive benefits from group interactions within the online course. These results also correspond with Cavanaugh, et. al. (2016) who found that student buy-in to active learning was positively associated with increased engagement in self-regulated/self-motivated learning behaviors, which often lead to academic success.

For future research cycles, the teacher-researcher identified needs for improvement in the project instructions/specificity, time allotted for project implementation and completion, and amount of instructor scaffolding. As the summer and online courses generally consist of fewer students, a means of effectively implementing the project with larger groups and additional sections requires additional logistical planning. Extending the short-term achievement benefits of the project into the long-term, as evidenced by cumulative exam performance analysis is a potential topic for further AR study.

CHAPTER FIVE

DISCUSSION, IMPLICATIONS, AND RECOMMENDATIONS

In all, this study revealed that implementation of the multimodal course project on photosynthesis, then organic molecules conferred positive effects in both student perceptions of learning and academic achievement in the short-term. Students were also observed to have demonstrated increased engagement with course content during this process. The findings of this study revealed three themes addressing the impacts of the project: 1) student assessment performance, 2) student perceptions of the multimodal design/structure, and 3) student perceptions of the project's impact on learning. Analysis of these themes suggest that the multimodal assessment project did have a positive impact on course-specific SLO achievement within two instructional units and perceptions of learning within the BI 114 course based on pretest-posttest results, student survey input, and teacher-researcher observations. Impacts on student SLO achievement in the long-term are currently deemed questionable based on exam comparisons between treatment and non-treatment groups.

Through the study findings, the teacher-researcher determined a basis of effectively implementing an authentic or alternative course assessment in the BI 114 course, through the application of the initial multimodal photosynthesis project and noting suggestions for further instruction and action research cycles.

This study may benefit education programs by highlighting the use of an authentic, alternative assessment within a college-level introductory biology course. Other introductory biology educators will also be able to determine the efficacy of such a project within their own unique classroom settings. Specifically, teacher-researchers will be able to see examples of the student impacts when multimodal assessment projects are integrated into the curriculum.

Research Question

The teacher-researcher of this study sought to answer the following research question: What is the impact of implementing a multimodal project on students' academic achievement regarding course-specific objectives mastery? Through observations, pretest-posttest distributions, exam comparisons and student survey responses, the teacher-researcher collected data to analyze if, and what, impact the multimodal project had on the Summer 2018 face-to-face and Fall 2018 online BI 114 participants' achievement and perceptions of such. Additional observations on six students of various backgrounds in the summer course, and five students in the fall course provided deeper insight into individual student impacts.

Purpose Statement

The purpose of the study was to determine if the multimodal course project on photosynthesis and organic molecules had an impact on students' academic achievement on course-specific SLOs, as well as perceptions of impacts on learning, interactions with content and project implementation. Course-specific student learning outcomes (SLOs) are operationally defined as major, departmentally-decided biology concepts to achieve and demonstrate proficiency to progress into future coursework at ESJC and beyond.

Overview and Summary of the Study

The initial study involved 24 students within one section of a Summer 2018 introductory biology, General Biology I (BI 114) course as they participated in a multimodal course project on photosynthesis over the course of 1-week in a 5-week summer semester. Over the course of the instructional week, students were provided opportunities to review the requirements, choose a project format and optional partner, interact with the teacher-researcher for scaffolding opportunities, and design and implement their course projects.

The teacher-researcher decided to implement a second cycle of the action research project during the Fall 2018 semester, with a group of 28 online BI 114 students. Students were placed into groups of three, to simulate a comparative laboratory environment to complete the project. Since this was an asynchronous, online environment compared to the Summer 2018 group, adjustments were made to implement the project using an interactive discussion board format (See Appendix I) to provide a space for each group's interactions and for the teacher-researcher to record student observations. Over the course of 1-week in a 16-week semester, students were able to plan, implement, interact with the teacher-researcher and submit the project via the ESJC learning platform, Canvas.

Throughout this action research study, the teacher-researcher used the project as an applicable model of the use of authentic, project-based assessment opportunities for other biology educators. In addition to answering the AR question of study, the teacher-researcher focused on the instructional techniques and reflective practices that make an effective classroom educator.

Several implications can be derived from this study:

- (1) Through the authentic and alternative aspects of the multimodal project, students' academic achievement was positively affected for the unit;
- (2) There were positive student perceptions of the project impacts on their learning, increased empowerment in their studies and self-regulation and information management techniques, and increased buy-in to the course material;
- (3) The project increased feelings of connectedness and interactivity within the online learning environment during the study period;
- (4) There remains an unclear understanding of the long-term impacts of the course project on student SLO achievement, particularly on exams.

An authentic assignment is one that requires application of what students have learned to a new situation, and demands judgment to determine what information and skills are relevant and how they should be expressed (Weimer, 2011; Stuckey, et al., 2013). The practice of these skills was evident in students' observed and reported interactions, as well as in the quality and range of their finished products. From their Likert-Scale and open-response survey inputs, students indicated that they "agreed" or "strongly agreed" that the project increased their content understanding and was effective in catering to individual learning needs via a multimodal, investigatory experience.

Students' responses and project submissions also indicated a better personal connection between theory (the material) and practice, or real-world applicability. This is in line with Dewey (1938) who posited that learning is an individualized experience impacted by how the world is navigated. Regarding the nature of science (NOS), students

practiced and exhibited what valuable transferrable knowledge skills are such as: 1) the use of a logical methodology to uncover solutions to issues, and 2) uncovering facts from hypotheses or beliefs (National Academy of Sciences, 1998). Hood (2018) posits: “While being responsible to individual students and ensuring individual students learn, we must also not lose sight of the collective, social enterprise that lies at the heart of education (but not always learning)” (p. 325).

However, there remains to be seen whether the short-term impacts of the project can translate into long-term gains and achievement in the course. The teacher-researcher observed that while students generally showed increases in pretest-posttest performance which spanned the course of a few days, there were no cumulative differences in exam score comparisons found because of the project. This was seen in other multimodal, project-based studies in the post-secondary science classroom as with Bennett (2011). There are also additional confounding factors to consider, that are external to the teacher-researcher’s focus of study such as the range of chapters covered on an exam that can mitigate unit impacts.

Overall, the multimodal course project provided positive interaction and engagement opportunities for the BI 114 students based on teacher-researcher observations, student feedback, and pretest-posttest scores. This is especially true considering online student/group responses within an asynchronous, technology-driven environment. “Digital technology is frequently positioned as being central to the establishment of a ‘future focused’ education system that provides high quality student-focused learning opportunities and re-envisioned educational outcomes” (Hood, 2018).

Transforming student perspectives of learning biology and experiences within the classroom corresponds to the transformative learning environments championed by constructivist and progressivist education.

New literacies, as with digital technologies are also deictic in nature, or dependent upon the context used (Leu, 2017). The re-imagining of any aspects of education or learning must be situated within the broader social contexts of their operation. Educators must consider the underlying reasons for this re-imagining, question what is being done and why, and how the reimagining will contribute to improvements in practice and to improved opportunities and outcomes for all learners. The digital aspects involved with the multimodal course project included: 1) World Wide Web navigation, research and evaluation, 2) digital presentation creation and organization using tools such as PowerPoint or Prezi, and 3) the use of online collaboration platforms in Canvas. Students not only gained empowerment in learning material and meeting course outcomes but also practiced multimodal, transferrable digital literacy skills in an increasingly technological age. “The ability to regulate learning behaviors and to adopt strategies and dispositions to facilitate this are critical to learning” (Hood, 2018, p. 324). Digital technologies have the potential to broaden teaching and learning to create greater connections to the ‘real world’ and contexts beyond the physical school environment.

With this study being influenced by the teacher-researcher’s experiences regarding the challenges students find in post-secondary introductory biology courses, it was rewarding to see positive learning gains and hands-on, creative expression from the participants. Students found unique and high-quality methods of organizing, expressing, and presenting complex topics. Students also expressed feelings of empowerment and

from conducting their own research in the process and increased engagement, indicating that they were not merely empty vessels to be filled with content, but were active participants in their learning. Therefore, it is the teacher-researcher's belief that the multimodal course project can and should confer positive benefits in the biology classroom, with the hope of further impacting students' post-secondary educational journeys.

Suggestions for Future Research

The teacher-researcher noted two areas that could lead to further research regarding multimodal projects and course-specific SLO achievement in introductory biology:

- 1) Exploring additional connections between the alternative form of assessment used in the classroom and methods by which SLO achievement is assessed (ex: question types used on pretest-posttests and exams), and
- 2) Expanding group interactions and engagement opportunities within the online, asynchronous learning environment.

Hood's (2018) research on massive online open (source) courses or MOOCs have shown that two key factors can work to undermine a focus on the student as determiner of their learning. The first is that while MOOCs theoretically allow learners to shape their own learning via self-pacing formats for example, success still tends to be measured according to traditional outcome measures and metrics. Retention rates, completion and exam scores are still used as the key determinants of learning and quality.

