DEEPENING CONCEPTUAL UNDERSTANDING IN THE HIGH SCHOOL AP BIOLOGY CLASSROOM USING ENGAGEMENT TOOLS AND TECHNIQUES

By

Dusti Jean Vincent

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Physical Science—Interdepartmental—Master of Science

2015

ABSTRACT

DEEPENING CONCEPTUAL UNDERSTANDING IN THE HIGH SCHOOL AP BIOLOGY CLASSROOM USING ENGAGEMENT TOOLS AND TECHNIQUES

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Instructing students within a curriculum framework based on conceptual understanding requires a shift from a lecture-style, teacher-centered delivery method to one that is student-centered and inquiry-driven. A challenge with this shift is holding students accountable to preparing for course materials so that class time can be spent exploring the content in more depth through class discussions, experiential and laboratory exercises, and modeling. Three components were implemented in an AP Biology classroom of 39 students to increase engagement and accountability. These components were short readings with corresponding tutorials, formative assessments called ConcepTests, and reflective writing. Student participation in these components was measured.

Conceptual understanding of biology was evaluated with a pre-test at the beginning of the term and measured again with a post-test. A Project-Based Learning (PBL) assessment was also implemented to further engage students and provide a way for students to apply their understanding to solving a real-world problem.

Students demonstrated significant gains in conceptual understanding through the concept and PBL assessment. Participation in the components ranged from 73% to 86%, but it was difficult to show a positive correlation between participation and conceptual understanding.

DEDICATION

Gratitude to my children, Minnie and Dashiell, and my husband, Brad for your patience, support, and understanding. You are the reason I do most things. I love you.

ACKNOWLEDGEMENTS

First and foremost, I must thank Merle Heidemann for her guidance, wisdom, and patience with me over the years as I complete this program. I have achieved so much growth as a professional thanks to this rigorous and relevant program that she helped to design. I also want to recognize Margaret Iding for always answering my questions and the members of my cohort for their support and feedback.

Completion of this program would not have been possible without the love and support of my husband, Brad. For the many summers I spent in East Lansing and the many weekends I spent working on this thesis, he was always accommodating, patient, and understanding. He provided the encouragement I needed when I wanted to quit. I have never felt such a sense of accomplishment as I do now.

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KEY TO ABBREVIATIONS

ACS……………………………………………………………………………………American Chemical Society

AP…………………………………………………………………………………………..Advanced Placement

CCSS…………………………………………………………………………...Common Core State Standards

ELA…….……………………………………………………………………………………English Language Arts

JiTT…………………………………………………………………………………………Just in Time Teaching

LO……………………………………………………………………………………………...Learning Objective

MDE……………………………………………………………………….Michigan Department of Education

MME………………………………………………………………………………………...Michigan Merit Exam

NGSS………………………………………………………………….......Next Generation Science Standards

PBL…………………………………………………………………………………….Project-Based Learning

PI………………………………………………………………………………………………….Peer Instruction

SLC…………………………………………………………………………………….Small Learning Community

SWH………………………………………………………………………………………Science Writing Heuristic

INTRODUCTION

Rationale and Statement of Problem

Advanced Placement (AP) curricula allow students to pursue college-level courses while still attending high school. AP® courses conclude with an examination that provides students with college credit or placement in a more advanced course in college. The College Board claims that performing well on AP® exams is a "gateway to success in college" (College Board, 2012). Although taking challenging courses in high school, such as AP® prepares students for the rigor of college, it's only part of the picture. The level of engagement and participation in AP® courses and general-education courses alike is strong predictor of college success (NSSE, 2006).

In the spring of 2012, the College Board launched a revision of its AP Biology curriculum framework from one of content coverage to a conceptual understanding of content. The revision's intent was to move students away from memorizing rote facts to applying understanding of biology through inquiry-based learning. The new curriculum framework also aligned to what college instructors agreed were skills and habits of mind that students should practice in order to be college-ready. These practices include: using models, applying mathematics, questioning, planning out and implementing data collection strategies, analyzing and evaluating data, working with scientific explanations and theories, and connecting knowledge across many areas (College Board, 2012). These curriculum changes follow the development of the Common Core State Standards (CCSS) in 2009 and the Next Generation Science Standards (NGSS) in 2010, both of which suggest a framework for learning that emphasizes skills and deep understanding (NGA 2010 & NRC, 2011). Both the NGSS and Common Core were developed with the goal of producing students who are "career and college-ready" with an emphasis on critical thinking skills. Instructing students within these frameworks requires a shift from a lecture-style, teacher-centered delivery method to one that is student-centered and inquiry-driven. One challenge with this shift is the accelerated nature of the AP Biology curriculum. Lecture-style content delivery, while time-efficient, generally does not contribute to student understanding, (Mazur, 1997). Another challenge is holding students accountable to preparing for course materials so that class time can be spent exploring the content in more depth through class discussions, experiential and laboratory exercises, and modeling.

Because of the student-centered nature of inquiry-based classrooms, student engagement is essential. Students must be active members of the classroom community. One way to measure engagement is participation in class activities (Chapman, 2003). Additionally, the quality of student work samples may also document engagement. In order to target the specific science skills that the College Board identifies as critical to college success, students must be apprenticed in these skills. Hence, the role of the teacher in an inquiry-based classroom is one of an expert facilitator to move students from being "marginal outsiders" to "competent outsiders" (Feinstein, 2010). With the help of an expert in the content area, students learn and practice the skills of a scientist.

Students operating in an inquiry classroom must also be able to achieve depth of understanding. Depth of understanding comes from questioning current conceptual understanding (Zirbel, 2005) and correcting misconceptions as they arise. Students might deal with discrepancies between their own understanding and accepted understanding by using metacognitive tools. Metacognition, or "thinking about your thinking", means understanding how we learn and make connections between new knowledge and existing knowledge (Schoenbach, et.al., 2012). Tina Grotzer, the chief investigator for the Harvard Project Zero educational research group, says that depth can be defined as "how concepts are represented in a student's mind and how they are connected to one another" (Grotzer and Bell, 1999). Expecting students to make these connections without support is unreasonable. In an inquiry-based classroom, students are exploring problems and asking questions about their learning. The social interaction among students and between students and teacher around content can shape ideas (Feinstein, 2010). Creating a classroom environment that values such interaction supports students willing to ask questions and/or identify when they need help (Schoenbach, et.al., 2012). Discussion, paired with metacognitive tools and reflection, can provide the means for students to make strong connections and achieve deep understanding.

Whereas achieving the depth of understanding required under the new AP Biology framework is one challenge, the other is time. The AP Biology course is the equivalent of two college semesters of introductory biology (College Board, 2012). However, in a college biology course, a typical schedule is a one-hour lecture 2 or 3 times per week and a laboratory session that may be 3 or 4 hours long. In a high school AP Biology course, laboratory work and content generally must be delivered in a one-hour period. The inquiry-based approach to the AP Biology labs also requires more time as students are designing their own procedures and getting approval and oversight from their instructor. A popular movement in AP courses is the "flipped" approach to teaching. The flipped classroom takes direct instruction out of the classroom and puts it in the hands of the student. The expectation is that students prepare on their own by watching an online lecture or video and/or reading an assignment prior to coming to class. Class time is then spent on discussion of the content students were asked to preview and application of the material that was learned outside of the classroom. Eric Mazur of Harvard University pioneered this approach with his introductory physics classes using procedures he calls Peer Instruction (PI) and Just in Time Teaching (JiTT). Peer Instruction is teaching that promotes interaction between students (Mazur, 2009). Students learn from one another by discussing difficult concepts and ideas that challenge their current understanding. This process complements the social environment of the classroom and values discussion described earlier. Just in Time Teaching, as the name suggests, is delivering content and providing explanation as students need it, very soon after students preview the material on their own.

In Mazur's class, students read an assignment prior to coming to class and provided feedback to the instructor about how well they understood the information. Then during class time, usually the next day, students answered questions called ConcepTests that addressed the content students were expected to preview independently. ConcepTests are high quality and high-level thinking questions that are designed to be challenging, yet reasonable (Mazur and Watkins, 2009). The format for ConcepTests involved first posing the question to the class. Students were expected to think about the question individually and silently, then answer, usually with clickers. Next, students turned to their neighbor and engaged in a discussion of their thinking about the problem (also called Think-Pair-Share). Students then had the opportunity to revise their answers and the students were polled again. If a large number of students provided an incorrect answer, then the instructor intervened with some explanation. Otherwise, the instructor proceeded to another

ConcepTest question. Dr. Mazur observed a strong correlation between student confidence in the concepts addressed through the ConcepTests and correctness (Mazur, 1997). Through PI and JITT, Dr. Mazur demonstrated that conceptual understanding of physics was vastly improved over traditional lecture-style teaching and gender gaps were diminished using this instructional method (Mazur and Watkins, 2009). Michelle Smith and her colleagues from the University of Colorado at Boulder confirmed Dr. Mazur's findings in an introductory genetics course. They found that the combination of peer discussion and explanation by the instructor increased performance in the course (as measured by exams, homework, and participation) than either method used alone (Smith, et.al., 2011). The flipped model allows more classroom time to be spent on addressing concepts and application, therefore targeting what students need to learn the most. The flipped model as Dr. Mazur applied it also engaged students with the ConcepTests and Peer Instruction. Students enjoy the game-like nature of ConcepTests, especially when using technology such as clickers or smart phones to collect answers. The use of discussion and metacognitive thinking also allowed for connections to be made and therefore deeper understanding. Catherine Crouch and Eric Mazur reported at the end of a 10-year study of PI and JiTT that "complex reasoning develops better with cooperative learning and engagement with material" (Crouch and Mazur, 2001). Not only did students talk to one another about their understanding with PI, but students also used evidence to support their thinking, a skill that is emphasized in CCSS, NGSS, and AP Biology.

Whiteboards are an effective and cost-efficient tool to document the conversations and the thinking that takes place during students' discussions. The use of whiteboards in the classroom also provided a means for students to engage in the content because it involves a public presentation of knowledge and further allows students to interact socially. In cooperative groups, students discussed a problem and developed a common understanding through clarification with one another. When students presented their whiteboards to other groups, they developed deeper understanding as their peers asked additional questions and got clarification. By training students with Socratic questioning and dialogue techniques, students probed one another for deeper understanding and targeted metacognitive thinking (Paul and Binker, 2012). Cooperative groups must be able to explain and justify their explanations with evidence. In a sense, the use of whiteboards is formalizing PI. For the instructor, students writing explanations and thinking on whiteboards allows him/her to identify how new, factual information is connecting with students' existing conceptual framework (Wenning, 2005). Whiteboards may also be used as a formative assessment tool and to check students' understanding of a concept.

The key strategies most closely related to college success are intellectual openness and inquisitiveness, analysis, argumentation, problem solving, writing, and research (Conley, 2007b). In order for students to develop these habits, they need to practice them repeatedly and in many contexts. Project-based learning (PBL) is one approach to addressing these skills. In PBL, a unit of study is introduced with an engaging activity framed by a driving question intended to inspire and motivate students to learn due to its relevancy and high interest (Larner and Mergendoller, 2010). Students work to solve the problem through research, data collection, development of models, and writing. In addition to addressing the academic skills of problem solving, research, and writing, students collaborate with one another and present their work to their peers and potentially to a public audience, which are additional 21st century skills that college professors agree are important for success in college and beyond (Conley, 2007a). Consistent with an inquiry-based teaching model, PBL is a very student-centered teaching methodology in which teachers provide support for students through teaching the necessary content and skills students need to successfully address the problem they are researching. In this way, learning is contextualized and is part of a relevant, meaningful task (Hmelo-Silver, 2004). The teacher models effective thinking and learning strategies and coaches his/her students in the application of those strategies. Through metacognitive routines and questioning, students come to explain the problem they are investigating by focusing on evidence. Just as in PI and JiTT, student collaboration is essential, as students rely on each other as contributors to a body of knowledge in solving a problem. As students work through a challenging problem, students pause and reflect on their progress, further developing strong learning connections and schema. Reflection is an opportunity for the teacher to provide feedback to students on their progress.

In a medical school setting that used PBL to train future physicians, data showed that students were more likely to use evidence-based reasoning to provide explanations of medical problems than students who were trained in more traditional programs that relied solely on data (Hmelo-Silver, 2004). Another study conducted at a technological school in Israel found that students trained in a PBL showed a post-test increase of 84% on a standardized assessment as compared to a 52% increase seen in the control group (Mioduser and Betzer, 2007). Although published studies investigating the use of PBL in secondary classrooms are lacking, the engagement students demonstrate with their learning process and the high-level thinking skills employed by using PBL make it a worthwhile technique to try in an inquiry-based classroom.

