STUDENT CONTRIBUTIONS TO OER TEXTBOOKS FROM A SOCIAL LEARNING PERSPECTIVE

A Dissertation
by
SCOTT P. EVANS

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Abstract

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This case study, conducted with an AP Biology class at a rural North Carolina high school, examines what students in the class would add to their OER class textbook when given the opportunity. Students were allowed to add learning objects to the class textbook, which under the Creative Common License, allows for remixing of appropriately licensed material. The goals of the study were to identify the types of learning objects that students would contribute, the processes they use in that decision, and if the social aspects of creating a class textbook lead to enhanced learning. By examining the comments made during the peer-review process and individual student interviews through a social learning lens, evidence was found that supports the idea that creating a textbook in a classroom can stimulate the cognitive aspects of motivation, attention, and memory. The results of the study suggest that the peer-review process employed to evaluate student submissions enhances self-efficacy of the students and helps motivate them to choose high quality submissions. Additional motivation stemmed from the learning objects being added to the textbook with the student's name attached to be used by the next year's AP Biology class. Student choice of the type of resource they could add was valued highly by the participants and was a key driver of student engagement and attention to detail as they chose how to improve their textbook. Memory was enhanced in some students through the process of evaluating and

choosing existing resources to add to the textbook, but was markedly enhanced when a student submitted their own original work.

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Table of Contents

Chapter 1

Introduction and Statement of the Problem

Overview

Open Educational Resources (OER) are an emerging construct in education. OER materials include videos, reports, textbooks, and even entire courses that have been published under the creative commons license (Wiley et al., 2014). The OER materials that I find to be most promising for both college and high school biology students are OER textbooks. These free, peer-reviewed textbooks are most often published as an e-text, but because of the creative commons license, an OER textbook can be copied, edited, printed and redistributed without fear of copyright infringement (Smith & Casserly, 2006). These permissions can be referred to as the 5R permissions: retain, reuse, revise, remix, and redistribute (Bodily et al., 2017).

As both a college and high school science instructor, I believe that a strong biology curriculum is a critical part of a student's education. I am not alone, as an emphasis on STEM (Science, Technology, Engineering, and Mathematics) education has been part of the national conversation since the days of the space race (Dean, 2007; Hoff, 1999; Powell, 2007). Many STEM advocates believe that these professions will be essential to maintaining and advancing quality of life as the human population expands exponentially. Some promising tools for instructors and students in STEM, as well as other disciplines, are the aforementioned OER materials.

OER offers many advantages when used as part of a STEM curriculum. The fact that these educational resources are free to use is the first obvious benefit to consider for an educational institution. The state of North Carolina spent $29 million on textbooks for

students in 2018 (North Carolina Department of Public Instruction, 2019). The public school system where I am employed as a teacher purchased brand new Biology textbooks, despite there being several free alternatives available as OER. Secondly, as will be described later, there are multitudes of other free educational resources to enhance learning in STEM courses. Because of their creative commons copyright, these resources are free to use and can be edited to fit the needs of a course. The nature of OER allows for these things to be combined to produce a learning instrument that goes far beyond the scope of a traditional textbook.

The Problem

Making the transition from using traditionally published textbooks in a classroom to using OER materials can be a time consuming but beneficial process. Researchers, evaluating the adoption of OER materials by 80 community college instructors for their courses, found that while instructors reported spending more time preparing for their course, both teachers and students reported significant cost savings with their OER textbook, and both groups reported the quality of their OER textbook to be equal to traditional textbooks (Bliss et al., 2013).

While there is a plethora of materials available to enhance an OER textbook, teachers often do not have the time to evaluate all of the online learning objects that are available. Additionally, teachers may not know which learning objects that students find most useful as they strive to learn a concept. I believe that many high school students, particularly those I interact with, are adept at using the internet to find information online. Many teachers would agree with this perception of student skills with online research as 75% of 2000 teachers in Advanced Placement (AP) and National Writing Project (NWP) courses say that digital

search tools had a “mostly positive” impact on their student’s research habits (Purcell et al., 2012).

Students could be great resources to find materials that might be useful in an OER textbook used in a classroom. However, little research has been done on student contributions to existing OER materials, and what has been done is largely focused on post-secondary students. It is the absence of this topic in the literature that drives my primary research questions:

1. Given the opportunity, what resources will a class of AP Biology students add to an existing OER biology textbook?
2. Why do students choose the resources and processes they use when reviewing and designing their own OER contributions?
3. How are the cognitive concepts of attention, memory, and motivation impacted by the production and evaluation of Open Educational Resources?

a. How can online interaction help reinforce subject specific stimuli in the form of peer evaluations and peer comments to enhance memory creation and retention?

b. How does creating an educational resource that will be viewed by future students affect student perception of work they produce?

c. How does contributing OER material help students meet learning targets in a biology class?

Definition of Terms

For the purposes of this research, several terms are operationally defined as follows:

- **Open Educational Resource (OER)** – any educational work that is published under the creative commons license.
- **Creative Commons** - a non-profit organization that provides free licenses for creators to use when making their work available to the public.
- **Creative Commons Attribution (CC-BY)** – The license granted by the creative commons which allows for sharing and remixing of work as long as original work is attributed to the original author
- **Learning Object** – Any resource that can be added electronically to an OER textbook.
- **5R-** 5R permissions of OER; retain, reuse, revise, remix, and redistribute of learning objects under the creative commons license.
- **Advanced Placement (AP)** – College Board's registered courses for high school students to earn college credit.
- **Class Textbook** – The OER textbook at the center of this project that students will be modifying by adding learning objects.

Purpose

The purpose of this research is to examine and understand how students and teachers work together to research, choose, and evaluate learning objects that would be added to an OER textbook in a high school AP Biology classroom to provide enhanced learning for all participants.

Importance/Significance of the Research

This research will provide a seminal look at what high school students would add to an OER textbook to make it a better learning instrument. The educational benefits of students helping to design an existing textbook need to be explored for cost saving reasons at a minimum, but also to investigate how that experience translates into successfully meeting learning targets. The social interactions between students as they evaluate each other's submissions may also encourage them to be more conscientious of their own work. This case study will examine the process of obtaining and editing an OER textbook in one AP Biology class. This study aims to describe what types of learning objects students find useful and how they locate said objects. It will examine how students can help in the evaluative process of determining which learning objects can be included to secure the integrity of a modified textbook. The study will also examine how social learning principles apply to students working together to produce an object that will hopefully allow students to perform at high levels in AP Biology assessments. The results of this case study may help direct further proposals for replicating the process at a district or state level, allowing local educational agencies to improve their budgets by replacing expensive static textbooks with interactive free OER textbooks.

Significance to research base

There is a great deal of research on Open Educational Resources. A search of ERIC, the Education Resource Information Center, returns over 1,300 journal articles from 2015 to 2020 that are tagged with Open Educational Resources as one of their subjects. Only a handful explore post-secondary student contributions to OER. No articles have been found that explore the subject of secondary student contributions to OER. The case study presented

in this dissertation will provide the first look into expanding high school pedagogy with the use of the 5R permissions offered through OER in the classroom.

Significance to practice

The biggest advantage to the use of these resources in a STEM classroom is cost savings. The AP Biology class under study has been using the Pearson textbook "Campbell Biology 12th Edition, AP Edition" as a part of that course. A quote for a six-year license for one class of 32 students was $3871.04 (Savvas Learning Company, personal communication, January 22, 2020). In addition to the learning targets set in place, the College Board requires that AP Biology students spend 25% of instructional time performing hands-on laboratories (CollegeBoard, 2020). The costs of equipment necessary to provide students with basic molecular lab experience such as gel-electrophoresis or polymerase chain reaction are very costly. The money spent for the Pearson textbook could be used to provide these materials that could likely be maintained to last longer than six years.

Overview of the Research Method

To answer the research questions presented above, a case study of a single class of AP Biology students at a rural North Carolina high school was completed. This study involved 17 students made up of three juniors and 14 seniors enrolled in the high school, 12 of whom identified as female and 5 as male. The students were asked to provide materials that fulfilled the 5R's of OER that could be included in an OER textbook adopted to be used in conjunction with the traditionally published textbook adopted for the AP course. Students evaluated the materials submitted by classmates for inclusion in the OER textbook using the OER rubric published by Achieve, a nonprofit education reform organization, after each round of three submissions. This was followed by interviews with students about their own

submissions, the evaluation process, and their feelings about their work being featured for future students taking the course.

The purpose of this case study is to explore a novel use for OER textbooks in a high school Advanced Placement (AP) Biology course. This study will be evaluated by drawing on aspects of Albert Bandura's Social Learning Theory and Self Efficacy Theory.

The Proposal

This study will be set up as an exploratory case study to gather basic, initial data that will be available to help identify research questions for larger studies in the future. It will focus on a small group of high-school students in an Advanced Placement Biology course and their engagement with their OER class textbook and each other. Students will examine the College Board's *Big Ideas* for AP Biology and will be asked to make contributions to the textbook by finding, creating, and remixing multimedia materials for possible inclusion in the book. Working together on an online peer-review platform, as well as in the classroom, students will evaluate the collected resources using the Achieve OER Evaluation Tool based on the following criteria: (1) alignment to standards, (2) explanation of subject matter, (3) quality of technological interactivity and (4) opportunity for deeper learning (Achieve, 2014). Students will use the evaluation results to decide which resources will become official additions to the book to be used by the next year's AP Biology class.

The actions that the students take in selecting and appraising items to include in an OER textbook will be examined using Social Learning Theory and Self Efficacy Theory. As AP Biology students move through their year-long course they will be required to contribute with the addition of three resources to the class OER textbook. After each assignment, students will examine and evaluate each other's contributions using an online Achieve

survey. I will follow this up with evaluation of their interactions on the online platforms and individual interviews with the participating students about their experiences with this project.