“Despite a high proportion of MOOC participants stating that they do so for personal enjoyment and interest, rather than to complete a course, the measures of success continue to be driven by traditional outcomes” (Hood, 2018, p. 323).

While biology leads the hard sciences in using an assortment of assessment types to ascertain content knowledge and achievement (Goubeaud, 2009), exploring alternative means of expressing content knowledge gained from the multimodal project may be beneficial in more accurately assessing individual success and transferability of the skills and knowledge gained. An emphasis on a narrow set of outcomes restricts the ability to have a truly responsive education system which meets the needs of all learners while also addressing the changing and challenging contexts in which we live. “We want to ensure we do not create what Biesta (2009) termed ‘normative validity’; that is “whether we are indeed measuring what we value, or whether we are just measuring what we can easily measure and thus end up valuing what we [can] measure” (Hood, 2018, p. 35).

Broadening of education outcomes can support the development of an education system in which every child can succeed and there are high expectations for all students.

Rapidly developing technology has facilitated distance education in all disciplines, and it has proven to be popular among students for various reasons, such as convenience and equal opportunity. “However, many students and researchers comment that distance learning courses lack interaction” (McBrien, Jones, & Cheng, 2009, p. 1). During the week of implementation within the online BI 114 course, the teacher-researcher observed via e-mail and discussion posts that while many students expressed positive perceptions of classmate interactions, some groups found difficulty with interacting with other members to effectively plan and complete the multimodal

assessment project. According to the theory of transactional distance established by Michael Moore, “the sense of distance a learner feels during the learning process transcends geography and is concerned with student interaction and engagement in the learning experience” (McBrien, Jones, & Cheng, 2009, p. 3). The teacher-researcher hopes to explore additional means of not only encouraging student interaction and buy-in with assignments, but also increasing student interactions to formulate the sense of an online community of learners.

Action Plan

The results of this action research study showed that the implementation of a multimodal course project in an introductory biology course at a community college had a positive impact on content knowledge and course experiences. With the focal point of this study being learning and improvement, it was fitting that the teacher-researcher develop an action research plan in order to continue a process of learning and improvement.

According to Mertler (2014), action planning is an extremely appropriate time for professional reflection and moving forward. Using Mertler’s (2014) approach to action planning, the teacher-researcher has devised an action plan for continued and future research, not only in the teacher-researcher’s classroom, but throughout the biology department. The on-going plan consists of continued reflection while following these phases (see Figure 5.1):

- (1) Sharing the findings of the study with colleagues.
- (2) Conducting additional research through implementing the multimodal project within additional BI 114 courses and others.

(3) Identifying future collaborative research opportunities throughout the biology department with colleagues.

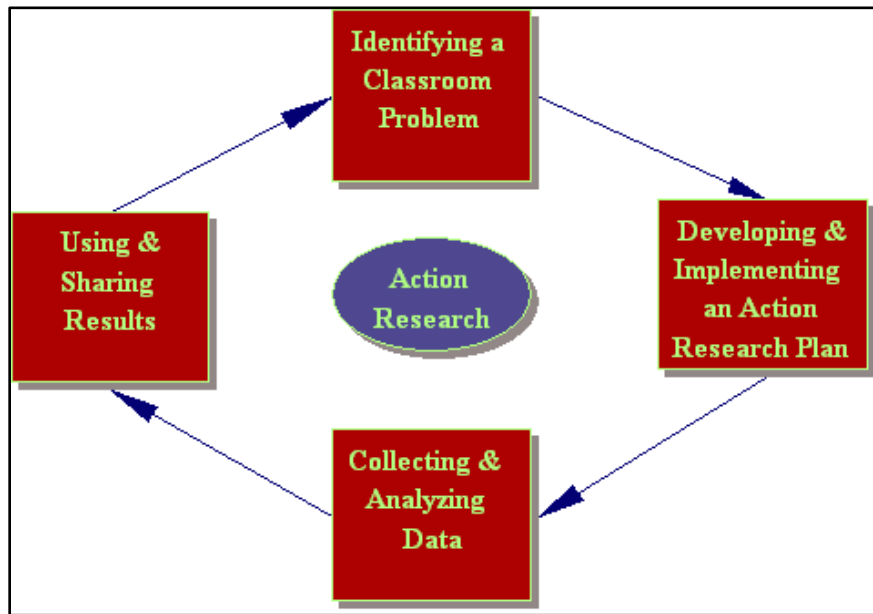


Figure 5.1: Cyclic Action Research plan

In order to continue the study and implementation of reflective practices in biology courses at ESJC, the teacher-researcher plans to first share the findings of the current study. Through a presentation for colleagues and the Dean of Arts, Sciences and Learning Support for the next Spring semester during the first faculty meeting, the teacher-researcher will outline the purpose of the study, its process, and the findings. The teacher-researcher also plans to organize and share data received from the participants. Handouts for faculty members will be provided and will include graphic representations along with narratives of the findings. The teacher-researcher plans to request that the faculty share any suggestions they may have in terms of implementing project-based or alternative assessments within the program's curriculum in a cohesive manner. Collaboration with faculty is a key component for the teacher-researcher to interpret and address new ideas and strategies which could improve the implementation of reflective

practices within the biology courses (Mertler, 2014). Frequent interactions among colleagues is another piece of being a reflective practitioner, one of the teacher-researcher's roles.

The second phase of the action research plan is to conduct another study using a larger group of students that may have differing lecture and lab professors. During the Fall and Spring semesters at ESJC, the face-to-face lecture BI 114 courses contain up to 65 students each, with the same or separate professor for lab depending on registration. The teacher-researcher wants to collaborate with other biology instructors to be able to effectively implement the study within this team-teaching lecture/lab environment, so that a greater number of students can be reached. Additional studies could also focus on the projects' impacts on ESL student achievement more particularly.

It is the teacher-researcher's belief that this form of action research study will provide additional evidence to whether the multimodal project has an explicit impact on course-specific SLO mastery at-large, especially as it pertains to our most prevalent student body for the course. Another avenue of study would be to compare achievement, engagement, etc. between a face-to-face treatment group and non-treatment (control) group *during* the implementation period (as opposed to exam scores afterwards). In doing so, the teacher-researcher may be able to better answer the research question: What is the impact of implementing a multimodal project on students' academic achievement regarding course-specific objectives mastery? Again, the findings of these studies will be shared with colleagues as part of the cyclic action research process to gain additional perspectives and to strengthen the collaborative efforts among the teacher educators in the department.

The third phase of the action plan heavily involves the teacher-researcher's colleagues. The goal is to plan and conduct additional research on multimodal project-based learning throughout the biology department, not only in the teacher-researcher's BI 114 course. Possible research questions for the future studies include: (a) What are the impacts of the multimodal project in higher-level coursework within the biology department?, (b) How could a multimodal assessment project impact biology majors (versus non-majors) at ESJC? and (c) Are teacher educators effectively assessing the impacts of the multimodal project among their students throughout the biology department, and what are their findings?

The first two questions derived from teacher-researcher reflections after the first two trials of the study were conducted. Many of the BI 114 students plan to major in nursing or a related health-science field, which requires additional 200-level anatomy and physiology coursework. Considering, potentially adopting similar multimodal project within the higher-level biology courses may provide additional alternative/authentic learning opportunities as well as increasing continuity in skills such as independent research and self-regulation gained from prior coursework. Also, as the vast majority of BI 114 (and BI 124) students are non-science majors, the teacher-researcher became interested in how the project could be expanded and adapted to meet the needs of science majors within the BI 134- Biology I for Majors or BI 144- Biology II for Majors course. As the BI 134 and BI 144 lectures and labs are formatted similarly to the non-majors except for greater detail, the teacher-researcher believes that the multimodal project can also positively impact this student dynamic.

The third research question came from one of the two suggestions for future research. During the initial trials within the AR study, the teacher-researcher noted through reflections and conversations with other teacher educators within the USC EdD-C&I program that a more authentic means of ascertaining content mastery using the student projects was needed. Whereas the multiple-choice pretest-posttest data provided convenient, quantitative insight into SLO gains over the course of the project, the teacher-researcher also hopes to implement an additional aspect to the study where the students can present (or “teach”) their work to the class, thus demonstrating their content knowledge more authentically. Regarding oral presentations, Falchicov (2005) posits:

[In oral presentations] students, working alone or in small groups, typically research a topic and present their work to their peers. Several overviews of alternative or new assessments refer to oral presentations as a widely used vehicle in classrooms to evaluate content knowledge. (Falchicov, 2005, p. 16)

The teacher-researcher also hopes to work with colleagues in this process of researching and creating a more refined and authentic instrument to accurately assess whether content-specific achievement has been reached from the project. If positive impacts are ascertained from these changes, other teacher-educators could use the study and instrument as a model within their programs to strengthen content achievement among their students.