All of the aforementioned frameworks and techniques were designed to address and deepen students' conceptual understanding. The final piece of this problem is assessing conceptual understanding. Dennie Wolf and other collaborators from Project Zero at Harvard University inform us to "assess thinking over the possession of information" (Wolf, et. al., 1991). This could be done through performance tasks, longitudinal studies tracking student progress, and reading and writing with authentic tasks. Another important piece of assessing conceptual understanding is the social experience of explaining understanding to others, which corroborates the work of Eric Mazur, Esther Zirbel, and others mentioned throughout this introduction. Wolf makes the case that theses defenses and the scientific review process is akin to the kind of assessment we might ask of students to demonstrate deeper conceptual understanding. Although this is best practiced in teaching, the climate of standardized testing and teacher evaluation from state lawmakers runs contrary to what teachers and educational researchers know is more authentic learning.

The presentation of a research project at the end of a unit of study is certainly a performance task that accurately measures conceptual understanding. Assessing conceptual understanding targets development of the essential skills students need to be college-ready and also provides practice in reading and writing (Wolf et. al., 1991). The Common Core College and Career Readiness Anchor Standards in Writing state that, "students need to learn to use writing as a way of offering and supporting opinions, demonstrating understanding of the subjects they are studying, and conveying real and imagined experiences and events (CCSSI, 2015). Regardless of the content, students must become competent at gathering information, evaluating sources for accuracy and credibility, and citing sources appropriately. In the digital age, students often don't consider the quality of what they read online and that published material, even if it is in a digital format, is intellectual property and therefore must be cited. In other words, research skills must be taught in a variety of contexts and often enough so that students develop the adeptness that comes with being "college ready". The challenge that non-English Language Arts (ELA) teachers often cite with requiring students to write in content-area classrooms is assessing it. One might argue, however, that a content-area teacher knows what writing should look like in his/her content area and can provide appropriate feedback to his/her students. Peter Elbow, English professor at the University of Massachusetts Amherst, would suggest that when teachers assess writing, we should focus on evaluating rather than judging or ranking writing. As teachers, we can provide feedback to students on the strengths and weaknesses of their writing and their ability to follow the criteria as provided in a rubric or assignment (Elbow, 1993). Effectively, we are using writing as a learning tool, to help students deepen their understanding and make connections. In an inquiry classroom where student questions are valued and explored, the Science Writing Heuristic (SWH) is a framework that blends guided inquiry with writing-to-learn strategies (Burke, et. al., 2005). The SWH replaces the traditional lab report by putting the questions students are asking about a phenomenon or event at the forefront and guiding students through a logical thinking process. In following the SWH, students make claims and support them with evidence, both from their own experimentation and published sources. In using the SWH, students connect valuable research skills with their writing. The SWH also parallels the framework teachers employ in a PBL classroom by first identifying questions, then following those questions with tests and gathering evidence. The part of the SWH that a traditional lab report lacks is a reflective piece where students explore the question, "How do my ideas compare with other ideas?" In this section of the SWH, students not only evaluate evidence from published works, but that of their peers as well. This models a scientific review process where students read and respond to each other's work in an effort to gain deeper understanding. This process also has a social component, which engages the students and develops their presentation skills. K.A. Burke and others have observed significant gains on the American Chemistry Society (ACS) exam among college freshmen in an introductory chemistry course at Iowa State University who were instructed with the SWH (Burke, 2005).

Class Descriptions and Demographics

Students in AP Biology at Skyline High School in Ann Arbor, Michigan participated in this study to observe how various engagement tools impacted their understanding of biology concepts. Ann Arbor is a city with over 115,000 residents that lies 36 miles west of Detroit. Ann Arbor is home to the University of Michigan, a world-renown science and medical research institution. The university is the main basis of the city's economy, population, and cultural awareness. Skyline High School opened in the fall of 2008 as the city's third comprehensive high school to relieve overcrowding at the other two high schools. The school was designed with a focus on 21st century skills, mastery learning, and small learning communities (SLC's). SLC's were implemented as a way to make the school's population of approximately 1500 students feel smaller and provide opportunities for students and teachers to form strong relationships with one another. Most of the students who attend Skyline live within the school boundary, but every year approximately 300 open-enrollment spaces are available for students who live outside of the boundary. The population of 1440 students is 55% male and 45% female. The school is 54.4% Caucasian, 16.9% African American, 10.8% Asian, 9.8% Multiethnic, 3.1% Hispanic/Latino, 2.9% Arab, 0.3% Native American, and 1.7% of students who identify as "other". Prior to the 2014-2015 school year, Skyline was identified as a "Focus School" by the Michigan Department of Education for having the "largest achievement gap between the top and bottom 30% of students" (MDE, 2015). The focus school designation is based on the average scale score as measured on the Michigan Merit Exam, or MME.

Skyline High School operates on a schedule of three twelve-week trimesters (Skyline High School, 2013). There are five 72-minutes periods in a school day. In AP Biology, the demographics don't entirely reflect that of the school as a whole. There are 66 students enrolled this year in AP Biology, 61.9% of them identifying as Caucasian, 19.8% Asian, 7.1% African American, 4.8% Middle Eastern, 4.8% Hispanic/Latino, and 2.4% Multiracial. Despite our efforts to reach out to our minority population for inclusion in AP and higher-level courses, we still observe fewer students of color in the AP sciences, a problem that extends beyond Skyline and Ann Arbor. Of the 66 students who are enrolled in the course, 47 students were enrolled in my 2 sections of AP Biology. Of those 47 students, 39 agreed to participate in the study, or 83% participation.

IMPLEMENTATION

General Considerations

To implement engagement tools and techniques, the big ideas addressed in AP Biology that would pique students' interest and apply basic concepts taught at the beginning of the year were considered. *Big Idea 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce and to maintain dynamic homeostasis* (College Board, 2012) was chosen because the standards addressed include understanding of macromolecules and cell structure, which are introductory units in the course. The unit in this study was designed using the theme of metabolism, which included the aforementioned standards in addition to understanding of cellular respiration and photosynthesis.

Metabolism is typically a challenging topic to learn and teach, partly because of the complex biochemistry associated with metabolic pathways and partly because of the inability to observe it directly. We rely extensively on the use of models and diagrams to visualize the processes of cellular respiration and photosynthesis and perform lab activities that investigate the processes on a large scale by manipulating variables that will influence the process as a whole.

The unit was subdivided into 4 smaller units: Biochemistry, Cell Structure and Function, Cellular Respiration, and Photosynthesis. Due to the length of the PBL assessment, the entire unit was implemented over the course of 15 weeks. The PBL assessment was presented during the final exam periods at the end of the first 12-week trimester. The remainder of the unit was implemented over the course of the first 3 weeks of the second trimester. Table 1 shows the full unit plan implementation.

TABLE 1: Unit plan implementation and schedule of activities.

Date	Activities	Objective(s)
9/2/14	Parent letter and consent form sent home	Alert parents and students of research study
9/5/14	Consent forms due Concept Pre-assessment	Determine student understanding of biology concepts
9/9/14	PBL component launch and submit project interest form	Engage students in PBL assessment
9/10/14	Meet in assigned PBL groups and submit project proposal	Provide time to plan PBL project
9/15/14	Properties of water reading (Ch. 3) and Mastering Biology assigned	Provide necessary background understanding of content
9/19/14	Biochemistry reading (Chs. 4 & 5) and Mastering biology assigned	Provide necessary background understanding of content
9/28/14	Properties of water (Ch. 3) Mastering Biology due Biochemistry (Chs. 4 & 5) Mastering Biology due ConcepTests #1 & #2	Formatively assess understanding of macromolecules
9/30/14	ConcepTest #3 Enzymes and Metabolism reading (Ch. 8.4 & 8.5) and Mastering Biology assigned	Formatively assess understanding of properties of water
10/1/14	PBL Check-in #1—Charette protocol	Provide PBL teams with peer feedback about project idea
10/3/14	PBL Assessment work day	Provide time for teams to work on PBL assessment
10/7/14	ConcepTest #4 Enzymes and Metabolism (Ch. 8.4 & 8.5) Mastering Biology due	Formatively assess understanding of macromolecule synthesis
10/9/14	ConcepTest #5	Formatively assess understanding of enzymes
10/10/14	Biochemistry unit reflection assigned	Assess students ability to connect unit concepts and practice writing
10/13/14	Biochemistry unit reflection due	
10/14/14	Biochemistry unit test Cell types and functions reading (Ch. 6) and Mastering Biology assigned	Assess student understanding of biochemistry concepts
10/16/14	ConcepTest #6	Formatively assess understanding of cell types
10/17/14	PBL assessment work day	Provide time for teams to work on PBL assessment
10/21/14	ConcepTest #7	Formatively assess understanding of cell transport
10/22/14	PBL Check-in #2—Gallery Walk	Provide PBL teams with peer feedback about project progress

TABLE 1 (cont'd)

10/23/14	Cell types and functions (Ch. 6) Mastering Biology due Cell size whiteboard formative assessment	Formatively assess student understanding of cell size surface area: volume ratio
10/26/14	Membrane structure and function reading (Ch. 7) and Mastering Biology assigned	Provide necessary background understanding of content
10/27/14	ConcepTest #8	Formatively assess understanding of cell structure and function
10/30/14	ConcepTest #9 PBL Assessment work day	Formatively assess understanding of cell membrane structure and application of biochemistry concepts
11/2/14	Membrane structure and function Mastering Biology due	
11/3/14	Cell structure and function unit reflection assigned	Assess students ability to connect unit concepts and practice writing
11/5/14	ConcepTest #10	Formatively assess understanding of cell types
11/7/14	PBL Check-in #3—Critical Friends protocol	Provide PBL teams with peer feedback about project progress
11/9/14	Cell structure and function unit reflection due	
11/10/14	Cell structure and function unit test Introduction to metabolism reading (Ch. 8.1-8.3, 9.1, & 40.2) and Mastering Biology assigned	Summatively assess student understanding of cell structure and function concepts
11/12/14	PBL Check-in #4—rough draft due	Provide teacher feedback to PBL teams on assessment
11/18/14	Introduction to metabolism (Ch. 8.1-8.3, 9.1, & 40.2) Mastering Biology due ConcepTests #11-13	Formatively assess understanding of thermodynamics and metabolism
11/19/14- 11/20/14	PBL Assessment due/Media Project Presentations PBL Reflection assigned during presentation	Assess student completion of project and student ability to cite evidence about most convincing claim
11/24/14	Cellular Respiration reading (Ch. 9) and Mastering Biology assigned	Provide necessary background understanding of content
11/25/14	Cellular respiration whiteboard formative assessment	Formatively assess understanding of the steps of cellular respiration
12/8/14	Photosynthesis reading (Ch. 10) and Mastering Biology assigned	Provide necessary background understanding of content
12/9/14	ConcepTests #14 & #15	Formatively assess understanding of aerobic/anaerobic respiration
12/10/14	ConcepTests #16 & #17	Formatively assess understanding of cellular respiration processes
12/12/14	Cellular respiration unit reflection assigned	Assess students ability to connect unit concepts and practice writing
12/16/14	Photosynthesis (Ch. 10) Mastering Biology due	

TABLE 1 (cont'd)

12/17/14	ConcepTests #18 & #19	Formatively assess understanding of cellular respiration processes
12/18/14	Cellular respiration unit reflection due Cellular respiration unit test Cellular Respiration (Ch. 9) Mastering Biology due	Summatively assess student understanding of cellular respiration process and concepts
1/6/15	ConcepTests #20-22	Formatively assess understanding of photosynthetic reactions
1/9/15	Photosynthesis unit reflection assigned	Assess students ability to connect unit concepts and practice writing
1/13/15	ConcepTest #23	Formatively assess understanding of photosynthetic process
1/16/15	Photosynthesis unit reflection due Photosynthesis unit test	Summatively assess student understanding of photosynthesis process and concepts

Discussion and Analysis of Unit Components

To make this unit more interesting and engaging to students because of its difficulty and abstractness, the unit revolved around a project called *Burn, Baby, Burn* (see Appendix A1). The project required students to investigate diet and exercise claims and how they impact obesity. With this project, students were required to perform research, collect data, and write a paper, three very important science and college readiness skills. Students also had to apply their understanding of cells, macromolecules, and metabolic pathways.