Context of study

In researching this problem, I found a tremendous amount of literature regarding OER materials had been published, however, very little of it focused on the use of OER textbooks in secondary classrooms. Additionally, there is very little research concerning student contributions to OER textbooks. The idea of asking students to contribute to an OER textbook appeals to me as an admirer of Paulo Freire, the educator who coined the banking model of education (Freire, 2005). In this model, first described in *Pedagogy of the Oppressed*, Freire described traditional educational approaches as acts of depositing, in which valuable knowledge held by the instructor can be poured into student receptacles (2005). In this top-to-bottom relationship, the assumption of the instructor is that students have nothing to contribute on the subject being studied. The narrative character of this type of instruction in the classroom is referred to as the banking concept (Allman, 1994). This failed instructional method is as faulty today as it was when Freire first described it in 1968. Freire believed that dialogue was necessary for true learning to occur. Writing about educational systems, he said, “If the structure does not permit dialogue the structure must be changed” (Freire, 2005, p. 54). Corroborating this, a review of 72 studies focusing on the interactions of digital technology and classroom dialogue found, **“**that affordance, interdependency and dialogue itself are key concepts that frame the social situation in which students build knowledge and meaning with and through digital tools” (Major et al., 2018, p. 2015). OER turns the banking model on its head, granting students freedom to contribute to their own and others’ education.

This brings us back to my primary research question: what would students add to an OER textbook if given the opportunity? The information that students might potentially add to a biology textbook should contain information gleaned from peer-reviewed research. If you search the internet for the age of the Earth, you will find some sources stating 4.5 billion years while others proclaim with authority that this world is only 6,000 to 10,000 years. How does one know which is correct and is derived from a trustworthy source? In the case of biology, post-positivism is a framework often used to make that decision. Post-positivism, where knowledge acquisition is accomplished via the scientific method, directs scientific research and reporting. Consequently, science instructors rely on the authors and peer reviewers of published science textbooks for the empirical evidence which validates the information the textbook contains. This may present possible complications depending on what students choose or design to be included with an OER biology textbook. This potential peril is the one I consider the biggest challenge to this type of project and will be addressed later.

I adopted traditionally published textbooks in my college courses for the peer-reviewed process that led to the inclusion of materials and also as a result of my desire to present a reductionist model of Biology using a post-positivist framework. The fact that many of my own professors had presented the information to me using textbooks probably influenced my decision as well. The textbooks helped me and other students proceed through a biology curriculum in a planned course of study that best enabled us to understand the larger systems at play in the study of life. The reductionist model would have students study organ systems to understand the organism, learn about tissues in order to appreciate organs, engage with cells to know about tissues, and so forth until we get to sub-atomic particles. The

reductionism that is used in science courses introduces students to the parts that make up biological systems, in order to understand the systems as a whole (Godfrey-Smith, 2014).

Knowledge Aquisition

The ontological position of positivism is that universal truths can be elucidated and transcribed through the scientific method of inquiry or through careful observation and inference. The epistemology of positivism believes that the subject under inquiry is independent of the researchers. In other words, facts are discovered and verified through measurements of observable events (Coll & Chapman, 2000). In this type of quantitative research, the methodology of the researcher is considered value free and moral and political stances are rarely part of the reporting process. Many scientists have rejected pure positivism and instead have adopted the stance of post-positivism, which acknowledges that the background, culture and knowledge of the researcher can affect what is observed (Robson, 2002). These philosophies along with the peer-review process used when publishing findings in academic journals helps to ensure that the knowledge being shared is trustworthy. It is essential that these frameworks be observed if material is added to an OER textbook. Without such safeguards in place, a Biology OER textbook could easily become a vehicle for misinformation.

Molecular biology, along with physics and chemistry, is often viewed as a hard science, as much of the knowledge generated in those fields comes from controlled experiments where results may include many decimal points (van de Lagemaat, 2011). However, much of the knowledge found in a biology textbook, especially in sub-fields like ecology, evolution, or animal behavior, is based on observation and inference rather than carefully controlled experiments. This extends beyond the hard sciences into the pejoratively

termed soft sciences. The differences in the type of knowledge generated across academic disciplines comes down to the tools employed to measure or *operationalize* a concept (van de Lagemaat, 2011). Once an investigator has defined what and how he is going to observe and measure the object of interest, the results of that work can be presented to peers in the field. Much of the validity of the knowledge generated, no matter how it is measured, is derived from the peer-review process (Kelly et al., 2014).

It is very important that students understand what information is supported by the peer-review process and what can be discarded as biased or possibly imagined. In my high school, this is often coordinated with the school's librarian, who regularly hosts training sessions for classes. In a survey of public school teachers and librarians, over 90% of teachers and librarians agreed that a major duty of the school librarian, as well as the teacher, was to teach students to "evaluate information for accuracy and reliability before using it for research" (Crary, 2019, p. 58). It will be critical to the integrity of an OER textbook that contributors have training in information literacy.

Quantitative research, while suitable to biological inquiry, will not be useful for the questions I want to address and for the small number of students who will participate in this study. Instead, I will rely on qualitative methods to help answer my primary research question. Sharan Merriam offers this explanation on the difference between the two: "…qualitative research, which takes apart a phenomenon to examine component parts (which become the variables of the study), qualitative research can reveal how all the parts work together to form a whole" (1998, p. 6).

In Chapter 2, an overview of OER research will be presented. The cost savings of OER materials will be covered, along with its history, the types of OER currently available,

and student and teacher perceptions of these resources. In Chapter 3, I will review the methodology employed in this case study and review Albert Bandura's theories of social learning, which were instrumental in its design. Finally, in the last chapter, I will describe the types of learning objects submitted by students and how they fit into the class textbook. I will follow this by an analysis of the participating students' perceptions of the project gleaned from comments during the peer-review process and individual interviews with me.

Chapter 2

Review of Literature

Types of OER materials

Introduction

My first exposure to OER materials was during my time as a community college biology instructor. I was often contacted by traditional textbook publishers about adopting their materials for my classes. A guaranteed way for those publishers to sell numerous textbooks is to get as many professors as possible to adopt their textbook. College students are then obligated to buy those books. Students sometimes have scholarships, Pell grants or their parents' credit card to pay for the books, and without any choice in the matter, they simply pick up a new stack of textbooks each semester. Those that do not have the resources to purchase the textbooks start classes at a distinct disadvantage. I personally witnessed a student in the campus bookstore agonizing over which books he would buy from his required list because he did not have enough money to cover all three. This student was unknown to me, but I could easily imagine many students in the same predicament.

Today, with the advent of the World Wide Web (WWW), the information contained in most introductory biology textbooks is available at the stroke of a few keys or simply by asking your phone a question. Why then do college instructors still require their students to purchase textbooks when the information is free? The answer to this question is probably varied, but I suspect that in addition to the ancillary materials provided by publishers, many professors use them to guide the curriculum for their introductory classes. Additional reasons why instructors may be reluctant to forego the use of a textbook include the intensive process to retrieve this information from disparate locations on the web, the disjointedness of

retrieved information (i.e. not in a traditional curriculum order), and being assured of its trustworthiness.

Textbook Spending in North Carolina

North Carolina spent $31 million dollars on textbooks in 2017 (Public Schools First NC, 2017). With quality OER materials available, much of this money spent on textbooks could be used to support labs in science classrooms, materials for libraries, guest speakers, or other resources that cannot be obtained for free. For college students, the price of textbooks is an additional financial burden that they must bear in order to gain a college degree. Between 2006 and 2014, the cost of an average college textbook rose by 73% (Weisbaum, 2016). A national survey of college students found that 65% had not purchased a required textbook due to price despite the fact that more than 9 in 10 of these students expressed concern that it would negatively impact their grade (Senack, 2014).

I taught in the North Carolina Community College System (NCCCS) for 18 years before transitioning to secondary education. Using conservative estimates of 100 students per academic year and $175 for the required textbooks and lab manuals, my college students spent over $300,000 on textbooks. This expenditure is in addition to their tuition and expenses for other courses. I believe the actual amount that all of my students spent on textbooks is closer to $500,000. It is my desire to help all students, regardless of means, achieve equity in education coupled with my love for the science of biology that led me to investigate a possible solution to this problem. In 2014, I adopted peer-reviewed OER textbooks to be used in my college courses and found them to be on par with traditionally published textbooks. I made the switch initially as a way to help mitigate some of the cost for my students. At the time I thought that OER was a relatively new concept and mainly

involved textbooks. I have since found that the roots of OER extend back 50 years and have evolved to include a much greater offering than simple textbooks.

History of OER

Open education, as opposed to open educational resources, has a history extending back to the late 1960s, with the formation of Open University in London (MacKenzie et al., 1975). In 1973, The Centre for Educational Technology at the University of Sussex developed a project devoted to open learning using the modern media of the time. MacKenzie et al. (1975) wrote about the idea of 'open'.

> The other term, 'open', has many meanings, and the aura of most of them seemed generous and 'charismatic'-open-handed, open-ended, open-hearted, open house, open choice. 'Open' as contrasted with 'closed' carried suggestions of the lessening or removal of restrictions, of exclusions and of privilege; of demolishing or lowering established barriers between subject areas; of enlarging and enriching the areas of activity and experience graded as educational. It symbolized a shift in the relationship between teacher and pupil towards that of student and adviser. (1975, p. 15)

In 1973 it would have been hard to predict the resources and modes of information transfer that we have with today's media and internet. Indeed, it was the proliferation of the World Wide Web at the turn of the millennium that laid the foundation for origins of the OER movement. Since that time, OER has seen rapid growth as more attention is paid to accessibility and the rising cost of education (Goldberg & LaMagna, 2012).

The term *open educational resources* was coined at the Forum on the Impact of Open Courseware for Higher Education in Developing Countries hosted by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 2002 (Hew & Cheung,

2013). At the UNESCO forum, a definition of OER was adopted, "technology-enabled, open provision of educational resources for consultation, use and adaptation by a community of users for non-commercial purposes" (United Nations Educational, Scientific and Cultural Organization (UNESCO), 2002).