“Changing social structures and evolving social issues are placing new demands on school systems. There is an increasing number of learners with unique learning needs, and an increasing demand for personalized learning opportunities” (Hood, 2018, p. 322). The teacher-researcher has created this action plan with the assumption that it will be a

cyclical process. This plan will be consistently explored, examined, and reassessed so that the teacher-researcher regularly reflects on its effectiveness (Mertler, 2014). While the plan is initially geared towards the individual teacher-researcher, the ultimate goal is to expand it to the biology department with collaborative efforts with colleagues.

Conclusion

This study examined the impact of the implementation of a multimodal, project-based assignment within an introductory biology course at a local community college. Authentic and alternative assessments such as with project-based learning have continued to be a topic among educational institutions and student-centered reforms. However, understanding the student impacts of these forms of assessment, particularly involving multimodality within a post-secondary science environment is still an area of growing research. There are noted benefits of multimodal, project-based assessment which have been discussed throughout this AR study, but identifying a means of effectively implementing and evaluating this form of activity among large groups of students or within a distance-education environment remain factors to consider for practicality and improvement. However, as found throughout the study, a project-based learning opportunity not only increased content knowledge for a topic, but also increased 21st century skill acquisition, student engagement, and interpersonal interactions within a subject often perceived as being overwhelming and complex. With continued fostering of research on the impacts of multimodal, project-based activities within the BI 114 course and biology department, it is possible to ascertain its effects not only on student learning but on the professional growth of the instructors as well.

As educators generally consider themselves to be lifelong learners, this knowledge would be a welcome addition to what is already present and could change the future of ESJC.

There were several implications discussed in this chapter that should be considered among educators and others who want to infuse authentic and alternative learning opportunities into the post-secondary science classroom. The assessment of students is an activity central to the role of any professional in higher education and is an area that is the subject of constant innovation and debate (Falchicov, 2005). The cultivation of student-centered educational practices should continue and expand in order to better understand the positive impacts and opportunities it provides for student and teacher growth, which contributes to society-at-large.

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APPENDIX A

CYCLE ONE: PRETEST-POSTTEST QUESTIONS

Directions: Choose the one response that best completes the statement or answers each question. Record answers on your Scantron.

1. The ultimate source of energy for living things comes from the _____.
 - A) Carbohydrates
 - B) Oxygen
 - C) Carbon dioxide
 - D) Sun
2. Which organism makes direct use of this ultimate source of energy?
 - A) Cats
 - B) Producers
 - C) Consumers
 - D) None of the above. It is not possible.
3. The producers provide _____ to the consumers, and consumers provide _____ to the producers.
 - A) Carbon dioxide and carbohydrates; oxygen and sunlight
 - B) Oxygen and carbohydrates; carbon dioxide and water
 - C) Oxygen and water; carbon dioxide and carbohydrates
 - D) Carbon dioxide and water; oxygen and carbohydrates
4. Carbohydrates and oxygen are the _____ in photosynthesis, whereas light energy, water, and carbon dioxide are _____.
 - A) Reactants; products
 - B) Reactants; more reactants
 - C) Products; reactants
 - D) Products; more products

5. Membrane-enclosed organelle in algae and plants with chlorophyll-containing membranous thylakoids; where photosynthesis takes place. _____
- A) Light energy
 - B) Reflection
 - C) Chloroplast
 - D) Absorption
 - E) Photosynthetic pigments
6. What is the reason that plants are green in color (primarily)?
- A) Photosynthetic pigments absorb green wavelengths and reflects red-blue wavelengths.
 - B) Photosynthetic pigments absorb red-blue wavelengths and reflects green wavelengths.
 - C) Solar energy gets changed into red-blue energy, leaving green in the chloroplast and showing.
 - D) Our eyes can only see the green color of the plant, although plants primarily show every color.
7. Why is the first stage known as the Light Dependent reactions?
- A) It is not dependent on input of solar energy at his point.
 - B) It does not weigh much, so it is considered to be light dependent.
 - C) It is dependent on the input of solar energy at this point.
 - D) The Light Dependent reactions is the second stage of photosynthesis.
8. What is the significance of the outputs of the Light Dependent reactions?
- A) Carbohydrates produced will power the plant and other living things.
 - B) The ATP and NADPH produced will power the Light Independent reactions.
 - C) The CO₂ and ATP produced will power the rest of the plant cell's needs.
 - D) The water and CO₂ produced will be recycled by the plant so that it can live in the desert.
9. What is the significance of the outputs of the Light Independent reactions?
- A) Carbohydrates produced will power the plant and other living things.
 - B) The ATP and NADPH produced will power the Light Independent reactions.
 - C) The CO₂ and ATP produced will power the rest of the plant cell's needs.
 - D) The water and CO₂ produced will be recycled by the plant so that it can live in the desert.
10. During photosynthesis, _____ is oxidized, and _____ is reduced.
- A) Water; carbon dioxide
 - B) Oxygen; water
 - C) Carbohydrates; water
 - D) Solar energy; oxygen

APPENDIX B

CYCLE ONE: MULTIMODAL PROJECT DESIGN

Project Overview:

In class, we have been discussing various aspects of photosynthesis. Based on what was presented and/or learned, you will create an individual (or two-person) course project to address major concepts pertaining to the process of photosynthesis.

Project Expectations:

- You will be required to answer specific topic outcomes for this assignment, regardless of your presentation style. You will be graded on project organization, timeliness, and addressing the specified outcomes clearly.
- You have a *choice* in how you complete the project. For example, you could complete a poster board with text and visuals, or make a video recording.
- You can use the Photosynthesis module (in Unit Two of Canvas) *as a guide when completing* your project.
- You will be responsible for any materials pertaining to your project. Do not plagiarize!
- Your project is due at the end of lab on Wednesday, June 6th. Late projects will be deducted points.

Learning outcomes (topic questions) to address in your project:

- What is the purpose of photosynthesis? Relate this to producers and consumers.
- Express the chemical formula for photosynthesis. What are the inputs/outputs?
- What is a chloroplast? What does it do? (Think about light waves, energy, etc.)
- Explain the Light Dependent and Light Independent (Calvin Cycle) reactions.
 - What is the importance of each?
 - What are major highlights of each process?

Below are some suggested strategies to combine for completing the assignment/project (Fleming, 2016). Remember, this should combine various means of presenting material, for a multimodal (varied) effect:

<p>Visual:</p> <ul style="list-style-type: none">• Draw things, use diagrams. For example: a comic or PowerPoint presentation• Use colors to express information.• Use a program like Google Sites or WikiSpaces to create a web page.
<p>Aural:</p> <ul style="list-style-type: none">• Imagine talking with someone. You could create a play, for instance.• Use videos (such as on YouTube). They also have an aural (hearing) component.• Speak information aloud. For example: Create/record a song.
<p>Read/Write:</p> <ul style="list-style-type: none">• Create your own test or study guide (with an answer sheet).• Write paragraphs, beginnings and endings. For example: a story• Arrange your words into hierarchies and points. For example: flow charts/diagrams
<p>Kinesthetic:</p> <ul style="list-style-type: none">• Create and write assignment answers, paragraphs.• Create/design/implement your own laboratory experiment.• Act out a play that you created (don't forget to record)• Use plenty of examples. Use case studies and real-world applications to help with principles and abstract concepts. For example: A physical model or diorama
<p>Multimodal:</p> <p>A multimodal project consists of various combinations of the four styles above. More than one strategy (for instance both pictures <i>and</i> text) should be used to guide your project.</p>

Analytic Rubric for Multimodal Project

Student Name: _____

Course Section: _____

Criteria	Proficiency Level (Points)			Weight	Score (Points)
	0	3	5		
Project creative/student effort provided	No attempt provided	Little creativity/student effort	Clear student creativity/effort	1	
Project based on multimodal (varied) nature in presentation	No attempt provided	Project design based on other method	Project design based on multimodal style	1	
Student learning outcomes addressed in project	No attempt provided	Incomplete or inaccurate information	Completely and accurately described	2	
Project is organized	No attempt provided	Material is not organized and/or legible	Material is organized and legible	1	
Project submitted on time	Not submitted	Late project submission	Timely submission	1	

Total points earned= _____ /30 pts

APPENDIX C

STUDENT SURVEY FORMAT

****Your informed consent to participate in this study under the conditions described is assumed by your completing the survey and submitting it to the professor. Do not complete or submit the survey if you do not understand or agree to these conditions.****

PART I Directions: For each of the statements below, choose the response that best describes your attitudes or perceptions about the topic according to the following scale:

- | 1 | 2 | 3 | 4 | 5 | |
|---|-------|-----------|----------|-------------------|---|
| Strongly agree | Agree | Undecided | Disagree | Strongly Disagree | |
| 1. I believe that the multimodal project increased my understanding of photosynthesis/organic molecules and its processes. | 1 | 2 | 3 | 4 | 5 |
| 2. The multimodal project helped me understand my individual learning needs more. | 1 | 2 | 3 | 4 | 5 |
| 3. The (photosynthesis/organic molecule) content objectives of the multimodal project were reasonable to complete. | 1 | 2 | 3 | 4 | 5 |
| 4. There was enough time allotted to complete the project. | 1 | 2 | 3 | 4 | 5 |
| 5. I plan to apply my multimodal project skills to additional topics or subjects. | 1 | 2 | 3 | 4 | 5 |
| 6. I believe that the photosynthesis/organic molecule project assigned to me was effective in delivering information in different ways. | 1 | 2 | 3 | 4 | 5 |
| 7. I understood the project instructions. | 1 | 2 | 3 | 4 | 5 |

PART II Directions: For each of the questions below, provide a *written response* in the space provided. Be specific.