To assess students' understanding of the concepts that the unit addressed, students were given a pre-assessment of concepts (see Appendix D1) that would be encountered over the term. These were assessed through 8 free-response items that were scored on a scale of 0-2. These standards were assessed throughout the unit with short, formative assessments in small and large group formats and summative assessments. In addition to formal assessments, students were also required to submit a reflection for each unit of study.

The formative assessments utilized included ConcepTests (see Appendix A2), an idea borrowed from Eric Mazur. Students read chapters from their textbook, *Biology* (8th ed.) by Campbell and Reece (2008), and completed corresponding online assignments through a companion site called Mastering Biology. The assignments on Mastering Biology were designed so that students had multiple attempts at the questions and were scored on a 100-point scale. The site has built-in settings that give students bonus points if they don't use any hints to help them answer the questions, thus some students earned scores greater than 100 points. The day after these assignments were due, students were asked multiple-choice questions that applied the concepts the students had read about the night before. The format of the ConcepTests was to pose the question and poll for results, then have the students turn to a partner and discuss their answer. After discussion with a partner, the question was asked again. If all students got the correct answer, very little discussion ensued. If answers varied, we had a class discussion to get students to a better understanding of the concept. Students wrote their answer choice on small (8 ½" x 11") whiteboards and held them up in the air when requested. An additional formative assessment employed throughout the unit was the use of whiteboards or creating posters to demonstrate understanding of key concepts. This was often done toward the end of the unit as a review.

To further engage students with the content and assess their understanding of concepts, students submitted a written reflection for each unit. This reflection was 500 words or less and had to connect the smaller ideas, such as chemical bonding, function and structure of macromolecules, properties of water, and intermolecular interactions together into a cohesive understanding of each unit, how macromolecules are synthesized and function in cells (see Appendix A3). The major premise of this thesis is that participation in the activities I described (Mastering Biology assignments, ConcepTests, reflective writing, unit project) would correspond to stronger understanding of the concepts as measured through free-writing prompts.

Components of the Unit

Component 1: Mastering Biology

This is a companion site to the AP Biology textbook, *Biology (8th ed.)* by Campbell & Reece (2008). Students must log in to the site to complete the assignments. With each assigned reading from the textbook, students completed a Mastering Biology assignment, which consisted of animations, multiple choice questions, and interactive simulations. The assignments were resumable and students had approximately 7-10 days to complete each assignment before we discussed them in class.

Component 2: ConcepTests

ConcepTest is a termed coined by Eric Mazur (1997) in describing his approach to conceptual teaching and learning. A ConcepTest is a multiple-choice question that is based on fundamental concepts in the course. Following each Mastering Biology assignment, class began with 2-3 ConcepTest questions that addressed key concepts of each unit. Students read each question (projected on the screen), wrote their answer choice on a small whiteboard, and results were tallied. Then, students turned to a partner to discuss their answers and voted again. If warranted, the topic was discussed. The list of ConcepTest questions used in this unit is included in Appendix A2.

Component 3: Whiteboards as a Formative Assessment

In following an inquiry-based and student-centered approach to teaching, it's important to check for students' understanding about key concepts they are learning. The Mastering Biology assignments provide an accountability piece for making sure students are reading the textbook and understand what they read. The ConcepTests are another way to check in with students. They also get students involved with the content due to the interactive and social nature of *Peer Instruction* and *Turn To Your Neighbor*. Large whiteboards allow for students to demonstrate what they know and understand about concepts. Students modeled their thinking and metacognitive processes. Because the whiteboards are editable, students easily made corrections when their peers or the instructor points out an error in their thinking. Students worked in small groups on a whiteboard assessment and presented to other groups or to the entire class. The presentations required students to justify their thinking and explain graphics they used. Sample whiteboard assessments of cell surface area to volume ratio and cellular respiration are shown in Figures 1 and 2.

FIGURE 1: Whiteboard Assessment samples
These whiteboard samples were utilized in the cell structure and function unit. Groups of 3-4 students responded to the prompt, “Explain how alveoli increase the surface area available for gas exchange in the lungs**.”**

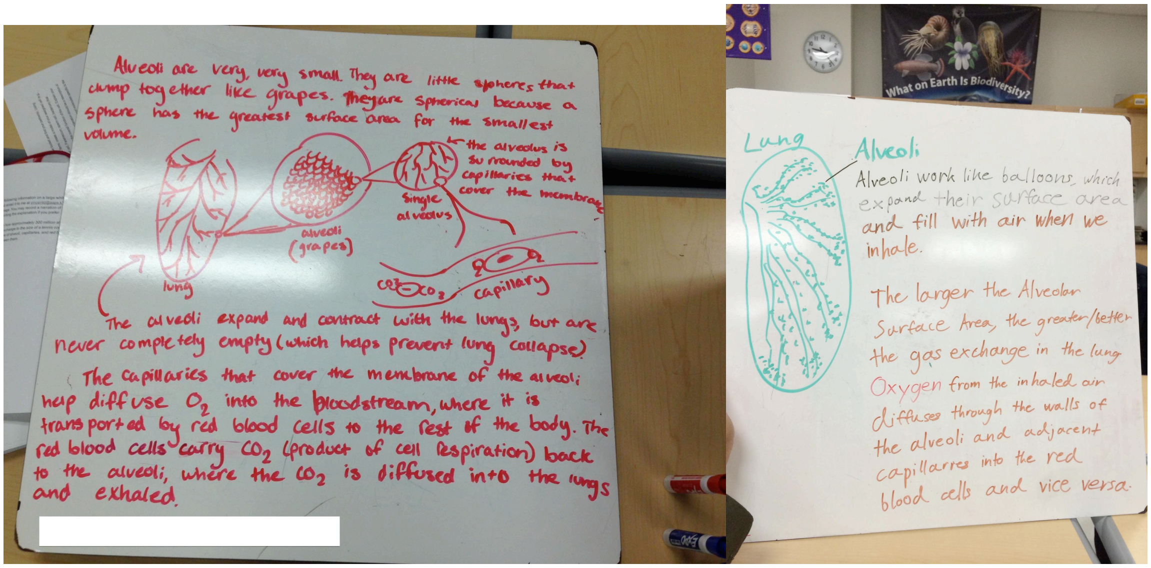
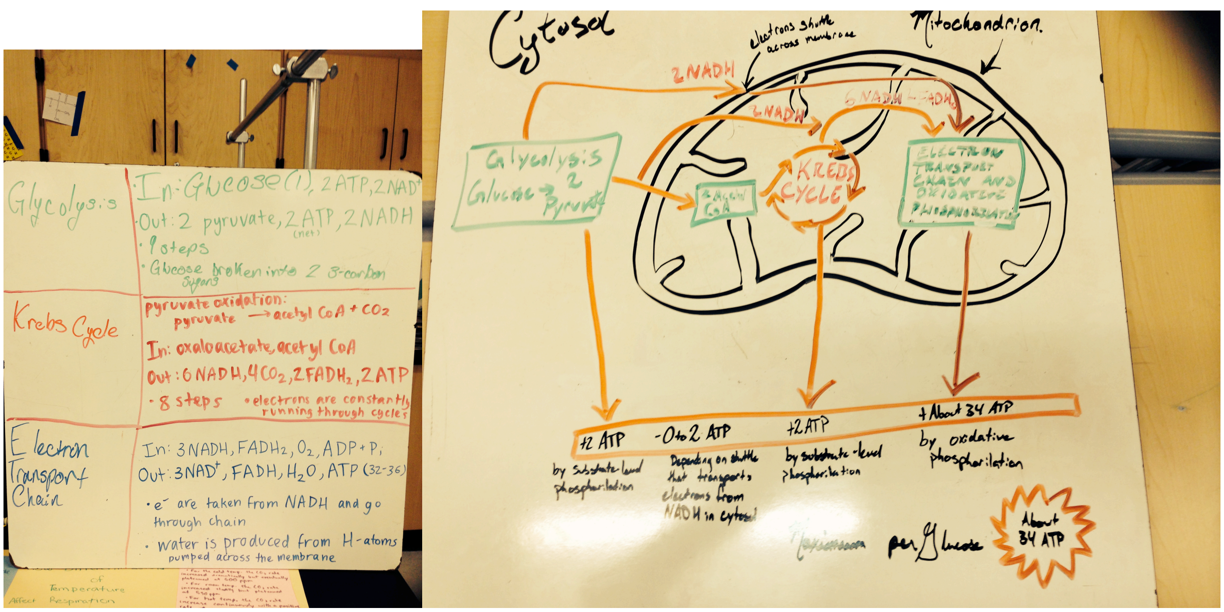


FIGURE 2: Whiteboard Assessment samples
These whiteboard samples were utilized in the cellular respiration unit. Groups of 3-4 students responded to the prompt, “Diagram the process of cellular respiration.”



Component 4: Using Socratic Dialogue

The use of Socratic dialogue facilitates deeper and more interactive discussion (Paul and Binker, 2012). Students practiced Socratic dialogue techniques in the form of bookmarks using sentence starters to push their peers to justify explanations with evidence and think more deeply about the topic (see Appendix A4). The bookmarks were adapted from Lucy Calkins' book, *The Art of Teaching Reading* and *Ready, Set, Science* by Sarah Michaels, Andrew W. Shouse, and Heidi Schweingruber. Students practiced using the sentence starters during whiteboard presentations, feedback protocols for the PBL component, and project presentations.

Component 5: Project Based Learning

The PBL component was the highlight of this unit plan in that it connected the individual subunits together in one comprehensive activity and assessment. This project was the students' final assessment for the unit and was presented during the final exam period at the end of the first trimester in November 2014. Students were first exposed to this project idea in the first week of the term. Following the "8 Essentials for Project-Based Learning" (Larner and Mergendoller, 2010), the project was introduced with an opening activity, the trailer for HBO's "The Weight of the Nation". This is a 4-part documentary film series that explores the obesity problem in the United States through case studies, scientific analyses, and factors that lead to obesity. The trailer, one and a half minutes long, is emotional and engaging. Students were shown a PowerPoint presentation that showcased many of the supposed claims that fight obesity, such as fad diets and weight-loss supplements. The class then developed the driving question, "How do different diet and exercise claims measure up to addressing the obesity epidemic in the United States?" and brainstormed a list of concepts they needed to know to answer this question. The Need to Know list that the students generated is shown in Table 2.

TABLE 2: Need to Know list generated as part of the introduction to the PBL unit.
The Need to Know list includes concepts and questions that students determined were necessary to answer the driving question for the PBL assessment

Need to Know: Concepts and questions that students must know in order to answer the driving question, "How do different diet and exercise claims measure up to addressing the obesity epidemic in the United States?

• What biological processes lead to obesity?
• How does the body process food?
    o Digestion
    o Cellular energy
    o Function of carbohydrates, lipids, and proteins
• How does exercise affect the body?
    o What is a healthy level for your body?
    o What is the affect on metrics like heart rate and blood pressure?
• Vocabulary terms
• What are consequences of obesity?

The project (see Appendix A1 for description) was introduced by students brainstorming topics of interest to them and submitting their ideas to a Google® form. Students worked in groups of 3-5 students based on similar interests. A sample of students' interests is shown in Figure 3.

FIGURE 3: Sample responses to PBL Project Interest Form.
Students were placed in groups based on their responses to this form.

9/10/2014 9:35:03	How certain foods effect a persons weight, Which vegetables or fruit give the most energy, how well do gluten diets work	Hour2
9/10/2014 9:39:50	Does aerobic or anaerobic exercise promote more weight loss? Effects of green tea, reducing excess sugar from your diet (ex juice, desserts, etc.)	Hour2
9/10/2014 9:41:34	Does exercising without a change in diet affect BMI?	Hour2
9/10/2014 9:34:42	Zero calorie drinks	Hour2
9/10/2014 9:43:21	effects of meditation on weight loss, yoga, reverse atkins.	Hour2
9/10/2014 9:37:29	juice fast and atkins diet	Hour2
9/10/2014 9:37:24	comparing the the effects of diet, exercise, or the combination of both. comparing those who eat healthily who don't exercise to people who exercise but eat unhealthily versus people who do both.	Hour2
9/10/2014 9:43:44	Or comparing the bmi, heart rate, blood pressure, of those who exercise (compare different sports). Trying to see if some sports are even effective in keeping you healthy. Or just comparing those who exercise to those who dont.	Hour2
9/10/2014 9:37:59	Green Tea Diet, Fletcherizing	Hour2
9/10/2014 9:38:46	Green Tea benefits health; the speed at which you eat affects health; Indoor exercise is less effective than outdoors exercise	Hour2

Students met with their team members the day after completing the interest form and submitted a project proposal. All teams were responsible for writing a research paper, but they also had to create a media presentation of their choice to share their findings. The presentation was designed to target a specific audience and provide a creative outlet for their work. Sample project proposals are displayed in Appendix A5.