The advent of the modern information age and the growth of the World Wide Web (WWW) made the OER movement possible. Along with the Gates and Mellon Foundations, the Hewlett Foundation has provided funding and support for many OER projects, which has helped to grow the field in its infancy (Stacey, 2013). Mike Smith, the director of the Hewlett Foundation, wrote:

> At the heart of the open educational resources movement is the simple and powerful idea that the world's knowledge is a public good and that technology in general and the World Wide Web in particular provide an extraordinary opportunity for everyone to share, use, and reuse that knowledge. (Smith & Casserly, 2006, p. 10)

To be considered a truly 'open' resource, David Wiley initially suggested that four permissions--reuse, revise, remix, and redistribute--must be granted (2010). Reuse covers the ability to keep a backup copy of the content, while revise gives a user the right to adjust or modify the content. Remix will allow the user to combine the content with other content to create something novel. Redistribution grants the right to share with other interested parties. In 2019, to deal with the concept of ownership of OER materials, Wiley introduced a fifth 'R', retain (2019). Retain refers to the rights of contributors of OER materials to make, own and control copies of their content.

Goldberg and LaMagna identify four categories of OERs: textbooks, full package courses, videos, and repositories (2012). The OER textbook category is of the most interest

to me as a classroom instructor of biology, however, a review of the history and explanations of the three remaining OER categories follows in order to provide context before moving on to OER textbooks.

OER Full-Package Courses

There are many institutes and organizations that provide open educational resources as full-package courses. Although the term "open educational resources" was first used in UNESCO in 2002, the origins of the full-package course can be traced to the Massachusetts Institute of Technology (MIT) in the prior year. On April 4th, 2001, MIT announced its MIT OpenCourseWare (OCW) project (Carson, Kanchanaraksa, Gooding, Mulder, & Schuwer, 2012). The MIT OCW project saw the publication of syllabi, assignments, lecture notes, and exams from all 2,080 MIT courses. In 2012, it was estimated that educational materials from this project had reached 100 million individuals (Carson et al., 2012).

The Saylor Foundation offers full-package courses that feature a syllabus, assignments, links to free online articles, and exams (Hilton III et al., 2014). The John Hopkins Bloomberg School of Public Health OpenCourseWare (JHSPH OCW) project has made over 60 courses, symposia, and trainings freely available to the public (Kanchanaraksa et al., 2009). Kanchanaraksa et al. describe the rationale for the John Hopkins decision to move into the OER arena as such:

> To address these disparities of opportunity, educational institutions are experimenting with Open Educational Resources (OER) by making valuable teaching materials and curricular content from academic courses freely available online and explicitly licensed for reuse. These efforts make a body of core and new scientific knowledge, as well as a collection of practical applications, available at no cost to hundreds of

> thousands of individuals who cannot pursue more formal modes of education because of distance, lack of funds, scheduling, and a host of other personal and professional hindrances. (2009, p. 40)

OER Videos

Free videos produced to aid students in learning are a popular category of open educational resources. One of the biggest providers of free educational videos is the Khan Academy. Salman Khan launched his academy in 2008 and as of 2015 more than 440 million free lessons had been viewed (Stegmeir, 2015). The site, containing more than 5,500 video tutorials on various subjects, is used by 29,000 classrooms and attracts more than 10 million users each month in 216 countries (Cargile, 2015). The model used by the Khan Academy challenges traditional methods of learning whereby students sit in a classroom and receive the same instruction at the same speed as their classmates at the schedule of the professor. With Khan Academy, students can simply search for a video when they are ready to learn a new topic. Users can easily track their progress in learning about a particular topic and accumulate points and badges as incentives for participation. Salam Khan acknowledges that great teachers are still central to sound education, but he also believes that the Khan Academy serves as an equalizer in an unequal educational system: “In terms of leveling the playing field, that’s the exact goal. That’s why Khan Academy was founded. That’s why free is part of our mission” (Stegmeir, 2015, p. 26). A Chilean study of college freshmen taking math courses utilizing Khan Academy courses performed as well as students using traditionally published textbooks demonstrating the value of this type of OER learning object (Venegas-Muggli & Westermann, 2019).

Academic Earth is a nonprofit organization that hosts videos from lecture halls around the United States (Goldberg & LaMagna, 2012). Academic Earth is a highly recommended organization that provides an advanced search engine with 32 subject areas (Anderson, 2009). The lectures are typically 45 to 90 minutes with courses containing 20 to 45 lectures. Additionally, the site offers guest lectures from luminaries like Facebook founder Mark Zuckerberg, or Google co-founder Larry Page, on leadership, business, and policy (Bjørner, 2009). Site users have reported a wide variety of uses for Academic Earth. Students have utilized the free videos to supplement their own coursework while instructors have used it to study the delivery styles of other professors (Information Today, Inc., 2009).

OER Repositories

Open educational resource repositories can be described as a library of resources such as learning objects, full-course curriculum, assessment tools, and OER textbooks. One such repository is the Multimedia Educational Resource for Learning and Online Teaching (MERLOT). Created by the California State University-Center for Distributed Learning in 1997, MERLOT is an internet portal aimed primarily at students and faculty in higher education (Orhun, 2004). MERLOT membership is open to all interested educators and there is no cost to members. Each subject area has its own editorial board of faculty from unrelated institutions (Goldberg & LaMagna, 2012). Instructors have the option to upload multimedia materials for their peers to use, but in order to gauge the effectiveness of materials deposited in the repository, a peer-review process is performed (Cafolla, 2006). The peer-review process ensures that the best and most effective tools will be found in the repository. Thamarassen states that the multimedia resources, like those offered at MERLOT, offer

students portability, flexibility, individualized learning, collaboration and community building, and a broader view of the world (2014).

High schools can benefit from two OER repositories - The OER Commons and Achieve - that both focus on aligning OER materials with Common Core State Standards (CCSS) (Waters, 2013). OER Commons offers tools for educators to build interactive lessons for K-12 and interactive modules for higher education. Serving a similar purpose, EngageNY is a repository for Common Core aligned materials run by the New York State Education Department (EngageNY, 2018). There is such a demand for CCSS aligned materials across the country that the fifth most used Common Core curriculum in California is EngageNY (Heitin, 2016).

Another OER repository, iTunesU was started in 2012 (Goldberg & LaMagna, 2012). This application enables the organization of courses lectures, notes, books, and other support materials for a college course (Shedd et al., 2010). Apple provides the iTunesU application through its iTunes store. Users in a first-year class at the University of Queenland found that iTunesU aided their communication capabilities and they found value in collaboration with fellow students (Harrison & Ernst, 2012). While the resources are free, one drawback is that use of the site requires the user to adopt Apple products to get maximum benefit from using iTunesU (Farrow et al., 2015).

Saylor Academy is an OER repository founded in 2008. Its mission is to make the cost of a college education free (Farrow et al., 2015). The Saylor Academy recognizes that two challenges facing OER users are the gathering of resources and assessing their quality. To address this issue, Saylor Academy has reviewed and organized material into a course, allowing a user to take Saylor's Biology 111 without facing the difficult challenge of

assembling the materials themselves (Hilton III et al., 2014). The Institute offers 241 courses with assessments and final exams which, upon passing, earns the student a Saylor Certificate of Completion. Through an agreement with the Saylor Academy, students at California's Brandman University can transfer 21 credit hours in Business Administration and Computer Science for free (The Saylor Academy, 2012). The vice-president of Saylor, Jeff Davidson, cites the benefits of this agreement, saying, "Getting a jump on college credit puts students at a great advantage, and not just financially. Studies show that students are more likely to persist to completion if they arrive at school having already earned some credits elsewhere" (The Saylor Academy, 2012, p. 2).

OER Textbooks

Textbook History

Textbooks have been used since systems of writing and formal schools have existed together. Records indicate that clay tablets, papyrus, scrolls, vellum, and parchment were being used in ancient Greece, Rome, China, Egypt, and elsewhere (Farrell, 2003). Until the invention of the printing press, textbooks were rare and only a very privileged minority of the population had access to them. The modern printing press was first used to mass produce textbooks in Europe and soon spread to the rest of the world during European colonization (Farrell, 2003). The United States, Canada, and Latin American countries all began to produce their own textbooks after achieving independence from their respective colonizers. Often the countries had to 'fix' their textbooks after achieving independence to reflect local history and to remove propaganda from the colonizing nation. Farrell notes that two key points emerge from studying the history of textbooks:

(1) Textbooks are as universal as formal mass schooling-where there are schools there are textbooks (except in some nations so poor that they cannot yet afford universal textbook provision); and (2) textbooks are not just pedagogical instruments-they are intensely political documents whose content reflects a given vision of a people, their history and position in the world, and their values and aspirations. (2003, p. 2552)

Much of this remains true for OER textbooks today. OER textbooks can help to alleviate some of the costs of education for developing nations by providing the books for free. However, if a country lacks the infrastructure to support rapid internet traffic, OER textbook use becomes more difficult, as most are published in electronic format. Because of the Creative Commons license, OER textbooks can legally be electronically copied and distributed via portable storage devices, but a lack of computers or tablets makes their effective use next to impossible. So, while OER offers the promise of free educational materials, the lack of modern computing devices in poorer communities, and the Digital Divide that exists in others, is still an impediment to their effective use. Sylvia Banister relates in a case study reviewing access in 39 poorer countries, that digital access is quite often a luxury that is not funded (2017). The Global Partnership for Education reports that less than 20% of education aid goes to low-income countries and that lack of funding is the number one impediment to education (Rueckert, 2019). There is some room for optimism as to the future of OER materials as smartphones and wireless networks become more ubiquitous. The global average for Smartphone adoption was predicted to be over 60% in 2020, while countries in Africa will be over 50% (Dahir, 2016). An advantage for developing countries is the advent of wireless communication, which is much cheaper for a government to furnish than physically wired infrastructure.