8. What were positive aspects of the multimodal course project?

9. What were aspects of the project that could be improved?

10. How did the project assist in your understanding of your personal learning needs and methods for learning material?

APPENDIX D

CYCLE ONE: EXAM 2 ANALYSIS QUESTIONS

- 1) Solar radiation emitted from the sun travels in

Neutrons
Different wavelengths
Solars
Pulsars

Course- Specific SLO: State the function of chloroplasts.

- 2) Which of the following wavelengths of light is absorbed least (and therefore reflected) by plants?

Red
Green
Blue
Black

Course-Specific SLO: State the function of chloroplasts.

- 3) Which of the following is INCORRECT concerning chloroplasts?

They are surrounded by a double membrane.
Photosynthetic pigments are located in the thylakoids.
Chlorophyll pigments are concentrated in the stroma of the chloroplast.
They contain their own source of DNA and proteins.
It is the site where photosynthesis occurs.

Course-Specific SLO: Draw a chloroplast and labels its structures. State the function of chloroplasts.

- 4) ___?___ is considered the end product of the Calvin Cycle and can be converted into a variety of organic molecules such as glucose, sucrose, starch, and cellulose.

PG
RuBP
G3P
BPG
PEP

Course-Specific SLO: Briefly explain the three stages of the Calvin cycle.

5) The light dependent reactions of photosynthesis occur in the ___ of the ___.

- thylakoids; chloroplast
- matrix; chloroplast
- stroma; mitochondria
- matrix; mitochondria
- stroma; chloroplast

Course-Specific SLO: Compare and contrast the light-dependent and Calvin cycle reactions that are associated with photosynthesis.

6) Which of these equations is the simplified equation for photosynthesis?

- a. $C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + \text{solar energy}$
- b. $C_6H_{12}O_6 + CO_2 \rightarrow O_2 + H_2O + \text{solar energy}$
- c. $CO_2 + H_2O + \text{solar energy} \rightarrow C_6H_{12}O_6 + O_2$
- d. $O_2 + H_2O + \text{solar energy} \rightarrow C_6H_{12}O_6 + CO_2$

Course-Specific SLO: Write the chemical formula for photosynthesis.

7) In most plants (known as C3 plants), carbon dioxide is chemically bonded to a _____ molecule during the first phase of the Calvin Cycle.

- RuBP
- G3P
- PG
- Glucose

Course-Specific SLO: Briefly explain the three stages of the Calvin cycle.

8) Which is NOT generated during the first stage of photosynthesis?

- G3P
- NADPH
- Oxygen
- ATP

Course-Specific SLO: Compare and contrast the light-dependent and Calvin cycle reactions that are associated with photosynthesis.

9) Which organism is INCAPABLE of undergoing the process of "photosynthesis"?

- Cyanobacteria
- Mosquitos
- Algae
- Plants

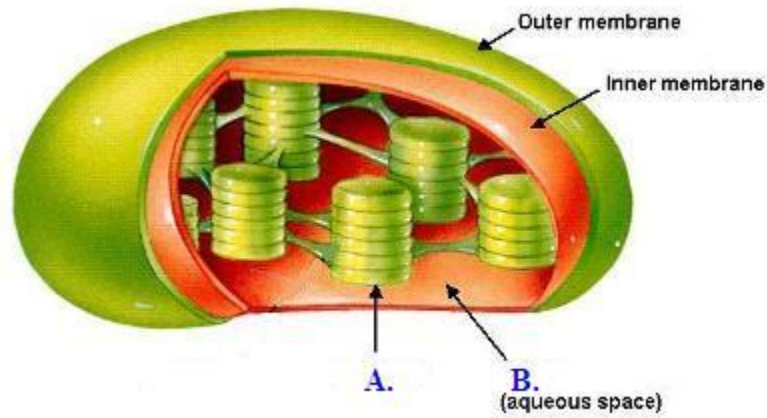
Course-Specific SLO: State examples of organisms capable of this process.

10) Denote whether the following is associated with the first or second stage of photosynthesis.

- A) Light dependent
- B) Carbon dioxide gas is taken up and assembled into a carbohydrate molecule.
- C) Uses the ATP & NADPH generated by the light-dependent reaction.
- D) Calvin cycle reactions
- E) Oxygen is produced as a result of water being split.
- F) Associated with the photosystems found on chloroplasts' thylakoids.

Course-Specific SLO: Compare and contrast the light-dependent and Calvin cycle reactions that are associated with photosynthesis.

11) Identify the parts of a chloroplast denoted on the diagram.



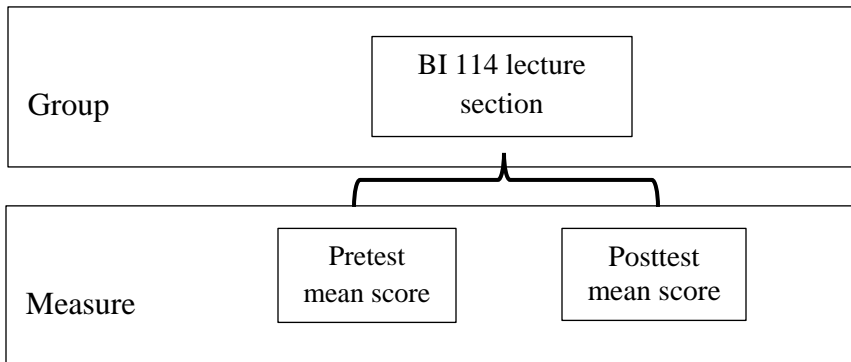
- A) Thylakoid membranes
- B) Stroma

Course-Specific SLO: Draw a chloroplast and labels its structures.

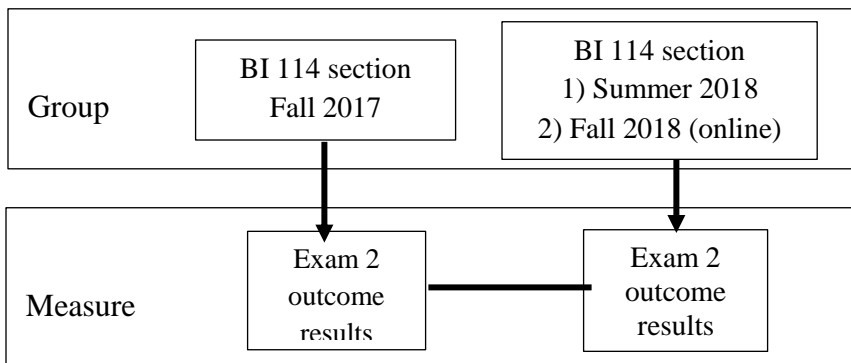
APPENDIX E

GROUP ACHIEVEMENT STATISTICAL ANALYSES

Repeated-measures t-test:



Independent-measures t-test:



APPENDIX F

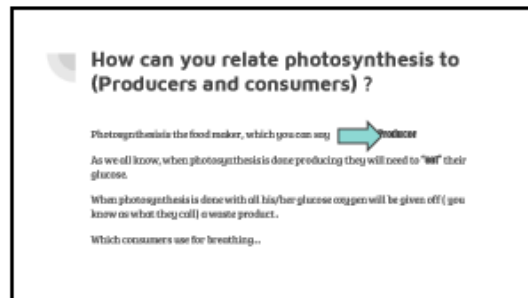
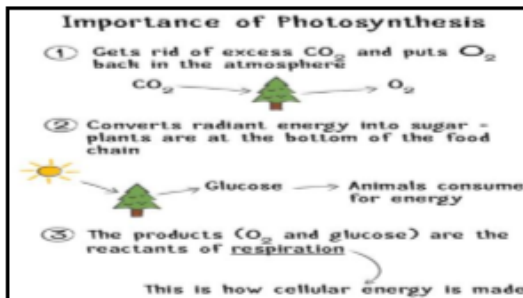
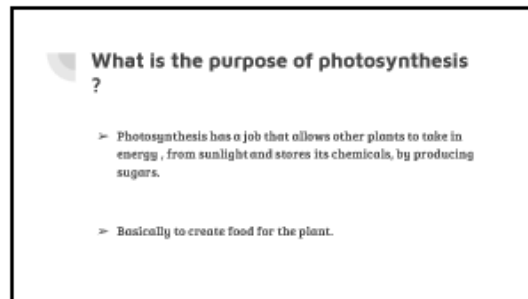
CYCLE ONE: FACE-TO-FACE OBSERVATION NOTES

Date: _____ Time: _____	Student Behaviors Observed *list any student behaviors that may affect project implementation*	Student Questions Asked, Responses Received, etc.	Observer's Comments (OC) *Use the column for any "preliminary interpretations of what has been observed" (as cited in Mertler, 2014, p. 128)

APPENDIX G

STUDENT PROJECT POWERPOINT EXAMPLES

Cycle 1) Photosynthesis PowerPoint project submitted by Rhonda.