Students followed the format suggested by the Science Writing Heuristic (Burke et. al., 2005) for organizing their research (see Figure 4).

FIGURE 4: The Science Writing Heuristic student template (from Burke et. al., 2005)

FIGURE 2

Comparing student report formats for the SWH and traditional labs.

Standard report format	SWH student template
1. Title and purpose	1. Beginning questions—What are my questions?
2. Outline of procedure	2. Tests—What do I do?
3. Data and observations	3. Observations—What can I see?
4. Discussion	4. Claims—What can I claim?
5. Balanced equations, calculations, and graphs	5. Evidence—How do I know? Why am I making these claims?
	6. Reflections—How do my ideas compare with other ideas?
	7. How have my ideas changed?

Once student teams decided on a research question, they began to plan out their procedure and assign roles. The Team Task List (BIE, 2012) in Appendix A6 was given to each group to indicate which team member was responsible for each part of the project and was submitted to me with their final project.

One class period every week or two was devoted to project development; students also met after school to work on their project. Regular check-ins (Appendix A7) provided the teams valuable feedback to further their work, and helped teams generate additional ideas about their projects. Students also practiced using Socratic dialogue sentence starters (Appendix A4) to model respectful and focused discussion. The feedback protocols were scaffolded so students shared more of their projects with one another during each check-in, ending ultimately with a poster presentation as we moved closer to the deadline of the project. The final check-in was for students to share a rough draft of their paper with me to receive feedback before submitting the final version. Most papers were submitted via Google® documents.

On the final exam day, student teams presented their projects. Each group prepared a media presentation of their choice that described the claim they were analyzing and the evidence behind it. As each team presented, the audience was listening for the most convincing evidence to respond to the reflection prompt, “If you were in a position to lose weight or get in shape, which method that you heard about would you try & why? Please refer to specific evidence presented.” (Appendix A8) At the end of each presentation, audience members had an opportunity to ask probing and clarifying questions. In addition to the media presentation and research papers, students submitted a self-reflection to provide feedback to me about how the team worked together and what students thought they did well or needed to improve.

Component 6: Reflective Writing

The final component to this unit plan was the use of reflective writing (Appendix A3). Students were assigned a reflection with each subunit of study so that students could make connections between concepts learned over the course of each subunit and show their understanding of those concepts. Each reflection followed the same guidelines and was submitted prior to a unit test.

In addition to reflective writing, students also wrote lab reports and responded to short and long-free response assessment items. These were evaluated using the SWH (Figure 4), but modified into a scoring rubric for the analysis of lab reports (Appendix A9).

RESULTS AND ANALYSIS

Pre-Test and Post-Test Administration

The Concept Assessment was designed to measure student understanding of essential biology concepts and served as the main assessment tool. It (Appendix D1) was administered during the first week of school as an 8-item, free response test. Students were prompted to answer each question to the best of their prior knowledge and if students did not know the answer to a question, to leave it blank. The free-response assessment items were aligned to AP Biology Learning Objectives (LO). For the post-test administration, the questions corresponding to each LO were divided among the 4 sub-unit tests administered throughout the term. Responses to the items were scored on a scale of 0-2.

Participation in the components described in the Implementation section was tied to the unit concept assessment. The PBL component was assessed separately due to its comprehensive nature as a stand-alone assessment. The PBL assessment rubric is in Appendix D2.

Data Analysis—Combined Pre-test and Post-test Item Analysis

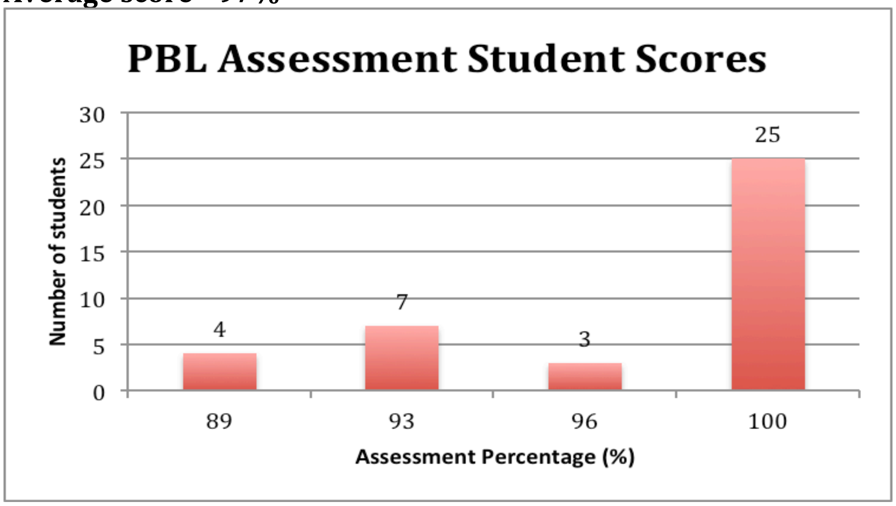
Table 3 provides a breakdown of each LO assessed and the average pre-test score, post-test score, and gain among all research participants. A one-tailed, paired t-test was used to show statistical significance of observed gains for each learning objective. A statistically significant change was observed among all assessment items, showing an overall gain of 0.56 points.

TABLE 3: Concept Assessment pre-test and post-test scores (n=39)
Paired t-test showing statistical significance of gain in post-test scores
Scoring Guidelines:
0—No response given or "I don't know"
1—Explanation is given, but it is incomplete or demonstrates a lack of understanding
2—Explanation is given and demonstrates understanding of concept

Learning Objective	**Pre-test Average**	**Post-test Average**	**Gain**	**p-value**
The student is able to use representations and models to describe differences in prokaryotic and eukaryotic cells. (LO 2.14)	0.54	1.79	+1.25	3.76E-11
The student is able to justify the selection of data regarding the types of molecules that an animal, plant or bacterium will take up as necessary building blocks and excrete as waste products. (LO 2.8)	0.72	1.90	+1.18	1.17E-11
The student is able to construct models that connect the movement of molecules across membranes with membrane structure and function. (LO 2.11)	0.67	1.62	+0.95	3.35E-08
The student is able to explain the connection between the sequence and the subcomponents of a biological polymer and its properties. (LO 4.1)	0.49	1.64	+1.15	1.07E-12
The student is able to explain how biological systems use free energy based on empirical data that all organisms require constant energy input to maintain organization, to grow and to reproduce. (LO 2.1) • Students are able to explain the role of enzymes in the use of free energy.	0.82	1.62	+0.80	6.97E-11
The student is able to explain how internal membranes and organelles contribute to cell functions. (LO 2.13)	0.74	1.87	+1.13	3.52E-15
The student is able to explain how biological systems use free energy based on empirical data that all organisms require constant energy input to maintain organization, to grow and to reproduce. (LO 2.1)	0.54	1.74	+1.20	4.55E-16
The student is able to construct explanations of the mechanisms and structural features of cells that allow organisms to capture, store or use free energy. (LO 2.5)	0.59	1.95	+1.36	4.77E-20
Total Score	**0.32**	**0.88**	**+0.56**	**4.53E-19**

Figure 5 shows the PBL assessment scores as grouped by percentages. The average score on this assessment was 97%.

FIGURE 5: PBL Student Assessment Scores (n=39)
This figure displays student percentages on the PBL Assessment
Average score =97%



Data Analysis—Evaluation of Practices

The main objective of this unit implementation was to determine if engagement tools and techniques positively influenced conceptual understanding, as measured by the Concept Assessment (Appendix D1). Table 4 shows the percentage of students participating in each of the three components implemented in this unit. Average scores for Mastering Biology assignments and unit reflections are included.

TABLE 4: Engagement Tools and Percent Participation (n=39)
Student participation in the three components implemented in this unit

Engagement Tool	Average % Participation	Average Score
Mastering Biology	88%	73.4%
ConcepTests	86%	N/A
Unit Reflections	73%	65.2%

Data Analysis—PBL Assessment

The final project submission for the PBL assessment included the written research report (see Appendix B for exemplar), the media presentation, a team task list, and one self-reflection (Appendix A10) per student. Common responses to the self-reflection questions are reported in Table 5.

TABLE 5: PBL Self-Reflection Responses
A report of common responses to the self-reflection component of the PBL Assessment

Was this project interesting to you? Why or why not?	All students (n=39) reported that the project was very interesting to them for various reasons relating to the topic they selected.
What is the most important thing you learned in this project?	Most students stated that the most important thing they learned related directly to their topic. But, some students noted that they learned how to use resources during this project, how to distribute labor/tasks, and that research studies take time.
What do you wish you had spent more time on or done differently?	Divide work more evenly Outline research Collect more data or from a larger sample size Start earlier Create a better media presentation Performed lab activities at the beginning Organized data differently Performed a controlled experiment Collected original data instead of published data
On what part of the project did you do your best work?	Various answers
How well did your group collaborate? Explain.	Worked well together, but work not divided equally Even work load for all team members Team got distracted because they were all friends Not all teammates worked as hard as others Lack of communication The team excluded some members The project allowed team members to get to know each other better
How well did your group make use of time? Explain.	Team wasn't as productive as they could have been Team made good use of time The team met frequently outside of class. The team was more efficient as time went on. Felt rushed at the end Trouble staying on task Procrastination

Students completed another reflection following the PBL project presentations. They responded to a prompt and cited specific evidence to support their answer (Appendix A8). The 7 different project topics are displayed in Table 5 as well as the percentage of students who identified each one as the most effective. Some students described a combination of methods as most effective. Sample quotes from student reflections are included as evidence.

TABLE 6: PBL Reflection Responses
A summary of which project claims were identified as most effective

Diet/Exercise Method	% Respondents	Evidence
Anaerobic/Aerobic Exercise	9.4%	"By building muscle and losing fat, you become healthier and more physically fit." "It will increase your endurance and strengthen your heart and cardiovascular system."
Juice Cleanse (2 groups)	18.8%	"…can rid the body of toxic build-up" "ingredients are high in antioxidants, vitamins, and minerals"
Green Tea (2 groups)	9.4%	"…acts as an appetite suppressant" "It's easy to change and has a lot of benefits."
Liquid/Solid Diet	15.6%	"reduces one's calorie intake" "This is the only diet to cause measurable weight loss." "The data was reliable." "One of the only diets that had data that was statistically significant."
Meditation	6.3%	"Decreasing stress would be very useful to me."
Eating Speed	18.8%	"The brain has to send a message to the body to tell the body that it's full." "The connection of leptin to fullness and that signal takes time."
Fast Food Elimination	6.3%	"There are healthier alternatives to fast food." "Fast food is full of empty calories."
Combination of Methods	15.6%	"I would vary the types of exercise and eat slower. This would allow sufficient time for hunger hormones to tell me to stop eating." "I would cleanse my body to get a fresh start. Anaerobic and aerobic exercise would get my heart rate up and burn fat."

DISCUSSION

The process of developing deeper conceptual understanding requires students to be more engaged in their learning and shifting the focus away from the teacher and toward the student. (Zirbel, 2005). In this study, students were expected to demonstrate deeper understanding of biology concepts by participating in the engagement techniques of Mastering Biology, ConcepTests, reflective writing, and Project-Based Learning. The data in Table 3 shows that students experienced statistically significant gains in all items of the concept assessment, with an average gain of 0.56 points for the whole assessment. However, demonstrating a causal relationship between the engagement techniques and assessment gains proved difficult. While a majority of students participated in the engagement components described (Table 4), a positive correlation between percent participation and concept assessment gains could not be observed. For this study, engagement was defined as participation in classroom activities, but engagement can also be defined by cognitive, behavioral, and affective indicators (Chapman, 2003).

To address the affective aspect of engagement, students participated in discussions through Peer Instruction and ConcepTests. Eric Mazur was able to demonstrate an improvement in student performance as measured by a number of different assessments when PI was implemented in his introductory physics course at Harvard University (Crouch & Mazur, 2001). Due to the lack of a controlled study in this unit plan, a similar conclusion cannot be reached.

To address the cognitive aspect of engagement, students submitted unit reflections to demonstrate the ability to make connections between concepts. Writing is a skill that is generally lacking among college freshman (Conley, 2007b), so providing opportunities to write in varied content areas is critical to producing more college-ready students. Among the three engagement components implemented in this unit, students participated the least in reflective writing, with an average of 73% submitting reflections for the 4 units defined in this study (Table 4). Writing may be perceived as more time-consuming and not directly beneficial to understanding content. Unfortunately, a causal relationship between reflective writing and assessment gains cannot be demonstrated.