As smartphones become more universal and affordable, more people will have access to a huge pool of free educational resources if their country's internet is allowed to connect to the rest of the world. Some world leaders will surely understand Farrell's second key point--textbooks can be intensely political--and may wish to control what their citizens read. Some subjects, history and economics for example, lend themselves well to being agents of political manipulation.

It is easy to imagine the vast differences that must have existed in history and economic textbooks published in Russia and the United States in the 1980s. All governments intervene in textbook development and distribution to some degree (Farrell, 2003). The extent to which governments interpose themselves in the process varies. In some nations the government is actively involved with the design, production, and delivery of textbooks, while in market-oriented nations, such as the United States and Europe, private publishers handle these three stages almost exclusively (Farrell, 2003).

As a trained biologist, it is tempting to believe that science textbooks can avoid the politicization of textbooks because of the nature of scientific knowledge, but that unfortunately is not true. In 2001, the Department of Education in the State of Alabama placed an insert into all biology textbooks suggesting that "no one was present when life first appeared on earth. Therefore, any statement about life's origins should be considered as theory, not fact" (Schlanger, 2015). Recognized as a problem very early in their use, textbooks were designed to advance political, economic, or religious views (Farrell & Heyneman, 1989). I believe this will be one of the largest challenges for OER textbooks moving forward.

Even with a biology textbook, which strives to present what is measurable and reportable, textbooks will always reflect the vision, national beliefs, inventions, and the dreams of their authors. As a biology textbook strives to report only what is measurable or has not been shown to be false, one of the toughest questions about OER science texts is how to study these unmeasurable aspects that undoubtedly seep into a textbook.

Ease of Use and the Creative Commons

The NCCCS experimented with e-textbooks in several pilot courses during the 2012-2013 academic year (NCCCS Virtual Learning Community, 2014). This pilot study examined published E-textbooks, rather than OER resources, but considering that delivery methods are virtually the same, the assessment results can help predict OER acceptance by faculty and students in the NCCCS. Both groups found the e-textbooks easy to use, noting features such as the ability to search the text, as well as being able to highlight and write reference notes in the text. Students were able to read the text on tablet computers or laptop computers, with most preferring the latter.

Among the negatives cited in the NCCCS study of e-textbooks were issues of digital rights for the books, accessing the book when devices were offline, or incompatibility with some operating devices (NCCCS Virtual Learning Community, 2014). Students would not encounter these problems with OER texts because of the creative commons licensing that governs their use. Traditional textbook publishers want to protect their intellectual work by limiting downloading of the material to a computing device's permanent memory or by requiring certain proprietary programs or devices to view the text book. The goal of such practices is to prevent illicit sharing of their intellectual property. The Creative Commons

license under which OER is copyrighted specifically alleviates these and other problems associated with a traditional copyright.

The Creative Commons is a non-profit corporation that promotes the re-use of intellectual works, including those published specifically for education (Creative Commons, 2017). Their website states "Creative Commons is a new system, built within current copyright law, that allows you to share your creations with others and use music, movies, images, and text online that's been marked with a Creative Commons license" (Creative Commons, 2017). Under a Creative Commons license, authors still retain the copyright to their work, but allow other users the ability to freely copy, distribute, print, or make derivative works, as long as the Creative Commons Attribution license appears at the bottom of every content page (Creative Commons, 2017).

In the e-textbook pilot project, NCCCS students also complained that they were unable to keep their rented e-textbook after the course ended. One in four students said they would prefer a printed text over an e-text, no matter the cost (NCCCS Virtual Learning Community, 2014). The Creative Commons solves both of these reported issues with e-texts, as the student is legally allowed to keep the textbook and print it if they desire to do so. The problem of needing online access or proprietary hardware or software is also eliminated because there is no desire to protect the intellectual property from being shared.

Rice University has created a non-profit publisher for e-textbooks called OpenStax (Wells, 2014). When desired by students, OpenStax can deliver a professionally bound copy of a biology OER text for $41.00, which is less than a quarter of the cost when compared to the pricing of traditional introductory biology textbooks used at NCCCS institutions (Caldwell Community College and Technical Institute, 2017; Central Piedmont Community

College, 2017; Wake Tech Community College, 2017). Students opting to view the book on an electronic platform are able to access the text for free for life, even having access to new editions of the textbook that might be published in the future.

As previously mentioned, the price of college textbooks is a significant contributor to college costs and represents a possible barrier to achieving a college degree. Textbook prices increased 82% from 2002 to 2012 compared to a 28% increase in overall consumer prices (United States Government Accountability Office, 2013). The difficulty in finding research to explain the inflation in textbooks compared to other consumer goods is troubling. The high cost of textbooks prompted Senators Al Franken and Dick Durbin to introduce the Affordable College Textbook Act to the 114th Congress of the United States (United States Congress, 2016). The bill, which did not advance in Congress, was written to provide grants to colleges to explore the use of open textbooks to achieve costs savings for students (SPARC, 2016). Since many students buy textbooks with Pell Grant money, adoption of free OER texts undoubtedly can save students, schools, and the Department of Education money.

Textbook prices are having an effect on students. In a survey of 2,039 students from 150 different campuses, The Student Public Interest Research Groups (Student PIRGs) found that 65% of students had declined to purchase a textbook because of expense even though 55% were significantly concerned and 38% were somewhat concerned that the decision would hurt their grade (Senack, 2014). A survey of 2,574 students conducted in Utah backed up this finding with the majority of students reporting that their academic success was impacted negatively because of the cost of textbooks (Fischer et al., 2020). Student PIRGs also reports that nearly half of the respondents said that textbook cost impacted how many or which courses they registered for (Senack, 2014). Additionally, more than 8 in 10

respondents felt they would do significantly better if the textbook were freely available online and buying a hard copy was optional. This is exactly how OER textbooks are designed.

Evidence of Lower Costs for Students

There are many reports of the cost savings enjoyed by students. The University of Maryland's pilot project with free OER texts was estimated to save 1,100 students a combined $130,000 (Wells, 2014). Georgia Highlands College estimates that they have saved their students $3.8 million over a five-year period with adoption of OER for specific courses (Dixon, 2017). OpenStax, an OER publisher, estimates that 690,000 students saved $68 million in a four-year period based on faculty adoptions (Straumsheim, 2016).

These free resources are particularly important for community college students. Individuals from lower socioeconomic statuses are more likely to choose a community college than their wealthier peers (Provasnik & Planty, 2008). They are also likely to delay entry into college. Bailey et al. (2005) found that 55% of community college students are from the two lowest income quartiles. North Shore Community College saved students $39,000 in one year by adopting OER textbooks in just ten courses (Martinez, 2016). There are many other recent reports of institutions lowering the barrier of student textbook costs by adopting OER textbooks (Miller, 2016; Ravipati, 2016; WSLS.com, 2016).

Peer Reviewed, Current, and Customizable

It is understandable that one might be wary of the legitimacy of a free textbook. However, many OER textbooks are funded by grants from several education foundations to provide free, college level OER introductory peer-reviewed textbooks (Smith, 2012). The peer-review process is absolutely vital to the authorship of any textbook to ensure the validity

of its contents. An amazing advantage of OER e-textbooks is how quickly they can be updated to include the most recent findings in their respective fields. If mistakes are found within the text they can be fixed immediately for all who are using digital copies. With the ability to post related media at the press of a button, links to news stories, research briefs, and scientific announcements can be added to the textbook as they occur.

Remixing of OER offers unique possibilities that traditional textbooks cannot. North Carolina educational institutions would have the ability to customize an existing OER biology textbook to reflect the natural history of North Carolina. While studying botany, all NCCCS biology students could watch one of North Carolina's native Venus flytrap plants in action in their OER texts or learn more about how pollution in their own state affects wildlife. This customization could even be done on individual campuses. Students at Wilkes Community College could have a map in their e-text pointing out the location of the 'living fossil' *Gingko biloba* trees on campus. Appalachian State University recently released a tree inventory of its campus that allows users to identify every tree growing on campus via Google maps (Appalachian State University, 2017). This online resource could be placed in the botany section of an OER textbook, directing users to appropriate living examples on campus. Unfortunately, the ability to customize textbooks also presents some potential problems.

OER Quality Questions

A popular saying posits *you get what you pay for,* alluding to a principle that free or cheaper items lack quality. The issue of quality must be at the forefront of research into OER materials. According to a national survey of higher education faculty, quality concern issues were one of the top barriers to OER adoption by faculty (McKenzie, 2017).

John Hilton reviewed nine published studies on OER's influence on student learning outcomes and only found one instance in which the use of OER was tied to lower student learning outcomes more often than positive results. Because of design differences in the studies he reviewed, he has hesitantly determined that utilizing OER does not appear to decrease student learning, though he does suggest exercising caution (Hilton, 2016). Overall he found no difference in OER materials versus traditionally published resources and asked, "If the average college student spends approximately $1000 per year on textbooks and yet performs scholastically no better than the student who utilizes free OER, what exactly is being purchased with that $1000?" (2016, p. 588).

In a review of rubrics used in evaluating OER, it has been reported that the wide availability of OER does not ensure their quality (Yuan & Recker, 2015). Unsurprisingly, instructors reported that low quality OER wastes their time and hampers instruction. The wide variety of resources available on the internet contains many examples of both high and low educational utility. Min Yuan and Mimi Recker of Utah State University reviewed fourteen rubrics, which all purported to measure OER quality, to reveal a complex picture of OER quality measurement (2015). Rubrics were found to emphasize different areas of OER. Some focused on pedagogical value, some on reusability, and some on aligning with existing educational standards. Yuan and Recker suggest that users decide what aspects of OER are most important to them when selecting a rubric. They also make suggestions for future OER rubric developers, including providing a rating scale, scoring guide, and appropriate training on the use of the rubric (Yuan & Recker, 2015).