Express the chemical formula for photosynthesis . . What are the inputs/outputs ?

- The chemical equation for photosynthesis involves the input of carbon dioxide, water, and sunlight to produce the outputs of glucose and oxygen

Stages of Photosynthesis

- Stage 1: The light reactions**
 - Inputs: H_2O , ADP, $NADP^+$
 - Outputs: O_2 , ATP, NADPH
 - Site: Thylakoids
- Stage 2: The Calvin Cycle**
 - Inputs: CO_2 , ATP, NADPH
 - Outputs: G3P, ADP, $NADP^+$
 - Site: Stroma

What is a Chloroplast ?

Chloroplast are  Organelles

Which can be found in plants or algae cells where photosynthesis occurs .

7/6/2

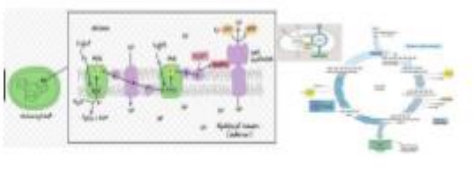
What does chloroplast do ?

- Chloroplast has a job to convert light energy of the sun into sugars that can be used by cells.

Explain the Light Dependent & Light Independent (Calvin Cycle) reactions..

- Light-dependent is reactions of photosynthesis. Light energy is initially converted into chemical energy as ATP and NADPH.
- Light-independent is chemical reactions , that convert carbon dioxide and other things into glucose.

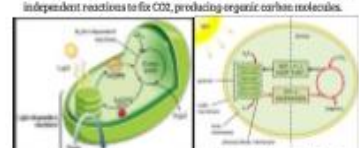
Light Dependent & Light-independent



The diagram illustrates the two main stages of photosynthesis. On the left, the light-dependent reactions occur in the thylakoid membranes, where light energy is used to split water and produce oxygen, ATP, and NADPH. On the right, the Calvin cycle (light-independent reactions) takes place in the stroma, where carbon dioxide is fixed into glucose using the ATP and NADPH produced in the light-dependent reactions.

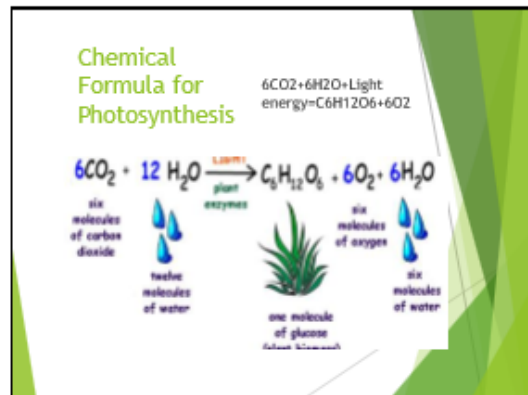
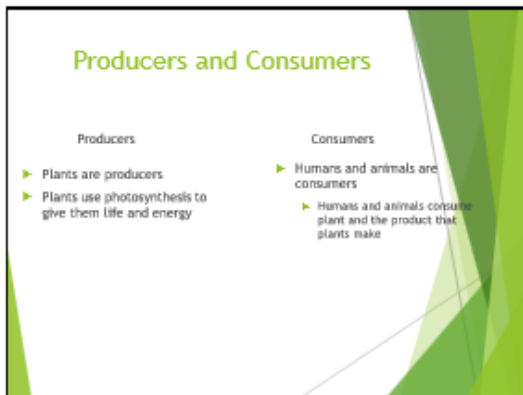
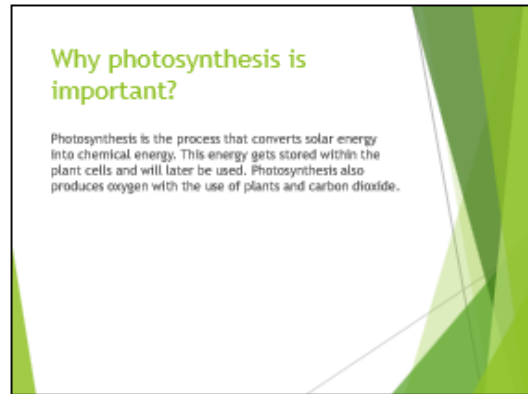
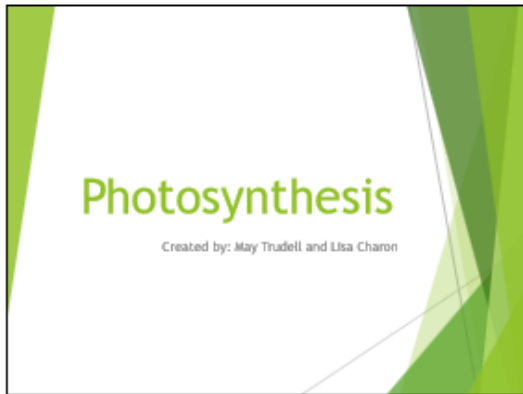
The importance of each & major highlights . .

- The light-dependent reactions of photosynthesis convert light energy into chemical energy, forming ATP and NADPH. These products are used by the light-independent reactions to fix CO_2 , producing organic carbon molecules.



This diagram shows a chloroplast with the light-dependent reactions occurring in the thylakoid stacks and the Calvin cycle occurring in the stroma. It highlights the flow of energy and matter between the two stages.

Cycle 1) Photosynthesis PowerPoint Project submitted by Lisa and May.



Input and Output

<p>Input</p> <ul style="list-style-type: none"> ▶ Water ▶ Carbon dioxide ▶ Photon energy 	<p>Output</p> <ul style="list-style-type: none"> ▶ Oxygen ▶ Glucose
--	--

What is Chloroplast and what it does.

- ▶ Chloroplast is plastid
- ▶ Contains chlorophyll
- ▶ Is in plant cell
- ▶ Photosynthesis takes place in chloroplast
- ▶ Happens in a plant cell
- ▶ Converts Sun energy into sugar for cells

7/29,

Dependent and Independent Light

<p>Light Dependent</p> <ul style="list-style-type: none"> ▶ Light energy is used to make two molecules ▶ Needed for photosynthesis ▶ Reaction takes place in thylakoid 	<p>Light Independent</p> <ul style="list-style-type: none"> ▶ Converts Carbon Dioxide into glucose ▶ Reaction takes place in chloroplast outside the thylakoid
--	---

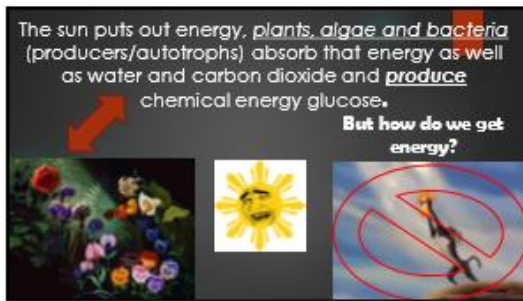
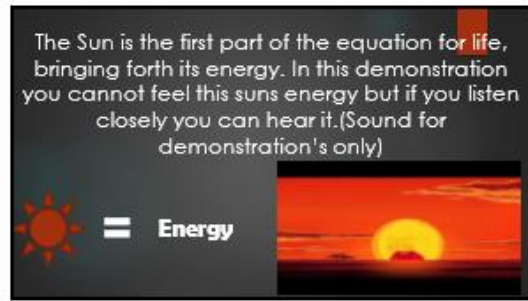
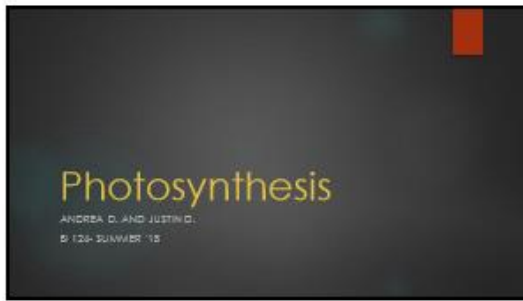
Major Highlights

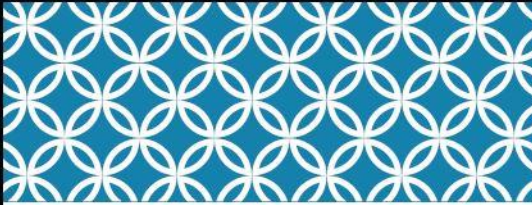
<p>Light Independent</p> <ul style="list-style-type: none"> ▶ Known as Calvin Cycle ▶ Is located in the Stroma of Chloroplast ▶ Reaction is Carbon Dioxide +ATP + NADPH ▶ Produces Glucose 	<p>Light Dependent</p> <ul style="list-style-type: none"> ▶ Known as Hill Reaction ▶ Is located in Thylakoid membrane of chloroplast ▶ Reaction is Sunlight +Water ▶ Produces ATP+ NADPH + Oxygen
---	--

Importance

<p>Light Independent</p> <ul style="list-style-type: none"> ▶ Turns Carbon into sugar ▶ Produces organic molecules from Carbon dioxide ▶ Does not require light to proceed 	<p>Light Dependent</p> <ul style="list-style-type: none"> ▶ Light energy is converted into chemical energy ▶ Makes two molecules ▶ Helps with photosynthesis ▶ Reaction helps make sugar ▶ Requires light to proceed
--	--

Cycle 1) Photosynthesis PowerPoint Project submitted by Andrea and Justin.