Students demonstrated a high degree of success on the PBL assessment, with an average score of 97% (Figure 5). The success may be credited to a couple of structures implemented with this assessment: the long-term nature of the assessment (11 weeks to complete the project, from the day it was introduced to the day it was presented, see Table 1) and the use of feedback protocols to improve student work (Appendix A7). However, it must be noted that the rubric assessed more than content, with only two of the seven rubric items assessing content and evidence (Appendix D2).

Although students scored high on the PBL assessment, a concern presented itself with the PBL reflection responses (Table 6). Students were asked to evaluate the claims of their peers. The exemplar included in Appendix B on anaerobic/aerobic exercise most effectively answered the driving question, "How do different diet and exercise claims measure up to addressing the obestiy epidemic" by collecting and analyzing original data from a large sample size and connecting the data to known information. However, only 9.4% of students reported this claim as the most convincing claim. The highest percentage of students (18.8%) reported the juice cleanse and eating speed as the best methods for weight loss or getting in shape. While the reasons for supporting the juice cleanse were vague and lacking in evidence, the reasons supporting the eating speed were more rooted in valid scientific explanations. Perhaps the reflection prompt did not emphasize the need to cite evidence clearly enough. Students may also have been swayed by the technological savvy of some of the presentations and overlooked the lack of evidence.

Despite the ability for many students to cite evidence from the presentations, all students learned important information from performing the PBL assessment. From the self-reflection (Table 5), most students learned important content relating to metabolism and diet/exercise claims, but some reported learning important research and collaboration skills, habits that are indications of college readiness (Conley, 2007a). Improvement in the areas of collaboration and time management is needed for future implementation of this assessment.

FUTURE CONSIDERATIONS

Engagement is challenging to measure. Participation alone is only part of the picture; quality of student work and attitude are additional aspects of engagement that are often subjective (Chapman, 2003). One consideration for future implementation of this unit is to compile survey data evaluating students' attitudes about class activities to determine which components were deemed most effective and impactful to learning. Another challenging aspect of this unit was writing effective concept-based questions. Some science disciplines, notably physics and chemistry, offer concept inventories to assess student understanding, however, biology lacks such an assessment. In some cases, the wording of ConcepTest questions caused students to get the incorrect answer. Having a bank of conceptual questions to draw from might alleviate this problem. Also, the way in which students responded to ConcepTest questions could be improved. Using smartphones, clickers, or another electronic data system would provide better tallying of answers and facilitate better data analysis.

To address some of the time management and collaboration issues raised by the PBL self-reflection (Table 5), assigning roles in future iterations of this project may be necessary. Students were asked to submit a team task list (Appendix A6), but this was up to each team to determine and some students are uncomfortable with delegating responsibility to their peers.

Lastly, despite strong efforts, many students value "correctness" over "process". When presenting ConcepTest questions, students often wanted to know the correct answer and not necessarily the metacognitive processes that lead to the correct answer. This is an attitude that is hard to change, given that is likely stems from very early childhood experiences. However, students must understand their own metacognitive processes in order to know themselves as thinkers and learners and develop empowerment and the ability to help oneself. For this reason, the focus in all science classrooms should be on uncovering the processes of science and reasoning to produce more college and career-ready students.

APPENDICES

APPENDIX A1: PBL Assessment Description

Burn, baby, burn

Investigating diet and exercise claims

Objectives:

- Construct explanations of the mechanisms and structural features of cells that allow organisms to capture, store or use free energy.
- Represent graphically or model quantitatively the exchange of molecules between an organism and its environment, and the subsequent use of these molecules to build new molecules that facilitate dynamic homeostasis, growth and reproduction.
- Analyze data to identify how molecular interactions affect structure and function.
- Design a plan for collecting data to answer a particular scientific question.
- Evaluate evidence provided by data in relation to a scientific question.
- Convey findings to an audience.

Your Task:

As a team, consider the question, "How do different diet and exercise claims measure up to addressing the obesity epidemic in the U.S.? " Then, think about the overwhelming information available regarding specific diet and exercise regimens and supplements aimed at weight loss, fat loss, increasing muscle mass, etc. Applying your understanding of how cells generate energy, what nutrients cells require, and how nutrients are transferred between cells, you will design a procedure for investigating a particular claim. You will share your results in a research bulletin and present your findings in a creative, engaging digital format of your choice. Presentations will be posted to a website to be shared with an online audience and an audience of peers and professionals.

Revisions and Check-ins:

Frequent reviews are an important part of the process of creating a high-quality final product. You will participate in a minimum of three reviews during the course of the project. These are the minimum expectations for what you will provide at each review (Record the due dates next to each revision):

#1—Charette Protocol with another team **Date: _______________**

- The beginnings of work samples, such as a rough draft of a report, a storyboard, or a written record of brainstorming
- An outline of your project
- A task list (shared with teacher)
- A professional example from which you will model your project
- Data and some background research collected

#2—Gallery Walk **Date: ________________**

- A complete draft of your work (i.e., a rough cut of a video, draft of an article, framework of webpage)
- A task list with assignments from team members (shared with teacher)
- A rough draft of research bulletin
- Additional research collected

#3—Critical Friends Feedback Protocol **Date: ________________**

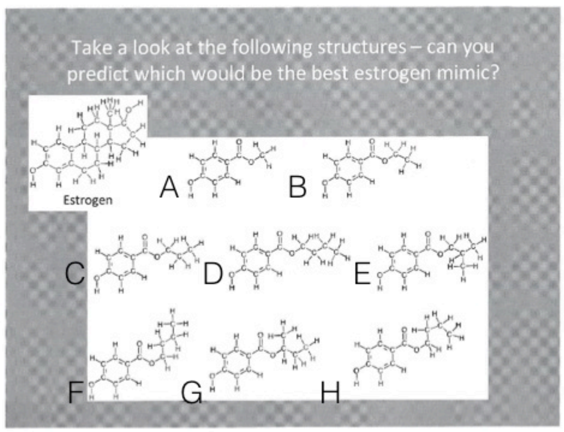
- A complete, functioning, revised draft of your work.
- A task list with assignments from team members (shared with teacher)
- A second draft of research bulletin
- Self-reflection completed (submitted to teacher)

#4—Teacher Conference (optional)

Final Project Due: _______________________

APPENDIX A2: ConcepTest Question Slides
FIGURE 6: ConcepTest Questions
This figure displays the 23 PowerPoint slides used to project ConcepTest questions to the class.

ConcepTest #1



ConcepTest #2

- Which of the following molecules is the body's best source of energy?

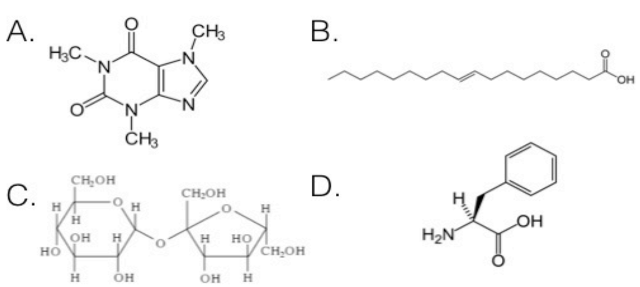
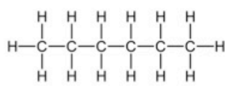
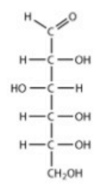


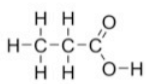
FIGURE 6 (cont'd)

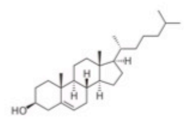
ConcepTest #3

- Based on your understanding of hydrogen bonding, which of the following molecules will interact the best with water?

A. 

B. 

C. 

D. 

ConcepTest #4

- A solution of starch at room temperature does not readily decompose to form a solution of simple sugars because

A. the starch solution has less free energy than the sugar solution.

B. the hydrolysis of starch to sugar is endergonic.

C. the activation energy barrier for this reaction cannot be surmounted.

D. starch hydrolysis is not spontaneous.

FIGURE 6 (cont'd)

ConcepTest #5

- An important group of peripheral membrane proteins are enzymes, such as the phospholipases that attack the head groups of phospholipids leading to the degradation of damaged membranes. What properties must these enzymes exhibit?

A. resistance to degradation

B. water solubility

C. membrane spanning domains

D. lipid solubility

ConcepTest #6

- In which way are prokaryotes and eukaryotes different in how they reproduce?

A. Prokaryotes do not transfer DNA between different cells; eukaryotes do.

B. Eukaryotes only reproduce sexually and prokaryotes only reproduce asexually.

C. Eukaryotic reproduction may involve meiosis; prokaryotic reproduction does not involve meiosis, but may involve conjugation.

D. Eukaryotes and prokaryotes reproduce in the same way.

ConcepTest #7

- Observe the eggs at the front of the room. Predict what will happen to the size of the egg (increase, decrease, no change) under the following conditions:

A. Salt Water

B. Sugar Water

C. Tap Water

D. Distilled Water

FIGURE 6 (cont'd)

ConcepTest #8

- The liver is involved in the detoxification of many poisons and drugs. Which of the following structures is primarily involved in this process and therefore abundant in liver cells?

A. Smooth ER

B. Rough ER

C. Transport vesicles

D. Golgi apparatus

ConcepTest #9

- When we want to know whether a specific molecule will pass through a biological membrane, we need to consider…

A. the specific types of lipids present in the membrane.

B. the degree to which the molecule is water soluble.

C. whether the molecule is actively repelled by the lipid bilayer.

D. whether the molecule is harmful to the cell.

ConcepTest #10

- With a partner, identify each microscope image A-F as a prokaryote or eukaryote and plant or animal (for eukaryotic cells). Record your answers on a whiteboard (1 per group of 2)

FIGURE 6 (cont'd)

ConcepTest #11

- How does the second law of thermodynamics explain the diffusion of a substance across a membrane?

A. The process is spontaneous and entropy increases.

B. The process is not spontaneous and entropy decreases.

C. The process is spontaneous and entropy decreases.

D. The process is not spontaneous and entropy increases.

ConcepTest #12

- A key process in metabolism is the transport of hydrogen ions (H^+) across a membrane. Which arrangement of hydrogen ions allows the H^+ to perform work in this system?

A. When the [H^+] is higher on the outside of the membrane than the inside.

B. When the [H^+] is higher on the inside of the membrane than the outside.

C. When the [H^+] is equal on both sides of the membrane.

D. Both A & B

E. None of the above

FIGURE 6 (cont'd)

ConcepTest #13

- Of the below reactions, which combination would release energy (be exergonic)?

1. ATP + H_2O —> ADP + P_i ΔG=-30.54 kJ/mol
2. Glucose + O_2 —> CO_2 + H_2O ΔG=-2870 kJ/mol
3. Glucose + Fructose + Sucrose ΔG=29.0 kJ/mol

A. 1 & 2

B. 1 & 3

C. 2 & 3

D. None of the choices

ConcepTest #14

- Which process is NOT common to both aerobic and anaerobic respiration?

A. Krebs cycle

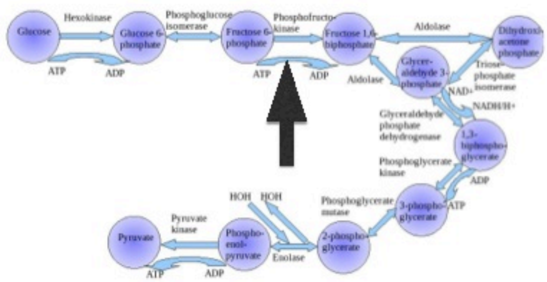
B. Oxidative phosphorylation

C. Oxygen as the final electron acceptor

D. Glycolysis

FIGURE 6 (cont'd)

ConcepTest #15



- Step 3 in the above figure (indicated by the arrow) is a major point of regulation of glycolysis. The enzyme phosphofructokinase (PFK) is allosterically regulated by ATP. Considering the overall result of glycolysis, what would you expect ATP to do to the activity of this enzyme?

A. Stimulate PFK

B. Inhibit PFK

C. Have no effect on PFK

D. Denature PFK

ConcepTest #16

- What are the molecules that conserve most of the energy from the Krebs cycle reactions and how is this energy converted to a form that can be used to make ATP?