Other OER providers rely on the users to provide assurances of quality. The peer-review process employed by MERLOT lets its users rate materials from one star to five stars

(Wiley et al., 2014). MERLOT's peer reviewers are required to be instructors at an institute of higher learning and must demonstrate the following: expertise in their field of scholarship, excellence in teaching, experience in teaching and learning with technology, and connections to professional organization in their discipline. While it is reassuring for the user that the review process is from credentialed academics, MERLOT takes the process further, providing an online training program called GRAPE Camp (Getting Reviewers Accustomed to the Process of Evaluation). These seminars, with people from a variety of disciplines, are conducted both synchronously and asynchronously and show MERLOT's commitment to offering quality educational materials (MERLOT, 2017).

Challenges for OER

Traditional scientific textbooks have always reflected the findings of the scientific community. Individuals are often able to ignore scientific evidence if they feel it refutes their religious beliefs. Evolution is one such area that historically has been challenged by pro-creationism groups (Schlanger, 2015). There have been many court cases pertaining to creationism and education and some of the most important were reviewed to guide biology teachers about court decisions (Moore et al., 2003).

In the case of *Willoughby v. Stever*, the DC Circuit Court of Appeals found that "publicly funded science textbooks cannot be tailored to particular religious belief" (1973). The U.S. Supreme Court found that creation science is a theory that "embodies the religious belief that a supernatural creator was responsible for the creation of mankind" in *Edwards v. Aguillard* (1987). The ability to customize a biology textbook could be abused to reflect the religious beliefs of the instructor over one of the most established and well supported theories in the realm of science. Worse, these religious beliefs may appear to the beginning student to

be an acceptable theory of science if they are found in the student's own classroom textbook. Whether it is the publication of biology textbooks or history textbooks, a group or an individual's own agenda or cultural assumptions will be found in its pages. This has led some detractors to express concern over the impact of OER on global education.

Critics of OER have referred to its spread as cyber-imperialism or pedagogical neocolonialism (Weiland, 2015). Skeptics see the dominance of Western providers of OER materials as a form of academic nationalism in which there is not enough regard for the user's local environment. Wiley, Bliss and McEwan identify localization as one of the least understood aspects of OER, but also rank it as one of the most important (2014). Localization is an effort to re-contextualize content for the actual circumstances in which it is experienced by the user. The act of revising OER to meet language requirements, cultural sensitivities, or readiness prerequisites increases useful access and may be an imaginative educational endeavor (Smith, 2009). One goal of publishing under the Creative Commons license is that OER can be remixed to meet the needs of the learners. This does not mean that a person adapting the material to a different country, for example, has the pedagogical or technological skill to make the needed changes. In an examination of OER localization in Nepal, it was concluded that Westerners do not possess the cultural, religious, and local knowledge that is needed to remix OER for optimal use in Nepal (Wiley et al., 2014). The idea that localization can only be accomplished by a local should encourage OER collaboration with scholars from varied cultural backgrounds.

Sustainability of OER

Centered on the topic of sustainability, a question that should be asked of the open educational resource movement is, *if a movement's goal is to give away things for free, how*

can it be continuously funded? Some researchers have proposed a public radio model with voluntary user contributions (Wiley et al., 2014). Some propose the commons-based peer production method, in which an OER is managed similarly to Wikipedia, where contributors are volunteers and not motivated by financial interests (Benkler, 2007). Khan Academy has been criticized for forming partnerships with Facebook and Google and selling user information to those third-party partners (Education Week, 2014). While this partnership may help to sustain the Khan Academy financially, it brings up serious questions about student privacy.

Hilton and Wiley received permission to review sales data from Flat World Knowledge, a publisher of Open Textbooks (2010). Flat World Knowledge operates Creative Commons License and its books are available freely online. Around 20% of students in classes where a Flat World Knowledge textbook had been adopted purchased a digital product from Flat World Knowledge (Hilton & Wiley, 2010). Around 30% purchased a printed copy through the company's web store, closely mirroring the NCCCS study finding that 25% of students want a print version of the text no matter the cost (NCCCS Virtual Learning Community, 2014). Half the class utilized the resources for free, while the half that did make a purchase averaged $30, much less than the typical $150 textbook. This attempt at sustainability may keep Flat World Knowledge solvent while still operating under an OER model.

Faculty Awareness and Perceptions of OER

Another important consideration of OER is how the primary users, faculty and students, perceive these resources. Understandably, one cannot have a perception of OER if one is unaware of this emerging construct. A 2011 study of educational professionals in

Florida found that 52% had never heard of OER (Morris-Babb & Henderson, 2012). In 2014, a similar survey on a national level found that only 34% of respondents had an awareness of OER and 65% claimed that, while they were aware of OER, they did not know much about them (Allen & Seaman, 2014). According to survey results published in 2020, university professors were becoming more aware of OER, with over 90% expressing willingness to use OER. It is interesting to note that when this survey was broken down by faculty rank, that adjunct and assistant professors were more likely to be open to OER when compared to Associate and Full professors (Fischer et al., 2020). This suggests that younger faculty are more open to using OER as they are more likely to have used OER as students or to have experienced the inflated prices of textbooks. The same survey also noted that less than half of all professors knew the list price of the textbook they had required for class (Fischer et al., 2020). With the disconnect between professors and the costs they are inflicting upon their students, it should be a priority for OER users to promote these resources to help ensure wider usage to help alleviate student costs associated with education. Allen and Seaman do note that, while not all faculty in their survey were familiar with the term OER, some of those were actually using these materials in their classrooms (2014).

Faculty perception of OER is generally positive and indicates that many faculty find OER textbooks to be at least comparable to their traditionally published counterparts (Kelly, 2014; Young, 2016). A majority of instructors using OpenStax textbooks in their courses reported satisfaction with OpenStax OER textbooks (Pitt, 2015). In this survey a majority of respondents said that OER made it easier for them to respond to student needs and often made teaching easier. A majority also perceived an increase in student satisfaction when using OER. In a survey of community college instructors using OER textbooks from Project

Kaleidoscope, 100% responded that they would be very likely to use OER in the future (Bliss et al., 2013). A survey examining OER implementation in the United States, Canada, South America, Africa and the Middle East found that sharing of information and resources was the number one benefit to faculty adopting OER materials for use in university settings (McGreal, 2019). Additionally, this study reported that many universities reported compelling improvements in both teaching quality and content provided.

Some instructors using OER found that personalized learning was a great benefit to teaching as it has allowed them to tailor the materials they presented to students to more effectively couple their instruction to the students' needs (Zhu, 2020). One of the instructors interviewed for this study of OER faculty perspective said this of designing personalized instruction:

> When I'm talking to a student in lab, I adjust what I'm saying to match the student's current level of understanding. If the student has never seen programming before, I don't use advanced programming comments in the way I talk to them. If they've never seen a circuit before, I don't use jargon. I've learned how to say things without using jargon. (2020, p. 262)

The application of this approach to OER is that an experienced high-school teacher can take materials from advanced, college level OER textbooks and remix or revise them to suit the needs of their students.

Student Perception of OER

Student perception of OER textbooks is also generally positive. In a review of the Project Kaleidoscope OER textbooks, only three percent of students indicated that the OER text adopted by their professor was worse than the quality of textbooks in their other courses

(Bliss et al., 2013). Echoing this finding, only 31 of 231 users found their OER statistics book to be of worse quality than their other textbooks (Illoswky et al., 2016). Hilton points out that student perceptions of OER may be colored because of the significant amounts of money they saved or the expediency of not having to carry a heavy book with them (2016). It may be that cost-savings or convenience influence perception more than the learning value of the OER materials. One recent study of the emotions students felt when using OER to expand what their required textbooks contained found that student's initially felt positive when they reflected upon their own learning needs (Zhang, 2020). Some students who felt negatively toward the use of OER transitioned to positive feelings after teacher mediation and as their own knowledge levels started to rise.

Future of OER

Open Educational Resources are a growing construct in the field of education. OER use around the world is growing. Over 150 universities in China are engaged in the China Open Resources for Education Initiative with 450 courses; 11 Universities in France have formed the ParisTech OCW project with 150 courses; and nine of Japan's most prestigious Universities participate in the Japanese OCW project with 250 courses in Japanese and 100 in English (Hylen, 2017). OER use is emerging in universities in Australia, Brazil, Canada, Hungary, India, Iran, Ireland, the Netherlands, Portugal, Russia, South Africa, Spain, Thailand, the UK, and Vietnam. The spread and popularization of OER will likely continue to expand for the foreseeable future.

In the United States, the Department of Education started requiring intellectual property created with Departmental funds to be published with an open license (U.S. Department of Education, 2015). This is part of an endeavor called #GoOpen that supports

states, districts and educators by advocating the use of OER to change the way we learn and teach (Office of Educational Technology, 2019). As of January 2019, #GoOpen had welcomed 100 school districts and 20 states as official participants who are sharing, editing and downloading lessons for free (Brown, 2019).

Future research in OER materials still needs to address quality concerns. To limit some of the potential biases of students against a free textbook, a side-by-side study could be launched. It would be difficult to ask students to compare two entire textbooks, but a more limited study may be useful to address questions of quality. For example, a biology class studying aerobic respiration could be presented with chapters covering this topic from two different textbooks. This could even be done blindly so that students do not know which text is OER. This could help mitigate some of the bias that may come from the convenience and free-price of the OER text.

Wiley, Bliss and McEwan suggest two areas of OER where further research is needed: open education policy and open assessment (2014). The Open Policy Registry has a collection of national, state, province, and institutional policies relating to OER (Creative Commons, 2017). The codification, adoption and impact of OER policies will govern how easy, or how difficult, sharing of OER materials will be and demands ongoing research.