ORGANIC MOLECULES

Alexia Powell
Charity Hensmans

DEHYDRATION SYNTHESIS

- It is known as Zimmmer's hydrogenasis.
- Refers to the formation of larger molecules from smaller reactants accompanied by the loss of water molecule.
- Dehydration reaction is a chemical reaction between two compounds where one of the products is water.

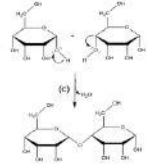
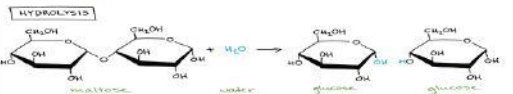


Figure A

HYDROLYSIS REACTIONS

- is the reaction involving the breaking of a bond in a molecule using water.
- is the breakdown of polymers into monomers by using a water molecule and an enzyme.
- This type of reaction usually changes the pH.
- There are three main types: salt hydrolysis, acid hydrolysis, and base hydrolysis.

Figure B



MONOMERS

- Monomers are small molecules which may be joined together in a repeating fashion to form more complex molecules called polymers. Monomers form polymers by forming chemical bonds through a process called polymerization.
- The purpose of a monomer is multifunctionality. Multifunctionality is the ability of having multiple functional groups in the same compound. Meaning it contains more than one function.

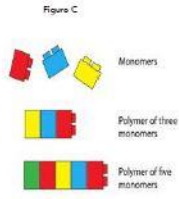


Figure C

POLYMERS

❖ Polymers, which means "many monomers", are also called macromolecules.

❖ They are known as the largest biomolecules because they are constructed by linking together the same type of subunit.

❖ "Polymers affect every day of our life. These materials have so many varied characteristics and applications that their usefulness can only be measured by our imagination. Polymers are the materials of past, present and future generations."

❖ Example of polymers in nature: spider silk and hair are protein polymers.

❖ Instead of getting polymer and monomers confused think of them like you plan on making a delicious cake. The polymer is the final product of the cake itself. The monomer is all the ingredients you need to make the cake complete.

❖ Polymers depend on monomers functionality to create bonds.

9/18/

FOUR MAJOR MACROMOLECULE GROUP

❖ Carbohydrates

❖ Proteins

❖ Lipids

❖ Nucleic Acids

Figure D

CARBOHYDRATES

❖ Are made up of monosaccharides which are simple sugars, like glucose. Special enzymes bind those polymers together creating larger sugar polymers or polysaccharides.

❖ They come in simple structures like sugars or complex structures like starches or fiber.

❖ There are 4 types of Carbohydrates:

- ❖ Monosaccharides, with one sugar molecule, are glucose, fructose, and galactose.
- ❖ Disaccharides, with two sugar molecules are sucrose, lactose, and maltose.
- ❖ Oligosaccharides, with 2-10 sugar molecules, are raffinose and stachyose.
- ❖ Polysaccharides, with 10 or more sugar molecules, are starches, glycogen, and cellulose.

Figure E

Types of Carbohydrate

- Monosaccharides
- Disaccharides
- Polysaccharides

EXAMPLES OF CARBOHYDRATES

COMPLEX CARBS

- Complex carbohydrates: apples, apricots, bananas, broccoli, carrots, cucumbers, soybeans, yams, zucchini, strawberries, pears, peaches, oranges, lettuce, kiwi, cherries, blueberries, artichokes, and grapefruit.

SIMPLE CARBS

- Simple carbohydrates: cake, candy, cookies, fruit juices, jellies, fudge, honey whole milk, and table sugars.




Figure F

LIPIDS

- A fat like molecule, they are a major building block of the cells of animals.
- They are organic meaning they contain carbon atoms.
- Hydrophobic, meaning they don't dissolve in water.
- Lipids include fats, oils, and hormones.
- Lipids can be categorized into 3 main types:
 - Triglycerides
 - Steroids
 - Phospholipids

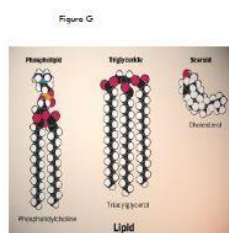


Figure G

EXAMPLES OF LIPID

- Triglycerides supply your body with insulation to keep you warm. They give internal organs a layer of cushioning for protection.
- Steroids are hormones and they include estrogen, testosterone, adrenaline, cortisol, and progesterone.
- Phospholipids vary on a molecular level. They are different because half of it can dissolve in water while the other can not.

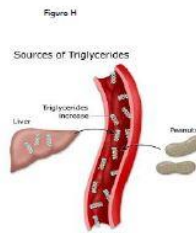


Figure H

PROTEINS

- Proteins are polymers of amino acids. They are basic building blocks of life. They are vital to every organism on earth.
- They are categorized into 3 types:
 - Fibrous
 - Globular
 - Membrane

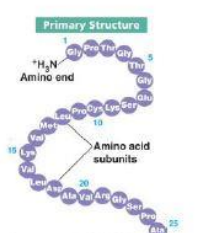


Figure I

EXAMPLES OF PROTEINS

- Fibrous proteins create muscle fibers, tendons, connective tissues, and bones.
- Examples are collagen, keratin, and elastin.
- Globular proteins assist in transportation, catalyzation, and regulation.
- Examples are hemoglobin, fibrin, and thrombin.
- Membrane proteins relay signals between cells and transport molecules.
- Examples are estrogen receptors, histone, and rhodopsin.

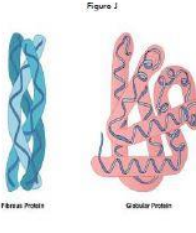


Figure J

NUCLEIC ACIDS

Structure of DNA & RNA

- Deoxyribonucleic Acid (DNA) and ribonucleic acid (RNA) are 2 types of nucleic acids. They are a polymer of nucleotides.
- There are five nucleotides:
 - Uracil, thymine, adenine, cytosine, and guanine
- Nucleotides are composed of three types of molecules:
 - A phosphate, a pentose sugar, and a nitrogen containing base.
- DNA carries the genetic instructions in the form of a double helix.
- RNA, in its 3 types, copies DNA and moves amino acids to be assembled at the ribosomes.

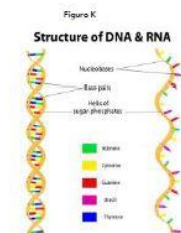


Figure K

WHY ARE THEY IMPORTANT?

- Carbohydrates:**
 - They are essential for energy. Your body uses food to store energy and build muscle tissue. Carbohydrates also assist your coordination by supplying your brain with fuel. (sugars)
- Lipids:**
 - They are necessary to all life on earth. The most vital purpose is being a building block in cellular membranes. They also store energy, insulate, and protect.
- Proteins:**
 - They play major roles in movement, structural support, storage, communication, digestion, and transportation. They are also an important building block in cartilage, bones, flexes, skin, and blood.
- Nucleic Acids:**
 - They contain the genetic information of all living things. DNA houses the instructions and RNA copies them. Without these functions life would not be sustainable.

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- ❖ diabeticsnet.net Figure H
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- ❖ <http://fb.bioninja.com.au/standard-level/topic-2-molecular-biology/24-proteins/fibrous-vs-globular-protein.html> Figure J
- ❖ <https://www.news-medical.net/life-sciences/-Types-of-RNA-mRNA-rRNA-and-tRNA.aspx> Figure K

Cycle 2) Photosynthesis PowerPoint project submitted by Nala's group.