A. ATP & Acetyl CoA; They activate enzymes that produce ATP.

B. Citrate & NADH; They provide an initial dose of energy to start the electron transport chain.

C. NADH & CO_2; They accept low-energy electrons from the electron transport chain.

D. NADH & $FADH_2$; They donate electrons to the electron transport chain.

FIGURE 6 (cont'd)

ConcepTest #17

- What cellular process(es) produce the carbon dioxide you exhale?

A. CO_2 released from pyruvate oxidation & CO_2 released during the Krebs cycle

B. CO_2 released from pyruvate oxidation & CO_2 released during the electron transport chain

C. CO_2 released from pyruvate during glycolysis

D. CO_2 released during aerobic respiration

ConcepTest #18

- Which part(s) of the electron transport chain would be interrupted if oxygen was not present?

A. Pumping of hydrogen ions into the inter membrane space

B. Activation of protein complexes

C. Phosphorylation of ADP

D. All of the above

E. A and B

F. A and C

ConcepTest #19

- A glucose-fed yeast cell is moved from an aerobic environment to an anaerobic one. How would its rate of glucose consumption change to be able to produce ATP at the same rate?

A. Glucose consumption would increase to about twice as much.

B. Glucose consumption would decrease to about half as much.

C. Glucose consumption would increase to about 19x as much.

D. Glucose consumption would decrease by about 19x as much.

FIGURE 6 (cont'd)

ConcepTest #20

- In the light reactions, what is the initial electron donor and where do the electrons end up?

A. CO_2 donates electrons and H_2O accepts them to become O_2.

B. Chlorophyll donates electrons and $NADP^+$ accepts them at the end of the electron transport chain.

C. A photon donates electrons and chlorophyll accepts them.

D. $NADP^+$ donates electrons to become NADPH.

ConcepTest #21

- In an experiment, chloroplasts in a solution with the appropriate components can produce ATP. What would happen to the rate of ATP synthesis if a compound is added to the solution that makes membranes more permeable to hydrogen ions?

A. The rate would speed up.

B. The rate would slow down.

C. There would be no change in the rate.

ConcepTest #22

- Why are the large numbers of ATP and NADPH used during the Calvin cycle a good energy investment by a photosynthetic cell?

A. To produce ATP, the cell needs to use some of its ATP.

B. In order to split water and produce oxygen in the light reactions, cells need to invest large quantities of ATP and NADPH.

C. Because glucose stores lots of potential chemical energy, large quantities of ATP and NADPH are required to reduce CO_2 to glucose.

D. ATP and NADPH are needed to produce large molecules like starch and cellulose.

FIGURE 6 (cont'd)

ConcepTest #23

- Explain why a poison that inhibits an enzyme of the Calvin cycle will also inhibit the light reactions.

A. Carbon dioxide would build up to toxic levels within the cell.

B. A lack of G3P production would prevent the formation of sufficient energy for chloroplasts to capture sunlight.

C. If the Calvin cycle stopped, then hydrogen ions would build up across the thylakoid membrane and damage cells.

D. ADP and $NADP^+$ needed for the light reactions would not be formed in high enough quantities from ATP and NADPH if the Calvin cycle stopped.

APPENDIX A3: Unit Reflection Directions and Rubric

Reflective Writing Post Scoring Guide

Directions: Your reflective writing post should be approximately 500 words of text (about 1 single-spaced page), although it can be longer if necessary. It should include pictures or video from class and hyperlinked URL's to relevant websites or online content that relates to what we are learning. It should also be written in the first person with correct grammar and spelling.

In writing your reflection, consider the following questions to guide your thinking:

- What were the main ideas we learned?
- How do the main ideas connect?
- What were some of the important details to the main ideas?
- What activities or experiments did we do that went along with these ideas?
- How did we come to know and understand the ideas we learned?
- What questions do I still have about what I learned?
- How was my participation in the learning?
- How would I rate my understanding?
- What do I still need to work on more?

TABLE 7: Reflective Writing Scoring Rubric

Ratings:	**2**	**1**	**0**
General Description	A post in this category presents a cohesive piece of writing, a well-articulated analysis of the learning that took place during the unit with appropriate detail, and conveys the impact that the learning had on the author with acceptable clarity and meaning.	A post in this category presents an acceptable analysis of the learning that took place during the unit, but lacks depth in explaining the impact that the learning had on the author.	A post in this category presents little analysis of the learning that took place during the unit and may only list the learning activities without addressing the impact that the learning had on the author.

TABLE 7 (cont'd)

	2	1	0
Specific Elements of Reflection	A post in this category exhibits the following: • develops a detailed summary of the learning that took place with well-chosen examples • is focused on how the author was changed by the learning that occurred • connects ideas together • contains one or more embedded URL's, photos, or videos supporting understanding of concepts • demonstrates strength with standard written English and has very few mechanical and grammatical errors	A post in this category exhibits one or more of the following: • relies heavily on a description of what took place in class each day, with few supporting examples • is vague or limited in addressing the task of reflecting on the learning • is weak in making connections between ideas • may contain an embedded URL, photo, or video to help support the author's description of the learning • contains occasional errors in grammar or mechanics	A post in this category exhibits one or more of the following: • provides only a list of activities that happened during the unit • lacks reflective elements, including how the learning connects to other class concepts • provides little or no evidence of understanding • contains no embedded URL, photo, or video to help support the author's understanding • has several problems in language and sentence structure • post was not submitted

APPENDIX A4: Student and Teacher Talk Moves (Socratic dialogue bookmarks)

Student Talk Moves	**Teacher Talk Moves**
-What you just said matches our thinking because… -Why did you say that? Can you explain your evidence? -Could you give me an example? -I'm not sure I understand what you are saying. Could you say it another way? -I hear what you are saying but my evidence said something different… -I'd like to add on to what ______________ said. -I have evidence of what you just said______________________. -Another thing we found that goes with that is… -So, are you saying…? -Going back to what ________________ said about ____________________... Adapted from: Calkins, Lucy. (2001) *The Art of Teaching Reading.* New York, NY: Addison Wesley.	-**Revoicing** ("So let me see if I've got your thinking right. You're saying…") -**Asking students to restate someone else's reasoning** ("Can you repeat what she just said in your own words?") -**Asking students to apply their own reasoning to someone else's reasoning** ("Do you agree or disagree and why?") -**Prompting students for further participation** ("Would someone like to add on?") -**Asking students to explicate their reasoning** ("Why do you think that?" or "What evidence helped you arrive at that answer?") -**Using wait time** ("Take your time…We'll wait") Taken from: Michaels, S., Shouse, A.W., Schweingruber, H.A. (2007) *Ready, Set, Science.* Washington, D.C.: The National Academies Press.

APPENDIX A5:
TABLE 8: PBL Student Project Proposals

What will be your team's final product?	**What is your method for collecting data?**	**Who is your audience?**	**What materials will you need? List any and all necessary materials, including technology needs.**	**What is your research question?**
PowerPoint and tea cups with green tea and labels with our findings	We will analyze someone else's data, and we could use human test subjects, such as having a group of people drink 16oz of green tea a day (this could prove problematic	General public (overweight people and health department)	green tea, computers, paper, people, ourselves, cups, printer, brains, time, wifi, tape	What is the effect of green tea on weight loss and maintenance?
Understanding how the digestive system works and what the juice cleanse does for the body.	Conducting our own experiment	People looking to lose weight	-Juice clense -Human subjects	How does the combination of food in the juice clense affect the body?
We will present our research through a informative and engaging infomercial	We will collate and analyze outside research.	Our audience is composed of people interested in a convenient and rewarding method of weight loss	Computers for research, video taking devices, actors, props.	How does meditation affect weight loss.
Poster and radio broadcast	A combination of both	American teenagers	Poster, Computer for broadcast, camera, lab equipment, food	How does the distribution of consumption throughout the day affect weight loss?

TABLE 8 (cont'd)

What will be your team's final product?	What is your method for collecting data?	Who is your audience?	What materials will you need? List any and all necessary materials, including technology needs.	What is your research question?
10-15 minute intervals and measure heart rate. Separating male and female	Using a timer to measure exercise time, then recording heart rate on a chart that separates male and female.	Athletes,Trainers, and coaches	Timer Human participates Data table Computer IMovie Camera	What are the differences in one's heart rate during anaerobic and aerobic exercise?
PowerPoint	research existing studies	general public	computers	What are the effects of a liquid-only diet vs a liquid/solid food combined diet and do either of them result?

APPENDIX A6: PBL Team Task List

PROJECT MANAGEMENT LOG: **TEAM**	
Project Name:	
Team Members:	

Task	**Who Is Responsible**	**Due Date**	**Status**	**Done**
				☐
				☐
				☐
				☐
				☐
				☐
				☐
				☐
				☐
				☐
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				☐
				☐

APPENDIX A7: PBL Project Feedback Protocols

Feedback Protocols for Reviewing Student Work

Charette Protocol

TABLE 9: Charette Protocol Directions and Timing Guidelines

PRESENTATION Presenter presents his/her work idea to a partner. The partner listens.	3 minutes
FRAMING QUESTION Presenter asks a specific question to frame the feedback. e.g. "What can I make better about…?" How can I improve…?"	1 minute
FEEDBACK Partner gives suggestions. Presenter listens. *Make sure your feedback is helpful, specific, and kind.*	2 minutes
OPEN DISCUSSION Presenter and partner have a dialogue about the suggestions/feedback.	2 minutes
TOTAL	**8 minutes**

Gallery Walk

TABLE 10: Gallery Walk Protocol Directions and Timing Guidelines

SET-UP Hang posters and distribute sticky notes	3 minutes
GALLERY WALK & FEEDBACK Silently record feedback on sticky notes. Offer one or more of the following: ● Praise--Tell why you like it; why it is a strength ● Question--Ask questions about pieces of the work that are unclear ● Polish--Provide suggestions for improvement *Make sure your feedback is helpful, specific, and kind.*	20 minutes
REFLECTION Reflect on the feedback and discuss the Gallery Walk.	5 minutes
REVISION Using the feedback you received, make necessary edits to your work.	
TOTAL	**28 minutes**

<u>Critical Friends Protocol</u>

TABLE 11: Critical Friends Protocol Directions and Timing Guidelines

PRESENTATION Presenters explain their project; Audience listens	5 minutes
CLARIFICATION Audience asks short clarifying questions; Presenters respond	2 minutes
ASSESSMENT Audience quietly uses rubric to assess the project; Presenters wait	1 minute
"I LIKE…" Audience shares what they liked about the project; Presenters listen	3 minutes
"I WONDER…" Audience shares concerns; Presenters listen	3 minutes
REFLECTION Presenters reflect on useful feedback; Audience listens	3 minutes
"I HAVE…" Audience shares ideas & resources for the project; Presenters may respond	3 minutes
TOTAL	**20 minutes**

APPENDIX A8: PBL Project Presentation Reflection

BURN, BABY, BURN PROJECT REFLECTION

After viewing and listening to your peers' projects, respond to the following question. Use the reverse side of this page to record notes on the presentations.

1. If you were in a position to lose weight or get in shape, which method that you heard about would you try & why? Please refer to specific evidence presented.

Topic	Notes

APPENDIX A9: Science Writing Heuristic (SWH) Scoring Rubric

Science Writing Heuristic

Title and Authors:

1 Point

Beginning Questions:

What do you have to investigate or figure out about this concept?
What will be the main questions that will guide your learning?

2 Points

Hypothesis:

Considering what you already know about this concept, write a cause and effect statement that explains what you anticipate will occur.

If ………… then………… due to………… (Must show cause and effect and should explain why you believe this will occur.)

2 Points

Tests:

What tests or procedures will I follow to help answer my questions? (Must include materials, safety, and procedures.)
What are the independent and dependent variables? What are the control and the constants to ensure test validity?

10 Points

Observations:

Observations (qualitative and quantitative) that occurred during the lab should be recorded using appropriate tables, graphs, and statistical analyses.

15 Points

Claims:

State your claim based on your evidence (data collected from observations).
What do you claim to be true?
In this investigation…

Evidence: This is where you use your data to back up the claim you made.

This involves analyzing your tables and graphs.
How can you prove what you are stating? (Back it up)
The claim that when ………, then ……….. (happens)

Refer back to your hypothesis:

The hypothesis was ***supported/unsupported*** *because…*

What procedural changes could you make if you were to repeat the experiment? What follow-up studies could be done?

15 Points

Negotiate: **What do others say about my claim?**	
Internal Sources: In this section you compare your data with *your classmates*. Make sure that you include any examples that may make your ideas clear. **5 Points**	**External Sources:** In this section you compare your data with other *scientists*. Use articles, books, or the internet. Below is an example to cite your sources (APA style): EXAMPLE: Harris, Robert. "Evaluating Internet Research Sources." *VirtualSalt*. 15 June 2008. Web. 20 Apr. 2009. <http://www.virtualsalt.com/evalu8it.htm>. **5 Points**

Reflection: How have my ideas changed?