Chapter 3

Method

Restatement of the Problem

Open Educational Resources present great opportunities for education. As shown in the literature review, OER materials have been used to lower the costs associated with education without sacrificing quality of the materials or negatively affecting student performance. Faculty perception of these books is generally high and faculty and students report no issues with using them in their classes when compared to traditionally published textbooks. Many universities and colleges have adopted OER textbooks with teachers and academic departments modifying these textbooks for their courses. The simplicity of the CC-BY license and the ability to employ the 5R permissions (retain, reuse, revise, remix, and redistribute) provide the opportunity for truly unique textbooks to be provided to students for free.

Significance of Problem

While research on the use of OER continues to expand, there has been very little that has examined what students would add to a textbook to support their learning. As a long-time science teacher, I have had great interest in not only using OER textbooks to lower costs for students, but also to provide them with a textbook that offers more resources of varying types when compared to a traditionally published textbook. As I pondered the items that I thought would make a classroom textbook better, I realized that if I alone made the choices, that I would be closer to Freire's banking concept of instruction than I wanted to be. It struck me that asking students to help decide what would make their textbook more beneficial would open the dialogue that Freire believes is necessary for true learning.

I believe that students, especially those with free access to digital tools and consistent internet connections, could play an influential role in helping to improve the educational tools they use. To provide some insight into what students find as appealing and useful entries in their textbooks, I started a case study with high school AP Biology students to answer questions about what they would select to add to a class textbook and the processes surrounding those choices.

Methodology

A case study is both a research process and a product of a qualitative investigation. One definition presented for a case study being a process is as follows: "a case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 1994, p. 15). OER will be the contemporary phenomenon as I investigate how student contributions to a biology textbook will aid student learning. The distinction between what students contribute and what they gain from the activity is difficult to define.

Case studies have also been defined in terms of an end product: "a qualitative case study is an intensive, holistic description and analysis of the single instance, phenomenon, or social unit" (Merriam, 1988, p. 21). This case study will produce a seminal look at what emerges from a high school biology class as they adopt and add to their OER textbook. Case studies are also used when the researcher is unable to manipulate the behavior of the subjects involved in the study (Baxter & Jack, 2008).

A successful case study will have five important components: the research questions, study propositions, a unit of analysis, linking the data to the proposition logically, and the criteria for interpreting the data generated in the study (Yin, 2014). Research questions that

ask “how” or “why” are often best served by conducting a case study. The questions addressing how students will perform when adding to an OER textbook and why they went about it in the manner that they did make a good fit for a case study. Below, I will discuss Yin’s five important components as well as a brief introduction to Bandura’s social learning theory and self-efficacy theory.

Restatement of Research Questions

1. Given the opportunity, what resources will a class of AP Biology students add to an existing OER biology textbook?
2. Why do students choose the resources and processes they use when reviewing and designing their own OER contributions?
3. How are the cognitive concepts of attention, memory, and motivation impacted by the production and evaluation of Open Resources?
    a. How can online interaction help reinforce subject specific stimuli in the form of peer evaluations and peer comments to enhance memory creation and retention?
    b. How does creating an educational resource that will be viewed by future students affect student perception of work they produce?
    c. How does contributing OER material help students meet learning targets in a biology class?

Study Propositions

Students in science classes at the high school where I will conduct this study are often assigned multi-media projects as a part of their coursework. Project based learning will not be a new type of assignment for these students. However, one key difference for the work students will do as they contribute to the OER textbook is the audience. Students are used to

creating work that will be seen by the teacher and they sometimes must present the work to their peers through classroom presentations. However, with OER, their projects will become part of the textbook used in the course with their names still attached to their work. One of my propositions for this work is that students will be more eager to produce quality work when they know their underclassmen peers will be seeing their attributed work in future semesters. I also propose that since students will be evaluating each other's work, they will incorporate the best examples and ideas they see into their own work. My last study proposition is that students will be able to better meet, and recall, the specific learning targets for the biology course when they contribute to the Biology class's OER textbook. Stating the specific study proposals will help in defining the case and help to prevent the researcher from trying to cover "everything" (Yin, 2014).

Designing a case study should allow the researcher to plan how to start with a set of initial questions and get to a place where they can be answered. To help guide the researcher in the planning and implementation of the study, a theoretical framework must be chosen and employed. Summed up by Becker, "We couldn't work at all if we didn't have at least an implicit theory of knowledge; we wouldn't know what to do first" (1993, p. 221).

Unit of analysis

Yin suggests that designing a case study includes the fundamental step of defining the 'case' under study. In choosing the units of analysis, the researcher considers two distinct points: defining the case and bounding the case (Yin, 2014). For my case study the case is defined by what is learned from the student participants. As the research questions I have asked focus on students and how their perceptions of their work might be influenced by

participating in biology class, not simply as a student, but as a contributor to the class textbook, it is essential that I learn as much as I can from those students.

Binding the case provides resolution to the subjects chosen as the units of analysis. In this proposed study, the students in an AP Biology class in a public high school will be the subjects of interest. These students will create works for an OER textbook in the first semester they are enrolled in the class. As students relay their experiences in interviews conducted by me and through their interactions with one another via the peer evaluation and review process, I will have means available to help me answer those questions. Once units of analysis are in place, a logical way to link the data to the study propositions is the next step in the design process.

Linking the data

Defining how I want to link the data generated to my study propositions will help create a solid foundation to analyze said data after conducting the study (Merriam, 1998). The first of my propositions is that students will be keener to deliver a higher quality of work when they are cognizant of the fact that their underclassmen peers will see what they have authored in their textbooks. The second proposition predicts that student contributions, especially after the class completes the first set of OER materials, will integrate the finest examples from their classmates in their subsequent contributions. The last proposition is that, upon supplementing the OER text with their own work, students will be better able to remember and demonstrate their understanding of the specific learning targets of their biology course.

To help determine the validity of these propositions, I will employ the semi-structured interview process with the students to see what themes emerge when interviews

are analyzed. Additionally, I will examine the temporal sequence of their work using the data collected from the Achieve OER evaluation tool. This evaluation tool will allow the students and instructors in the course to assess the OER material produced for alignment of standards, justification of using material for particular subjects, capacity for technological interactivity, and connections to deeper learning (Achieve, 2014).

Criteria for interpreting

To help guide my research questions and analysis, I chose to use Social Learning Theory and Self Efficacy Theory. These two theories were first proposed by Albert Bandura in the 1970s and present the notion of imitative responses as a key component of social learning (Deaton, 2015). Deaton says that "if anything can be taken from Social Learning Theory, it is this-for better or worse, people observe, imitate, and model the behavior of others" (2015, p. 1). My research question "How are the cognitive concepts of attention, memory, and motivation impacted by the production and evaluation of Open Resources?" is derived from readings on Social Learning Theory.

Self-Efficacy Theory essentially holds that choice of activities, effort, and persistence are guided by one's notion of self-value. Students with low-self-efficacy will avoid tasks while those that believe they are capable will participate more enthusiastically (Taniguchi et al., 2017). Bandura posits that experiencing personal mastery of a topic is one of the biggest builders of self-efficacy. Additional sources of self-efficacy come from observing others that are successfully fulfilling a task and receiving other people's verbal encouragement (Bandura, 1997). The concept of ability, whether it is acquirable or innate, also influences one's self-efficacy. If people believe that ability is acquirable, they are more likely to engage in a challenging task.

Often when interpreting a quantitative study, results are analyzed using a statistical approach. By convention, a *p* level of less than .05 demonstrates that observed differences are statistically significant. In a qualitative study, an alternative strategy is needed to evaluate the validity of conclusions. One method of addressing a qualitative study's results is identifying and addressing rival explanations for the results (Yin, 1994).

Bandura's theories are met with resistance from the behaviorist and developmentalist camps. According to behaviorists, observational learning can be explained by operant conditioning (Clark, 2018). Behaviorism, also known as *stimulus-response theory*, would not ascribe learning as a thinking or mental activity, but simply as the acquisition of new behaviors (Pritchard, 2005). Whereas Bandura believes that "Reinforcement does play a role in observational learning, but mainly as an antecedent rather than a consequent influence. Anticipation of reinforcement is one of several factors that can influence what is observed and what goes unnoticed" (Bandura, 1977, p. 37), behaviorist James Mazur concludes that "reinforcement is not essential for learning but it is essential for the performance of learned behaviors" (1994, p. 294).

William Crain, representing developmentalists, writes that adherents of Piaget's theory of cognitive development often express disagreement with Bandura's theories (2000). Piaget's theory, considered a developmental stage theory, hypothesizes four stages of cognitive development. The Sensorimotor Stage states that infants are only aware of items directly in front of them. It is not until around 8 months of age that infants comprehend that objects still exist, even when they cannot be seen. This important breakthrough, known as object permanence, is a sign of a developing memory (Kohler, 2008). The Preoperational Stage involves a child's ability for symbolic thought. Thinking for children is still based

upon intuition as they are unable to comprehend concepts such as time, analogy, and cause-effect relationships. The third stage, known as the Concrete Operation Stage, lasting roughly from the ages of seven to eleven, is when they develop reasoning. During this stage, children progressively become more conscious to external events and begin to understand that their own thoughts are unique and not necessarily shared by others. The last stage in Piaget's theory is the Formal Operation Stage. Onward from the age of eleven, children become able to use symbolic thought to understand abstract concepts in science and mathematics. Piaget wrote that lifelong intellectual development does occur, but such development depends on the agglomeration of knowledge (Crain, 2000).

Developmentalists do not accept that children learn in order to earn reinforcements but rather learn in response to intrinsic interest in the novel subjects. Bandura would argue that a child's underlying interest does not develop until they outperform their own standards for achievement. Bandura also disagrees with the developmentalist notion of learning due to exposure to novel events, arguing that if such were the case, they would be learning constantly, which he observed was not the case.