ORGANIC MOLECULES PROJECT
 H. GUTIERREZ, S. CARDONA-ANGEL, A. JAMES

HYDROLYSIS **DEHYDRATION SYNTHESIS**

- First of all Hydrolysis is a Greek word that means water and separation. This process is the main way to break the split of the bond H₂O to H₂O
- Hydrolysis occurs when you add water and it breaks or destroys two molecules
- It's the opposite of dehydration

DEHYDRATION SYNTHESIS

- Dehydration means to take water out and synthesis means to build something
- Dehydration is the process of bonding two molecules and taking away water
- It's the opposite of Hydrolysis

Hydrolysis **Dehydration Synthesis**

structures and functions of each major macromolecule group

	Structure	Functions
Proteins		They are built by amino acid
carbohydrates		They are built by monosaccharide (glucose and other sugars)
Lipids		They are built by fatty acids and glycerol
Nucleotides		They are built by nucleotides

Enzymes: speed up rates, transport, structure, Hair, nails, skin, Hormones: send messages thru body

This is a long term energy storage

Storing genetic information and protein synthesis

Four major organic molecules groups are:

- I. Carbohydrates
- II. Lipids
- III. Proteins
- IV. Nucleic acids

Each of them are particularly important to different functions in our bodies.

Carbohydrates

Carbohydrates are found in fruits, vegetables, pasta, breads and dairy products. They are important because they produce glucose. Glucose is the main source of our body's energy. It can either be used immediately or stored for later use.

Lipids

Lipids are important to have. They are known as fat. They are hydrophobic, and are not soluble to water. Triglycerides store energy in our bodies regulating insulation. That's why penguins can survive in degrees below zero.

9/18,

Proteins

Proteins are very important to living organisms. They have various functions.

Functions include:

- Support
- It makes up your hair and fingernails and gives them their strength.
- Metabolism
- They are enzymes that help speed up chemical reactions in the body.
- Transport
- Hemoglobin is a protein that transports oxygen in our bloodstream.
- Defense
- antibodies are proteins that destroy any cells unbalancing our immune system.
- Regulation
- hormones are proteins that can regulate the amount of glucose in our blood.
- Motion
- Myosin and actin are proteins that allow muscles to contract and relax in a regular cycle.

Nucleic Acids

Nucleotide is a monomer of a nucleic acid. It contains a phosphate group, a pentose sugar and a nitrogen containing base. This is the building block of DNA and RNA. They are genes that are responsible to reproduce every protein in our bodies.

Polymers & Monomers

- Polymers are the largest biomolecules made up of subunits called Monomers.
- Monomers must be energized before joining to form a Polymer.
- Monomers form Polymers in a process called dehydration.
- Polymers are broken down by a process called hydrolysis.

Examples of Monomers and Polymers

- Carbohydrates:
 - Monomer: Monosaccharides (simple sugars)
 - Polymer: Polysaccharides (complex carbs)
- Proteins:
 - Monomer: Amino Acids
 - Polymer: Proteins
- Nucleic Acid:
 - Monomer: Nucleotides
 - Polymer: DNA & RNA
- Lipids: Lipids are a little different in the building process because they don't form a solid structure.
 - Monomer: Fatty Acids
 - Polymer: Lipids (fats and oils)

Cycle 2) Photosynthesis PowerPoint project submitted by Sharee's group.

Organic Molecules
(group project)

Group members: Sharee Goree, Kyra Nicholson, Heather Sandoval

Dehydration

Dehydration means to take away water and synthesis means to build or create so **Dehydration synthesis** means building a polymer by taking away water.

Hydrolysis

Means separating with the use of water.

Dehydration Synthesis & Hydrolysis

In dehydration synthesis, two hydrogen's and two oxygen's are taken out. In hydrolysis, when water is added, it separates the bond between oxygen and hydrogen and reforms into two separate hydroxyls.

Similarities

- Both deal with water and other molecules
- Both work the same way with carbohydrates, proteins, nucleic acids and lipids.
- Both have a reverse reaction in relation to each other and also water.

Monomers

Monomers are small single sub units which when they combine together they form polymers.

Example: Glucose + Glucose + Glucose + Glucose

Example: Amino acid + Amino acid → polypeptide protein (polymer)

Fun fact from Greek:
Mono = one
Mere = part

Polysaccharides
Glucose molecules

Polymer

A polymer is a high weight substance made up of simple smaller

Fun fact from Greek:
Poly = many
Mere = Part

Monomers of Biomolecules

Nucleic Acid	Carbohydrate	Lipid	Protein

our major classes of biological macromolecules

- Carbohydrates
- Lipids
- Proteins
- Nucleic acids

Functions of Each

- Carbohydrates:** Providing energy and regulation of blood glucose sparing the use of protein.
- Lipids:** regulate membranes permeability. Serve as a source for fat soluble like A, D, A, K
- Nucleic acids:** They make up genetic information in living things.
- Proteins:** Structure, function, and regulation of the body's cells, tissues, and organs.

Examples of each:

- Carbohydrates** - Sucrose, glucose, starch, and cellulose (found in cell walls of plants). Grains, vegetables, fruit, beans.
- Lipids** - Milk, butter, olive oil, canola oil, peanut oil, corn oil.
- Nucleic acids** - ATP, NAD⁺, NADP⁺, DNA, and RNA.
- Foods with nucleic acids:** Fish, organ meats, beans, asparagus, chloroella, spirulina, and nutritional yeast.
- Proteins** - Collagen, enzymes, hemoglobin, insulin, and antibodies.

organic group is important & connected with real-wo

- Carbohydrates are monosaccharides consisting of one sugar molecule and disaccharides which are also simple sugars, but contain two monosaccharides.
- Carbohydrates also include glucose, ribose, and deoxyribose. They are present in the nucleic acids RNA and DNA. Some complex carbohydrates serve as short-term energy storage molecules such as glycogen and starch. They are not soluble in water and are much larger than simple sugars. Sometimes polysaccharides are structural polysaccharides like cellulose, chitin, and peptidoglycan.
- Lactose, sometimes called milk sugar because it's the major carbohydrate component of milk. People who are lactose intolerant can not break down lactose, a disaccharide, and when it is consumed they often experience digestive track symptoms that are usually unpleasant.
- Most lipids are insoluble in water due to lack of polar groups. Fats and oils are the most well-known lipids. They function as long-term energy storage molecules. Phospholipids are **(continued)** and that makes them soluble in water and are the main part of the plasma membrane. A large class of lipids

Proteins are polymers of amino acids. They have the same structure, generally, but the order by the side chain (backbone) of the side chain consists of proteins. Some of the main functions of proteins in animal cells are, support, movement, transport, defense, regulation, and motion. The shape of a protein is suited to its function. In a certain fashion, the sequence of amino acids will determine the final shape of the protein. The shape determines the structure and function in the cell. As much as 65% of the dry

Environmental conditions, the extreme temperature and pH can alter the shape of the protein and it will not be able to perform its function. Cooking an egg causes the protein in the egg white, or the albumin, to coagulate. Stomach acids also denature any proteins we ingest, including enzymes, the muscle protein found in meat, and hormones. This makes it more susceptible to hydrolysis by digestive enzymes.

DNA is the hereditary material for all and every species on the planet. DNA provides the information and ATP provide the cells with energy that allows cells to build proteins. ATP is a nucleotide as are the subunits of DNA. The nucleotide ATP is the cell's primary energy source. www.khanacademy.com

ATP can be compared to spending money or a product or services. Cells spend ATP when they need something done. ATP is called the energy currency of cells. ATP is a usable energy molecule, not an energy storage molecule like carbohydrates and lipids

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Thank you for watching!

APPENDIX H

CYCLE TWO: PRETEST-POSTTEST QUESTIONS

Directions: Choose the one response that best completes the statement or answers each question. Record answers directly on the Google Forms document.

- 1) Which choice correctly lists the four classes of biomolecules?
- A) Carbohydrates, proteins, lipids, and nucleic acids.
 - B) Monosaccharides, polysaccharides, monomers, and polymers.
 - C) Fats, oils, waxes, and steroids.
 - D) Carbohydrates, proteins, lipids, and amino acids.
- 2) Small molecules are combined to form larger molecules via _____. This process is called _____.
- A) hydrolysis reactions; synthesis
 - B) dehydration reactions; synthesis
 - C) hydrolysis reactions; degradation
 - D) dehydration reactions; degradation
- 3) Complex carbohydrates called polysaccharides have various structures and functions. For instance, some are branched while others aren't. Some are molecules that provide _____, such as starch and glycogen. Others serve as _____, such as cellulose, chitin, and peptidoglycan.
- A) short-term energy storage; structural components
 - B) long-term energy storage; structural components
 - C) structural components; short-term energy storage
 - D) structural components; long-term energy storage
- 4) _____ are characterized by the presence of double bonds between carbon atoms. The double bonds in these fatty acids create a bend in the chain that prevents close packing. _____ are characterized by the presence of only single bonds between carbon atoms. There is no bending in these fatty acid chains, allowing them to pack together tightly.
- A) Saturated fatty acids; Unsaturated fatty acids
 - B) Unsaturated fatty acids; Saturated fatty acids
 - C) Trans fats; Saturated fatty acids
 - D) Unsaturated fatty acids; Trans fats

5) Proteins are a very versatile class of biomolecules. They serve a number of purposes. For instance, antibodies are proteins that serve the purpose of _____, to prevent the destruction of cells. Other proteins, like hormones, function in _____, working as messengers that influence cell metabolism. Proteins such as actin and myosin serve yet another function, _____, allowing muscle cells to contract.