What did you learn about this concept?
How can you connect this learning to something outside of the classroom?
Are there any new questions you have about the concept?

- *Your thoughts after the experiment (Understandings, Related Thinking, Connections)*
  After conducting this experiment it is ………

- *How has your thinking changed based on internal and external sources?*
  This concept is similar to….. because….
  The evidence shows that …………. to be true…………… and not ……………..because this is what occurred.

10 Points

Total: _______________/65 Points

APPENDIX A10: PBL Self-Reflection

SELF-REFLECTION ON PROJECT WORK **Think about what you did in this project and how well the project went. Record your comments in the right column.**	
Student Name:	
Project Name:	
Was this project interesting to you? Why or why not?	
What is the most important thing you learned in this project?	
What do you wish you had spent more time on or done differently?	
On what part of the project did you do your best work?	
Collaboration:	
How well did your group collaborate? Explain.	
How well did your team make use of time? Explain.	

Anaerobic vs. Aerobic Exercise

Abstract:
All sorts of exercise exist in today's society. However they all can fall under two categories: aerobic and anaerobic exercise. As obesity is becoming an evermore-present problem, many people are increasing health awareness, especially physical wellness. Moreover, our society is obsessed with efficiency and therefore it would only make sense for us to determine the least time consuming, yet most physically vigorous activity. In this experiment, the change in heart rate of participants after exercising is used as an indicator for vigor of an exercise (aerobic or anaerobic). After review of data we find out that any correlations are insignificant. Therefore, neither anaerobic nor aerobic exercise is more vigor than the other or more efficient than the other. To battle this country's obesity, it's important to exercise, anaerobically or aerobically. There are many benefits in performing both types of exercises because each uses different groups of muscles.

Question:

Does anaerobic or aerobic exercise work a heart harder?

Variables:

- Independent Variables: anaerobic and aerobic exercise
- Dependent Variables: heart rate
- Controlled Variables: Duration of time they exercise, duration of time they take their heart rate, static data

Null Hypothesis:

Neither anaerobic nor aerobic exercise will affect the heart any differently.

Alternative Hypothesis:

Anaerobic exercise will result in a higher heart rate and therefore will work the heart harder resulting in a more effective form of exercise.

Research Plan:

There are all styles of exercise. For some toddlers, a game of tag will suffice, some elderly continue to ballroom dance, or some teenagers go for 6-mile runs. Whatever it may be, there are two main types of exercise: aerobic and anaerobic. According to the Harvard Medical School, "aerobic exercise is muscle movement that uses oxygen to burn both carbohydrates and fats to produce energy, while anaerobic exercise is muscle movement that does not require oxygen and only burns carbohydrates to produce energy". In simpler terms, anaerobic exercise, due to the fact that it is exercise done with a substantial oxygen deficit, it can only be done in short bursts. The intensity of the exercise causes the body to have to perform the exercise with low oxygen levels, as oxygen cannot be delivered fast enough to the muscles. On the other hand, aerobic exercise is able to be performed over long periods of time, as the intensity of the activity is lower, which allows oxygen time to get to your muscles to provide the energy necessary to perform the task. Aerobic exercise works to mainly improve cardiovascular health, while anaerobic exercise mainly focuses on improving strength in the large muscle groups in the body, such as the quadriceps and hamstrings. Therefore certain sports such as cross-country or swimming would be considered aerobic whereas weight lifting and sprinting would be considered anaerobic.

Most people exercise to push themselves and make their bodies healthier. Would a certain type of exercise, aerobic or anaerobic work your body harder? This experiment has been designed in order to test the relationship between how hard a person is working, based off of the change from their resting heart rate to their active heart rate, and the type of exercise they are performing (aerobic vs. anaerobic). Resting heart rate is defined as the beats per minute while a person is completely at rest (no motion).

Weight loss typically takes place with an increase in metabolism. Metabolism, or the number of calories the body burns, can be increased due to exercise. Increasing metabolism by exercising daily increases the number of calories that need to be taken in every day. Metabolism is like a balance: if calorie intake equals calorie expenditure, than weight remains constant. However, if calorie intake is lower than calorie expenditure, weight loss will occur. Metabolism can be increased in two different ways: increasing muscle mass, or increasing heart rate, which is the focus of this study. While dietary supplements can be used to increase heart rate, they do so in an artificial way that is often bad for the body. By increasing heart rate in a healthy way such as performing exercise, weight loss can be achieved.

It is harder for the body to perform an activity without the use of oxygen and therefore anaerobic activities are typically associated with more intense activities (activities that will work the heart harder and lead to greater fitness/weight loss). The body needs oxygen for cellular respiration in order to break glucose and oxygen into ATP, the body's usable form of energy. Thus, the body has more energy quickly available for aerobic exercises. Expected results include greater changes in heart rates for those performing anaerobic exercise versus those doing aerobic exercises.

Materials:

- Human Participants
- Human Informed Consent Forms
- Stopwatch
- Computer
- Camera
- Data tables to record results

- Pencil/pen

Procedures:

- Inform all participants of the purpose of this experiment, our methods, the risks, the benefits, and their protection of privacy. Obtain their verbal consent.

<u>Aerobic exercise</u>

- Request that each participant perform a type of aerobic exercise, either long distance running or playing soccer for 5 minutes at their typical work rate.

Soccer

- ★ Have each participant take their own pulse at their carotid artery in their neck for 30 seconds.
- ★ Multiply this number by two, and record it in the data table to get their resting heart rate in beats per minute
- ★ Have the participants play soccer for 5 minutes without any breaks
- ★ When finished, have each participant take their own pulse at their carotid artery in their neck for 30 seconds.
- ★ Multiply this number by two, and record it in the data table to get their heart rate in beats per minute.

Long Distance Running

- ★ Have each participant take their own pulse at their carotid artery in their neck for 30 seconds.
- ★ Multiply this number by two, and record it in the data table to get their resting heart rate in beats per minute.
- ★ Have each participant run around a track for 5 minutes without stopping.
- ★ When finished, have each participant take their own pulse at their carotid artery in their neck for 30 seconds.
- ★ Multiply this number by two, and record it in the data table to get their heart rate in beats per minute.

<u>Anaerobic exercise</u>

- Request that each participant perform a type of anaerobic exercise, either swing dancing or doing jumping jacks for 5 minutes at their typical work rate.

Jumping Jacks

- ★ Have each participant take their own pulse at their carotid artery in their neck for 30 seconds.
- ★ Multiply this number by two, and record it in the data table to get their resting heart rate in beats per minute.
- ★ Have each participant do jumping jacks for 5 minutes without stopping.
- ★ When finished, have each participant take their own pulse at their carotid artery in their neck for 30 seconds.

- ★ Multiply this number by two, and record it in the data table to get their heart rate in beats per minute.

Swing-dancing

- ★ Have each participant take their own pulse at their carotid artery in their neck for 30 seconds.
- ★ Multiply this number by two, and record it in the data table to get their resting heart rate in beats per minute.
- ★ Request participants to swing dance for about 2 songs (a total of 5 min.).
- ★ After 5 minutes, have each participant take their own pulse at their carotid artery in their neck for 30 seconds.
- ★ Multiply this number by two, and record it in the data table to get their heart rate in beats per minute.

Human Participants Research:

- Participants: People of any gender, age, ethnicity, physical and health condition will participate in this experiment.
- Recruitment: Ask peers, friends, and family to participate.
- Methods: Subjects will be asked to give up, at the most, 10 minutes to participate in this experiment. They must be comfortable with exercising, being videotaped, and getting their heart rate anonymously recorded.
- Risks: Extended periods of exercise may cause fatigue.
- Benefits: Subjects will be aiding us in the testing on the effect of aerobic and anaerobic exercise on heart rates.
- Protection of Privacy: Names will not be collected, their data will be plugged into the table anonymously. If not given consent, they will not be videotaped.
- Informed Consent: We will inform participants on the purpose of the study and the procedure of the experiment. Their participation is voluntary and they have the right to stop at any time. By asking each participant to give us their verbal consent, we will obtain their permission to participate in the experiment.

Data & Analysis:

The following graphs display the change in heart rate (in bpm) for each different exercise for each gender.

Statistical Analysis:

Mean (of difference between resting and active heart rate):

$$X = \frac{\Sigma X}{n}$$

Aerobic: 65.958 bpm

Anaerobic: 71.388 bpm

Variance:

$$\text{variance}=\frac{\Sigma(X-X)^2}{n-1}$$

Aerobic: 315.913

Anaerobic: 623.497

Standard Deviation:

$$\text{Standard deviation (S)}= \frac{\Sigma(X-X)^2}{n-1}$$

Aerobic: 17.774

Anaerobic: 24.970

T-test:

$$t= \frac{|X_1-X_2|}{\sqrt{1/n(S_1)^2+(S_2)^2}}$$

t= 0.593

Degree of Freedom:

2(n-1)

Aerobic: dF= 94

Anaerobic: dF= 96

One-Tailed Test:

The alternative hypothesis was directional. We hypothesized that anaerobic exercise would yield a higher heart rate.

Significance:

P=probability that the difference is due to chance

dF= 94

dF= 96

The t-test value was significantly smaller than any of the columns in the table of P values (1.5). Therefore, the data is not statistically significant.

Conclusion:

The null hypothesis (neither anaerobic or aerobic exercise will affect the heart any differently) can be accepted after running t-tests on the data. The slight changes in heart rate when comparing data for anaerobic and aerobic exercise lead to a t-value of 0.593. For the specific degrees of freedom for this experiment, 94 and 96, an acceptable t- value would have been around 1.5 or higher in order for it to be considered statistically significant. This value is very low compared to 1.5 and therefore the data can be viewed as being insignificant. Therefore, there is no correlation between the type of exercise (aerobic or anaerobic) and the change in heart rate (how hard your body worked). Sources of error could include not controlling the experiment enough. It was not possible to require specific diets for each participant. Participants could have easily consumed beverages/food that could give a false reading of their heart rate. Another source of error is the dependence on each participant to be able to correctly take their pulse, some participants may have reported wrong heart rates due if they didn't know how to take pulse. One last source of error includes not being able to regulate the temperature. The data for each activity was taken at different locations with different temperatures (such as playing soccer outside and doing jumping jacks in class). Places where the temperature was low could lead to participants having an elevated resting heart rate due to the cold versus the participants indoors. Although our results lead us to accept the null hypothesis, it wouldn't hurt to obtain more participants (get more data), which would increase our degree of freedom and give us more certainty in our insignificant t-value. Although there isn't a 'better', more 'efficient' way to exercise and reduce obesity, it is still vital to partake in both anaerobic and aerobic activities to better your health wellness.

Acknowledgements:

A huge thanks to all the participants, family, friends, coaches, and teachers for giving up their precious time for this experiment. Special thanks to __________________ for running and doing jumping jacks.

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APPENDIX C: Parent Letter and Consent Form

Parental Consent and Student Assent Form

Dear Students and Parents/Guardians:

I would like to take this opportunity to welcome you to AP Biology and invite you to participate in a research project, Tools for Engagement in Science, which I will conduct as part of the first trimester of this course. My name is Ms. Dusti Vincent. I am your AP Biology instructor and I am also a master's degree student at Michigan State University. Researchers are required to provide a consent form like this to inform you about the study, to convey that participation is voluntary, to explain risks and benefits of participation, and to empower you to make an informed decision. You should feel free to ask the researcher any questions you may have.

What is the purpose of this research? I have been working on effective ways to increase engagement in the classroom and I plan to study the results of this teaching approach on student comprehension of biological concepts addressed by the AP Biology Framework. The results of this research will contribute to my understanding of the best approaches to teaching and assessing science concepts. Completion of this research project will also help me earn my master's degree in Michigan State University's College of Natural Science.

What will students do? Students will participate in the usual instructional curriculum for AP Biology, but with added emphasis on increasing engagement. Students will complete the usual assignments, laboratory experiments and activities, class demonstrations, and assessments (unit tests, projects) just as they would do for any other unit of instruction. There are no unique research activities and participation in this study will not increase or decrease the amount of work that students do. I will simply make copies of student's work for research purposes. This project will take place in the first trimester of 2014-15. I am asking for permission from both students and parents/guardians (one parent/guardian is sufficient) to use copies of student work for my research purposes.