Exploring these alternative theories to Social Learning Theory will be helpful in determining if the propositions of this study can be explained by virtue of Bandura's theories. Even once alternative theories have been evaluated, researchers must be able to show the trustworthiness of their findings.

Trustworthiness in Case Study Research

Critics of qualitative research argue about the validity of case study research. To address the concepts of validity and reliability that cannot be met in a case study as they would be in a positivist model, Egon Guba proposed criteria by which to judge

trustworthiness of naturalistic studies. The constructs he suggests are credibility, transferability, dependability, and confirmability (Shenton, 2004).

In order to show that their study measures or tests what was intended by the study, positivists will seek to show internal validity (Guba, 1981). They seek to avoid confounding their study by ensuring that only the independent variable presented is responsible for the cause and effect reported. Alternative causes must be accounted for to link what the study tested and the results that were seen. Once they have been eliminated, the results of an inquiry can be validated. In qualitative work it is not always possible to eliminate other causes as reasons for observed phenomena. Yin acknowledges this by counseling that case studies should emulate procedures from previous successful projects (2014). Additionally, credibility can be enhanced by triangulation of different methods of data collection. Observation of students, review of student work submitted in the project, analysis of comments during the peer-review process, and interpretation of interviews all may have shortcomings on their own, but when combined add strength to findings that are elucidated from all four.

It is also important to help ensure that the participants are honest when contributing to the study, to the extent possible (Shenton, 2004). To aid in this endeavor, participants must be given the opportunity to refuse to participate, ensuring that only those who are genuinely willing are adding to the data collected in the study. Honesty in interviews can be enhanced when participants and the researcher have a good rapport. This can be accomplished by a frank discussion about what the researcher is studying and indicating that there are no right or wrong answers, allowing the participants to contribute without fear of feeling repercussions from their input. Additionally, iterative questioning may be employed to

uncover purposeful lying. By multiple interviews and rephrased questions, falsehoods may be distinguished and discarded by the researcher.

Transferability tries to account the extent to which the results of the study can be applied to other situations (Merriam, 1998). Positivists want to demonstrate that results of their work can be applied to a wider population or phenomena. The size and specific environment of a case study often precludes a straight transference to other situations and populations. However, if there is enough contextual information included in the case study, readers can make the transfer themselves (Shenton, 2004). By highlighting the boundaries of the study, similar projects conducted in different environments can add to the knowledge base being generated. Information presented in this context should report the number of organizations participating, any constraints on the participants that contributed data, the number of people in the study, data collection techniques (including the quantity and length of sessions), and the time period of the data collection process (Shenton, 2004). Although transferability is an important factor, it must be recognized that, fundamentally, case studies must be understood within the framework of when, where, and how they were conducted (Gomm et al., 2000).

The third area that can lend trustworthiness to a case study is dependability. Positivists use techniques that are designed in such a way that if the study were repeated that the results would be similar, provided that the same methods, techniques, and participants were used. Such methods are impractical for case studies, as case study "published descriptions are static and frozen in the 'ethnographic present'" (Florio-Ruane, 1991, p. 42). To tackle the dependability issue of qualitative work, the resulting work should include details on the research design and implementation with thick descriptions of how it was

planned and implemented. Detailing the minutiae of how the data was collected during the study will provide opportunity for reflective appraisal of the study by the investigator. This serves to gauge the effectiveness of the actions taken during the execution of the processes employed during the study (Shenton, 2004). There are close ties between credibility and dependability, and a thorough presentation of the former will give credence to the latter (Guba, 1981).

Lastly, confirmability must be assured. While the instruments of measurement used in quantitative work offer some detachment from human perception, the processes used in qualitative work will inevitably be intruded upon by the researcher's biases (Shenton, 2004). To combat this bias, great care must be taken to establish that the findings are the consequence of the participants' rather than the researcher's ideas and predilections. A crucial precedent for the qualitative researcher toward confirmability is to concede their own predispositions. Toward this end, Shenton recommends an "audit trail" that will allow readers to follow the steps and situations taken to ascertain how the results emerging from the work may be acknowledged (2004). A description of the audit trail will provide a way for readers to chart the direction of the course of study step-by-step by outlining the choices made with an explanation of the scheme that was followed. This can be accompanied by the author's acknowledgement of the study's deficiencies and possible effects owing to those deficiencies.

I have a great deal of faith in the opportunities for learning that can come from the use of OER textbooks and providing students with a way to add to them. Through careful planning and analysis of credibility, transferability, dependability, and confirmability, I intend to add to the growing body of knowledge concerning OER materials in education.

Limitations of the Research

The primary limitation of this case study is its small size, along with the participating school's demographics. I am only examining one class of students from a small rural North Carolina high school that provides both Chromebooks and home internet connections to students who need it. These results may not be generalizable in other contexts.

Theoretical Framework

To provide structure in qualitative research, an investigator employs a theoretical framework. The idea, or group of ideas, that compose the theoretical framework helps to guide studies, provide pathways for new perspectives, and to find connections that weren't apparent at the outset. In choosing a theoretical framework, several strategies have been suggested. One should examine the research problem, brainstorm what to consider as the key variables in the study, review related articles, and review key social science theories so their assumptions and propositions can be compared (USC Libraries, 2019).

This research project is designed to address what students will contribute to an OER textbook and how that contributes to their understanding of Biology. I initially investigated Critical Social Theory as a way to frame my investigation. In education, the term critical social theory (CST) describes scholarship that critiques domination and subordination, promotes emancipation, and uses cultural and social analysis combined with critique, interpretation, and social explanation. Zeus Leonardo argues "the multidisciplinary knowledge base of CST affirms the role of criticism as bound up in the definition of a quality educational experience" (2004, p. 11). My social views on education are neo-Marxist and I believe that education should be free. It was with this in mind that I was first attracted to

OER. While I think CST can be useful in evaluating research proposals looking at student contributions, it is more slanted toward the freedom that OER provides to educators. I was more interested at what was happening at the student and classroom level, than at the societal level.

To evaluate the perceptions and perceived benefits from students in this project, Social Learning Theory and Self Efficacy Theory will be employed. Social learning theory explores how learning takes place when people observe the behavior of others. Bandura suggested that observation, modeling, and imitation play major roles in learning (1977). His theory of self-efficacy is drawn from the aforementioned theory and examines student persistence and motivation to be (Bandura, 1997).

Bandura believed that, to be successful in an educational environment, students must be able to cultivate "the ability to regulate their own motivation and learning activities" (Bandura, 1977, p. 21). He believes that expectations and behavior transect to affect motivation, either positively or negatively, to engage in a particular endeavor. He states that students engage in behaviors when they expect that doing so will lead to positive outcomes.

Even before Bandura's ideas about the social aspect of learning, people were aware that learning did not occur in a vacuum (Grusec, 1992). History is full of stories of people observing, imitating and modeling the performance of others. Contemporarily, one just needs to examine social media platforms to see the same interactions at work. To paraphrase Erving Goffman, social media provides a stage for all the world, and men, women, and children (1956).

In the field of education, the importance of this has broad implications and possibilities. Social media can be used in almost all content areas to enhance learning and

encourage students to employ critical thinking about the world around them (Callens, 2014). The paradigm of social media furnishes a sandbox where players imitate behaviors and find encouragement and reward for doing so (Tur & Marlin, 2015). With the technological advances that are available to students today, the old paradigm of one-way communication, akin to broadcasting, is gone. In the social media age, communication tools have become two-way, five-way, or even hundred-way interactions that are ubiquitous, enveloping, and reciprocal. Numerous studies have investigated the application of social learning theory to social media in the classroom and have shown how they can enhance attention, memory and motivation (Deaton, 2015).

Attention

Attention is an important variable affecting whether a learning goal is internalized by a student. The student's sensory capacity, arousal level, perceptual set and past reinforcement affect their ability to be attentive (Deaton, 2015). For a social learning activity to be productive, it must be attuned to a student's internal characteristics of perception. Teachers know that simply calling a student by name often snaps them to attention when engagement is expected. Social media is exceptional at summoning a student's attention through the myriad of voices across the virtual landscape. Social media can provide a platform for sustained attention, granting an interactive model that facilitates the sharing of user-generated knowledge (Casey & Wells, 2015). Integrating social media environments into the classroom opens up many opportunities to facilitate learning rather than by simply watching, listening and memorizing. Casey and Wells' 18-month action research offered evidence indicating that participatory media provides an active student-centered learning environment that allows for knowledge growth and not simply knowledge propagation (2015). It is hoped that the online

peer-review process utilized in this study will advance the student learning process similarly by helping to maintain attention through a learning activity.

Memory

Theories surrounding the development of memory include behaviorist and cognitive approaches. Behaviorism emphasizes the role of external factors that influence behavior, while minimizing or separating the innate or inherited from the equation (McLeod, 2017). A cognitive approach often employs models of the mental processing that goes on inside peoples' minds (McLeod, 2015). Social learning theory provides a bridge between the two disparate views of memory formation. With a continual flow of material, it is not sufficient to simply pay attention to the social aspects of education; true learning requires external stimuli and the ability of memory engrams to be encoded by the brain (Deaton, 2015). The hope is that students will be able to recall these memories and apply them in situations external to the environment in which they were learned. Symbolization, in social learning theory, refers to the learner's ability to create mental images and memories from momentary sensorial experiences (Ponton & Rhea, 2006). These temporary experiences are augmented by social interaction, both online and live, through a variety of visual and physical stimuli that work together to create lasting memory. I believe that the materials that may be created or added to the Biology OER textbook, including graphs, videos, charts and graphics, combined with the social interactions involved in the peer-review process, will enhance memory creation and retention.