- A) support; metabolism; transport
- B) defense; motion; transport
- C) support; regulation; motion
- D) defense; regulation; motion

6) Steroids have _____ structure when compared to fats. This molecule has a skeleton of _____.

- A) a very similar; glycerol attached to saturated fatty acids
- B) an entirely different; long-chain fatty acids attached to long-chain alcohols
- C) a very similar; glycerol attached to long-chain alcohols
- D) an entirely different; four fused carbon rings

7) DNA is a _____-stranded polymer of nucleotides that contains the bases _____ and the sugar _____. RNA is a _____-stranded polymer of nucleotides that contains the bases _____ and the sugar _____.

- A) (double; A,G,T,C; deoxyribose) (single; A,G,U,C; ribose)
- B) (single; A,G,U,C; ribose) (double; A,G,T,C; deoxyribose)
- C) (double; A,G,U,C; deoxyribose) (single; A,G,T,C; ribose)
- D) (single, A,G,U,C; deoxyribose) (double; A,G,T,C; ribose)

8) Phospholipids are similar to _____ in structure. However, they are _____ molecules. This structure creates a hydrophilic end and a hydrophobic end, well-suited for interactions with water.

- A) carbohydrates; polar
- B) carbohydrates; nonpolar
- C) fats; polar
- D) fats; nonpolar

9) The “Subunits” column in the table below is scrambled. What is the correct order of the subunits?

Biomolecule	Example	Subunits
Carbohydrates	Polysaccharide	1. Amino acids
Proteins	Polypeptide	2. Glycerol + fatty acids
Lipids	Fat	3. Monosaccharides

- A) 1,3,2
 - B) 2,3,1
 - C) 3,1,2
 - D) 3,2,1
- 10) Once a protein has been denatured by extreme heat:
- A) It can be reformed by cooling it back to room temperature
 - B) It can be reformed by further heating
 - C) It will no longer be able to perform its normal function
 - D) It will still work the same as before the denaturation process

APPENDIX I

CYCLE TWO: MULTIMODAL PROJECT DESIGN

BI 114 Online Group Project Overview:

In class, we have been discussing various aspects of organic molecules. Based on what was presented and/or learned, you will interact with assigned group members to create a unique course project to address major concepts pertaining to the four major organic molecule groups (Chpt. 3).

Project Expectations:

- Your group has a *choice* in how to complete the project. For example, you could complete a PowerPoint or Prezi presentation, use Google Docs, or make video recordings.
- You will be required to answer specific topic outcomes for this assignment, regardless of the presentation style. You will be graded on project organization, timeliness, and addressing the specified outcomes clearly and thoroughly.
- Projects should be multimodal in nature, meaning that creativity and a mixture of methods for conveying information should be used. Ex: Pictures AND text. Not just text! (See below for more examples that could be used)
- You will be responsible for any materials pertaining to your project. Do not plagiarize!
- The project is due by **11:59 pm on Sunday, September 9th in your group's assigned discussion area** (upload the PPT, post link, etc.). Late projects will be deducted points.

Learning outcomes (topic questions) to address in your project:

- Distinguish between dehydration synthesis & hydrolysis reactions.
- Distinguish between monomers and polymers.
- Identify the structures and functions of each major macromolecule group & give examples of each.
- Describe why **each** organic molecule group is important.
 - Connect the organic molecule groups to a real-world scenario or situation.

Below are some suggested strategies to combine for completing the assignment/project (Fleming, 2016). Remember, your group's work should combine various means of presenting material, for a multimodal (varied) effect:

<p>Visual:</p> <ul style="list-style-type: none">• Draw things, use diagrams. For example: a comic or PowerPoint presentation• Use colors to express information.• Use a program like Google Sites or WikiSpaces to create a web page.
<p>Aural:</p> <ul style="list-style-type: none">• Imagine talking with someone. You could create a play, for instance.• Use videos (such as on YouTube). They also have an aural (hearing) component.• Speak information aloud. For example: Create/record a song.
<p>Read/Write:</p> <ul style="list-style-type: none">• Create your own test or study guide (with an answer sheet).• Write paragraphs, beginnings and endings. For example: a story• Arrange your words into hierarchies and points. For example: flow charts/diagrams
<p>Kinesthetic:</p> <ul style="list-style-type: none">• Create and write assignment answers, paragraphs.• Create/design/implement your own laboratory experiment.• Act out a play that you created (don't forget to record)• Use plenty of examples. Use case studies and real-world applications to help with principles and abstract concepts. For example: A physical model or diorama
<p>Multimodal:</p> <p>A multimodal project consists of various combinations of the four styles above. More than one strategy (for instance both pictures <i>and</i> PowerPoint text) should be used to guide your project.</p>

Analytic Rubric for Multimodal Project

Group Name: _____

Course Section: _____

Criteria	Proficiency Level (Points)			Weight	Score (Points)
	0	3	5		
Project creative/student effort provided	No attempt provided	Little creativity/student effort	Clear student creativity/effort	1	
Project based on multimodal (varied) nature in content presentation	No attempt provided	Project design based on other method	Project design based on multimodal style	1	
Student learning outcomes addressed in project	No attempt provided	Incomplete or inaccurate information	Completely and accurately described	2	
Project is organized	No attempt provided	Material is not organized and/or legible	Material is organized and legible	1	
Project submitted on time	Not submitted	Late project submission	Timely submission	1	

Total points earned= _____ /30 pts

APPENDIX J

CYCLE TWO: EXAM 2 ANALYSIS QUESTIONS

Which of the following is an UNTRUE statement concerning organic molecules?

- They always form through ionic bonds.
- They are stable and can be quite large molecules.
- They are associated with living cells.
- They always contain a carbon backbone.

Course-specific SLO: Identify the structures of the major organic molecules.

The terms alpha helix or pleated sheet are terms associated with which level of protein structure?

- Primary
- Secondary
- Tertiary
- Quaternary

Course-specific SLO: Identify the structures of the major organic molecules.

A chemist is studying organic molecules in her lab. Which of the following molecules would she be least interested in studying?

- Carbohydrates
- Proteins
- Water
- Nucleic acids
- Lipids

Course-specific SLO: Be able to give examples of each major organic molecule.

A biologist is studying the chemical composition of an unknown molecule. The biologist discovers that the molecule contains adenine, cytosine, guanine, and thymine. Based on these findings, what is this unknown molecule?

- A protein
- A lipid
- A carbohydrate
- RNA
- DNA

Course-specific SLO: Identify the structures of the major organic molecules.

The three components which make up a nucleotide are: a sugar, a phosphate, and a nitrogen base.

- TRUE
- FALSE

Course-specific SLO: Identify the structures of the major organic molecules.

The building blocks (or monomers) of proteins are called:

- Monosaccharides
- Amino acids
- Phospholipids
- Fatty acids
- Nucleotides

Course-specific SLO: Identify the structures of the major organic molecules.

A scientist is studying the polysaccharide which is used in plants for support. Which of the following molecules would he or she be most interested in studying?

- Chitin
- Cellulose
- Peptidoglycan
- Glycogen
- Collagen

Course-specific SLO: Identify the functions of the major organic molecules.

Which of the following molecules is NOT a monosaccharide?

- Ribose
- Glucose
- Starch
- Deoxyribose

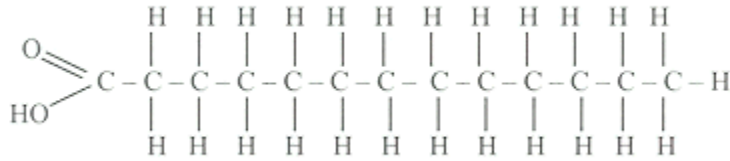
Course-specific SLO: Be able to give examples of each major organic molecule.

When digesting a protein (a polymer) into smaller amino acids (monomers), which of the following chemical reactions would be needed?

- A hydrolysis reaction
- An isomeric reaction
- A dehydration reaction
- A hydrophobic reaction
- A hydrophilic reaction

Course-specific SLO: Distinguish between dehydration synthesis & hydrolysis reactions.

Which of the following statements is true about saturated fatty acids?



Course-specific SLO: Identify the structures of the major organic molecules.

In metabolism, which of the following molecules would be used for an immediate and quick source of energy for living organisms?

- Protein
- Nucleic Acids
- Lipids
- Water
- Carbohydrates

Course-specific SLO: Identify the functions of the major organic molecules.

APPENDIX K

CYCLE TWO: ONLINE OBSERVATION PROTOCOL

Date (s):			
Types of Interactions	# of posts	# of students posting	Other observations noted and/or interpretations
General Communication/Planning			
Assignment of duties/tasks			
Confusion about instructions			
Issues/concerns with group interactions			
Miscellaneous (state the topic)			
Number of student logins to Canvas:			
Additional notes:			