What are the potential benefits? My reason for doing this research is to learn more about improving the quality of science instruction. I will not know about the effectiveness of my teaching methods until I analyze my research results. If the results are positive, I can apply the same teaching methods to other science topics taught in this course, and you will benefit by better learning and remembering of course content. I will report the results in my master's thesis so that other teachers and students can benefit from my research.

What are the potential risks? There are no foreseeable risks associated with completing course assignments, laboratory experiments and activities, class demonstrations, and assessments. In fact, completing coursework will be very beneficial to students. Another person will store the consent forms (where you say "yes" or "no") in a locked file cabinet that will not be opened until after I have assigned the grades for the trimester. That way I will not know who agrees to participate in the research until after grades are issued. In the meantime, I will save all written work. Later I will analyze the written work for students who have agreed to participate in the study and whose parents/guardians have consented.

How will privacy and confidentiality be protected? Information about you will be protected to the maximum extent allowable by law. Students' names will not be reported in my master's thesis or in any other dissemination of the results of this research. Instead, the data will consist of class averages and samples of student work that will not include names. After I analyze the data to determine class averages and choose samples of student work for presentation in the thesis, I will destroy the copies of students' original assignments, tests, etc. The only people who will have access to the data are me, my thesis committee at MSU, and the Institutional Review Board and MSU. The data will be stored on password-protected computers (during the study) and in locked file cabinets in Dr. Heidemann's locked office at MSU (after the study) for at least three years after the study.

What are your rights to participate, say no, or withdraw? Participation in this research is completely voluntary. You have the right to say "no." You may change your mind at any time and withdraw. If either the student or parent/guardian request to withdraw, the student's information will not be used in this study. There are no penalties for saying "no" or choosing to withdraw.

Who can you contact with questions and concerns? If you have questions or concerns about this study, please do not hesitate to contact:

Ms. Dusti Vincent	Dr. Merle Heidemann
Skyline High School	118 North Kedzie Lab
2552 N. Maple Rd.	Michigan State University
Ann Arbor, MI 48103	East Lansing, MI 48824
vincentd@aaps.k12.mi.us	heidma2@msu.edu
(734) 994-6515 ext. 55426	(517) 432-2152 ext. 107

If you have questions or concerns regarding your role as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if desired, MSU Human Research Protection Program at: **irb@msu.edu**

How should I submit this consent form? Please compete the attached form. Both the student and parent/guardian must sign the form. Please return with your a form indicating interest either way. **Please return this form in a sealed envelope (included) to Ms. Vincent's room, B401 by Monday 8 September 2014.**

Parents/guardians should complete this following consent information:

I voluntarily agree to have ______________________________________ participate in this study.

(Student Name)

Please check all that apply:

Data:

________ I give Dusti Vincent permission to use data generated from my child's work in this class for her thesis
project. All data shall remain confidential.

________ I do not wish to have my child's work used in this thesis project. I acknowledge that my child's work will be
graded in the same manner regardless of participation in this research.

Photography, audiotaping, or videotaping:

________ I give Dusti Vincent permission to use photos or videotapes of child in the class room doing
work related to this thesis project. I understand that my child will not be identified.

________ I do not wish to have my child's images used at any time during this thesis project.

______________________________________ ________________

(Parent Signature) (Date)

______________________________________ ________________

(Student Signature) (Date)

Important: Please return this form in the sealed envelope (included) to Ms. Vincent in Room B401 by Monday 8 September 2014.

APPENDIX D: Assessment Tools

APPENDIX D1: Concept Pre-Assessment and Post-Assessment Free-Response Items with aligned learning objectives

Pre-test

Directions:
Respond to each question as completely and honestly as possible.

1. What characteristics do all prokaryotic and eukaryotic organisms share? **(LO 2.14)**
2. What are the major types of macromolecules and their corresponding functions in cells? **(LO 2.8)**
3. Describe the structure of the cell membrane and how it assists with moving materials into and out of cells. **(LO 2.11)**
4. How would a change in the sequence of subunits of a macromolecule affect its function? **(LO 4.1)**
5. Describe the role of enzymes in cellular reactions. **(LO 2.1)**
6. List as many cellular organelles as you can remember and their corresponding functions. **(LO 2.13)**
7. Describe how cells obtain energy. **(LO 2.1)**
8. Compare/contrast photosynthesis and cellular respiration in terms of energy and matter. **(LO 2.5)**

Scoring Guidelines:
0—No response given or "I don't know"
1—Explanation is given, but it is incomplete or demonstrates a lack of understanding
2—Explanation is given and demonstrates understanding of concept

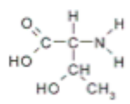
Post-test

1. During an investigation of a freshwater lake, an AP Biology student discovers a previously unknown microscopic organism. Further study shows that the unicellular organism is eukaryotic.
    a. Prokaryotic cells lack membrane-bound organelles found in eukaryotes. However, prokaryotes must perform many of the same functions as eukaryotes. Choose THREE organelles found in eukaryotes and explain how prokaryotic cells carry out the associated functions. (Cells Unit Test long FRQ, 2011 FRQ)
2. The drawings below illustrate monomers or polymers of the 3 types of macromolecules we studied in this unit. (#21 Biochemistry Unit Test)

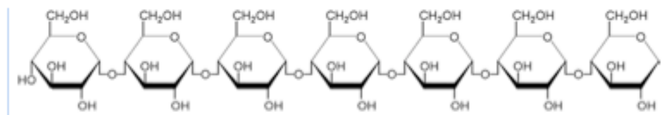
FIGURE 7: Concept Post-Assessment Macromolecule Structure Diagrams

a. Identify the category of organic molecules to which each molecule belongs

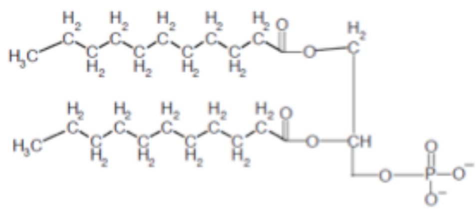
A



B



C



and describe how you identified the molecule.

b. Discuss the biological importance of the organic compounds in relation to cellular structure and/or function.

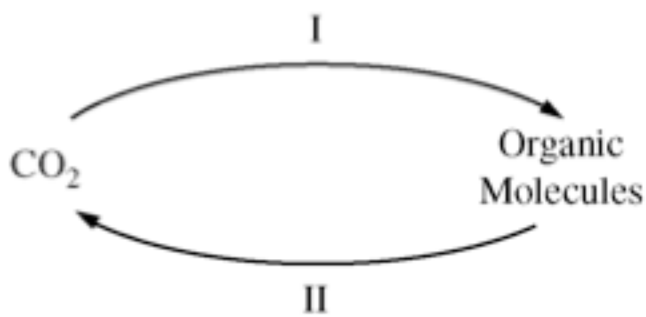
3. Membranes are essential components of all cells.
    a. Identify THREE macromolecules that are components of the plasma membrane in a eukaryotic cell and discuss the structure and function of each in moving materials into and out of cells. (Cells Unit Test short FRQ, 2007 FRQ)
4. <u>Question #1:</u>
   What happens to the shape and function of a protein if one of the amino acids is replaced with a different type of amino acid? (#7 Biochemistry Unit Test)
    a. The protein's quaternary structure will be damaged.
    b. The protein will not change; several amino acids must be altered to have any effect on protein function.
    c. The protein will always denature and become entirely nonfunctional.
    d. Depending on the chemical nature of the amino acid, the protein may lose its function or there may be no measurable effect on the protein's function

   <u>Question #2:</u>
   How might an amino acid change at a site distant from the active site of the enzyme alter the enzyme's substrate specificity? (#18 Biochemistry Unit Test)
    a. by changing the enzyme's location in the cell
    b. by changing the enzyme's stability
    c. by changing the shape of the protein
    d. an amino acid change away from the active site cannot alter the enzyme's substrate specificity

5. <u>Question #1:</u>
   Which of the following statements regarding enzymes is true? (#20 Biochemistry Unit Test)
    a. Enzymes increase the rate of a reaction by lowering the activation energy barrier.
    b. Enzymes change the equilibrium point of the reactions they catalyze.
    c. Enzymes make the rate of a reaction independent of substrate concentrations.
    d. Enzymes increase the rate of a reaction by reducing the rate of reverse reactions.

   <u>Question #2:</u>
   According to the induced fit hypothesis of enzyme catalysis, which of the following is correct? (#16 Biochemistry Unit Test)
    a. Some enzymes change their structure when activators bind to the enzyme
    b. A competitive inhibitor can outcompete the substrate for the active site.
    c. The binding of the substrate changes the shape of the enzyme's active site.
    d. The binding of the substrate depends on the shape of the active site.
6. During an investigation of a freshwater lake, an AP Biology student discovers a previously unknown microscopic organism. Further study shows that the unicellular organism is eukaryotic.
    a. Identify FOUR organelles that should be present in the eukaryotic organism and describe the function of each organelle. (Cells Unit Test long FRQ, 2011 FRQ)
7. Describe how cells obtain energy in the form of ATP. (Cellular Respiration Unit Test short FRQ)
8. Matter continuously cycles through an ecosystem. A simplified carbon cycle is depicted below.

FIGURE 8: Concept Post-Assessment Carbon Cycle Diagram



    a. Identify the key metabolic process for step I, the key metabolic process for step II, and briefly explain how each process promotes movement of carbon through the cycle. For each process, your explanation should focus on the role of energy in the movement of carbon. (Photosynthesis Unit Test short FRQ, 2013 Practice exam)

APPENDIX D2: PBL Assessment Rubric

Burn, Baby, Burn Final Project Rubric

TABLE 12: PBL Project Scoring Rubric

Final unit project rubric to score written and media components

	Distinguished—2	Mastery—1	Novice—0
Content	The team: • Identifies how molecular interactions affect structure and function • Explains the features and mechanisms of cells that allow humans to capture, store, and use energy • Represents the exchange of molecules between a human and its environment • Represents the use of molecules in metabolism, homeostasis, growth, and development.	3 out 4 of the content elements from the "Distinguished" column are met.	2 or fewer of the content elements from the "Distinguished" column are met.
Evidence	• Evidence is thoughtfully chosen to answer the question. • Evidence is integrated into the writing and final product. • A variety of data are represented. • Evidence is quoted and managed thoughtfully.	• Some evidence is thoughtfully chosen. • Some evidence is integrated into the writing and final product. • Some evidence is quoted and managed thoughtfully. • Evidence is somewhat varied.	• Little evidence is thoughtfully chosen. • Little evidence is integrated into the writing and final product. • Little evidence is quoted and managed thoughtfully. • Evidence is not varied.

TABLE 12 (cont'd)

Communication & Clarity	• The thesis fully addresses the research question. • The final product clearly and elegantly communicates the message found in the research.	• The thesis somewhat addresses the question. • The final product communicates much of the message found in the research.	• The thesis is incomplete. • The final product communicates little or some of the message found in the research.
Structure/ Organization	• All ideas and evidence are logically and systematically organized to develop and establish the points of the thesis. • The written structure clearly supports the thesis and reflects professional writing conventions (mechanics, usage, sentence structure).	• Some ideas and evidence are logically and systematically organized to develop and establish the points of the thesis. • The written structure somewhat supports the thesis. • The written structure somewhat reflects professional writing conventions.	• Few ideas and evidence are logically and systematically organized to develop and establish the points of the thesis. • The written structure does not reflect professional writing conventions.

TABLE 12 (cont'd)

Quality of Craftsmanship & Use of Technology	• The final product shows evidence of drafting & revision. • The media chosen to convey message is appropriate and well produced. • The final product is a complete and high quality work sample.	• The final product shows some evidence of revision. • The media used to convey message is somewhat appropriate and well produced. • The final product is a somewhat high quality work sample.	• The final product needs to be revised. • The medium used is not appropriate or produced well enough to convey the message. • The final product is incomplete or a low quality sample.
Collaboration	• In addition to meeting the Mastery criteria, team members describe: ○ challenges to the group effort while completing the task ○ solutions that were used to address the challenges	• All team members contribute to the final product. • All team members provide appropriate oral responses to audience questions, concerns, and comments.	• Some team members contribute to the final product or work is assigned unequally. • Some team members provide appropriate oral responses to audience questions, concerns, and comments.
Citations	• All evidence is cited in the appropriate format. • Citations are integrated into the writing and final product.	• Some evidence is cited in the appropriate format. • Some citations are integrated into the writing and final product.	• Little to no evidence is cited. • Little to no citations are integrated into the writing and final product.

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