Motivation

Self-efficacy, or motivation, plays a central role in Bandura's theories of social learning. In terms of social learning, a learner's beliefs about the influence they can have on

the world are preeminent to realizing that impact. Students are more likely to put more effort toward a goal if they believe in their ability to achieve that goal (Deaton, 2015). To illustrate this, one can imagine a student with high self-efficacy and one with low self-efficacy at a high-school dance. Both may desire to dance, but sociological influence may lead each to contemplate the perceived impression that such activity will have on their social standing. The analogy can be applied to student engagement in the classroom. If one believes that engaging in an activity will result in a favorable outcome, they are more likely to put forth extra effort. Bandura believed that learning is primarily a social undertaking and therefore is more likely to take place when sociological factors lead to positive reactions. Students take part in learning based projects, but often the only viewers of these works are the student and the teacher. In an OER book, learning projects can find a permanent home and will be seen by student's peers immediately, as well as in the future. I believe that Bandura's social learning theory predicts that students will put forth greater effort and are more likely to exhaust resources when producing work that will be attributed to them in a biology textbook.

Context of this Study

This study took place at a local North Carolina secondary school. Students enrolled in an AP Biology course were asked to participate. The project was explained to students, and their legal guardians if they were under the age of 18, and they were asked to sign consent and assent forms prior to taking part in the study. Interviews with participants were scheduled outside of normal class time.

Students were asked to contribute their own work or learning objects they believed would benefit readers of the OER biology textbook, or class textbook, as ancillary materials designed to better understand key concepts presented in the course. Prior to the study taking

place, I envisioned that students might submit their own artwork, any number of printed materials, interviews with professionals, charts, diagrams, audio recordings, video recordings, visual displays, or computer animations. Students evaluated their classmates' submissions with selected components of the Achieve OER Evaluation Tool based on the following criteria: (1) alignment to standards, (2) explanation of subject matter, (3) quality of technological interactivity and (4) opportunity for deeper learning.

Student ratings and remarks using the Achieve OER Evaluation Tool were considered in any determinations made through this study. Students were also asked to participate in a semi-structured interview with the primary researcher, which was recorded and transcribed for analysis. The student submissions and their ratings, comments, and interviews were analyzed by looking for emerging themes regarding their work, attitude, and feelings about the assignment.

Class Textbook

To start this project, an existing OER textbook needed to be chosen as the base for the class textbook. As I had previously adopted textbooks from OpenStax for college courses, I was familiar with the setup of this publisher and chose their *Biology for AP Courses* title as the class textbook that the students would be working with. This textbook is available for free and is published under the CC-BY license which allows for the textbook to be remixed and shared freely as long as the original attributions of work are in place (Zedalis & Eggebrecht, 2018). OpenStax is based at Rice University and was created to offer peer-reviewed, open-source materials for freshman survey courses like Biology, Physics, and Psychology (Coldeway, 2012). Devin Coldeway reports that OpenStax's textbooks are:

> …fueled by grant money from a number of private foundations (i.e. not government grants), they're putting together full-on textbooks, peer-reviewed, professionally laid out, and all that. These textbooks will be provided for free in file form. But supplementary materials — quizzes, videos, presentations, and the like, presumably — cost money. (2012, p. 1)

Relationship to Participating Students

As I started to plan this project, I decided that I would not use one of my own classes for the research. I also did not want to influence student choices of what they may submit to the textbook. I also felt that upperclassmen students would have more experience in research methods. For those reasons, I worked with another teacher in the science department and his AP Biology classes. Many of the students in the class recognized me as a teacher in the science department, and five of the 17 students who participated had been enrolled in one of my sophomore level biology courses. I think most students felt comfortable with participating in the project and agreeing to participate in an interview as I was not a total stranger to a majority of them. As I went through each stage of the study, the participating teacher would allow me to come into their classroom and talk to the students about what would be happening next.

Making the Class Textbook Available to Students

The OpenStax *Biology for AP Courses* textbook, is offered as described above. The book can be viewed in its original form at the OpenStax website or can be downloaded as a Portable Document Format (PDF) (Zedalis & Eggebrecht, 2018). In order to edit the textbook, I downloaded the PDF from the OpenStax website. This PDF file was large,

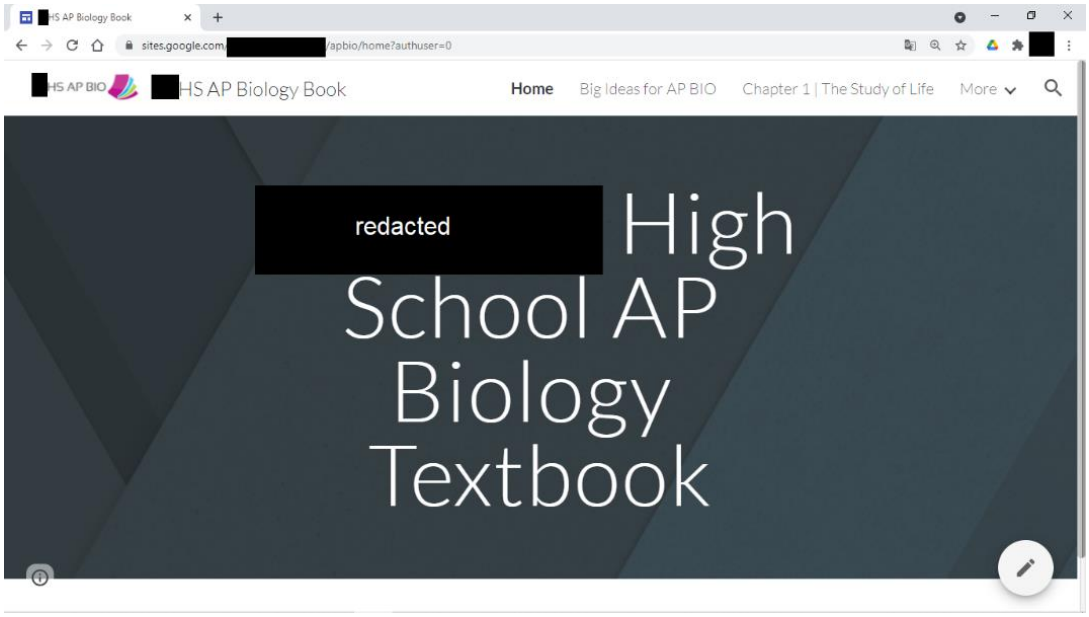
consisting of 1802 pages consuming 197 MB of storage space. I realized that to make the project manageable, that I would need to divide the file up.

Using Adobe Acrobat DC PDF editing software, I divided the textbook into 39 chapters. The 39 PDF chapters were loaded into my google drive and then linked to the google site for the class textbook under the high school's domain. Students were able to access the textbook on their school Chromebooks, home computers, or devices like phones and tablets. The title of the class textbook includes the host high school's name and when communicating with students I referred to it as the "*Generic* High School AP Biology Textbook" or "*G*HS AP Textbook." I will continue to use the term class textbook when referring to the textbook that the AP Biology class remixed. The students were provided a link to the textbook which resulted in them being taken to the book's homepage as seen in Figure 1.

The class textbook link provided to students directed them to the home page for the class textbook. Students could click the *Big Ideas* link for AP BIO to review the standards set in place by the College Board for teaching AP Biology (Figure 2). They could also use the pulldown menu to select an individual chapter to read (Figure 3).

Figure 1

Screenshot of Class Textbook



Note. Information that could identify the host school has been redacted

Figure 2

Screenshot of Big Ideas for AP Biology in the Class Textbook

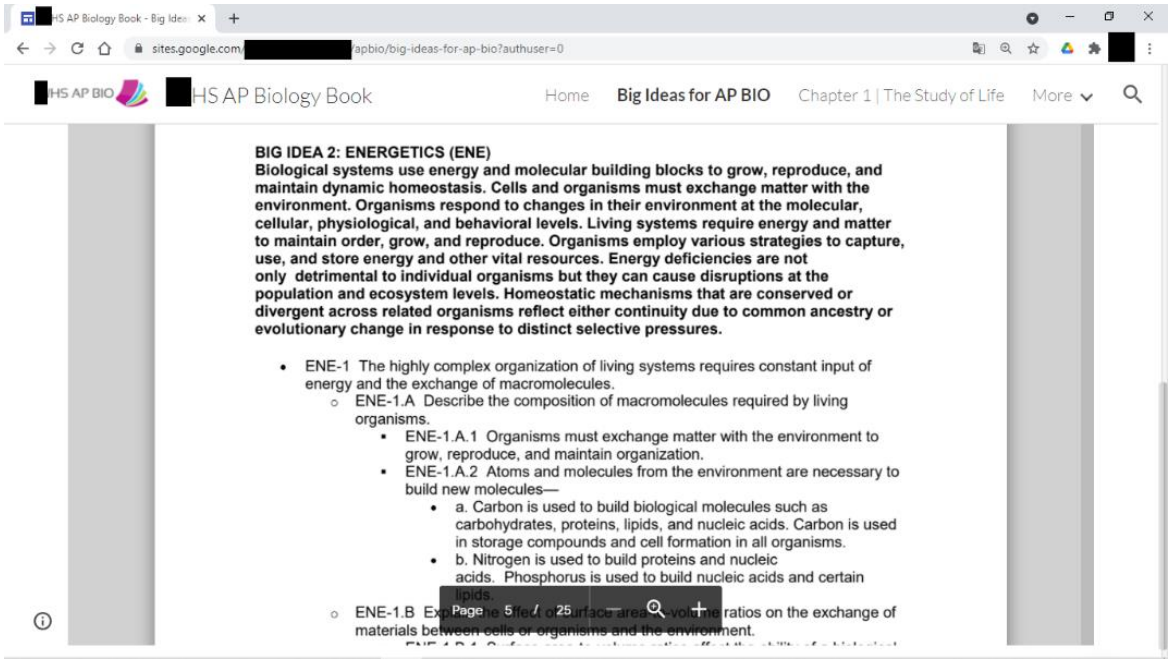
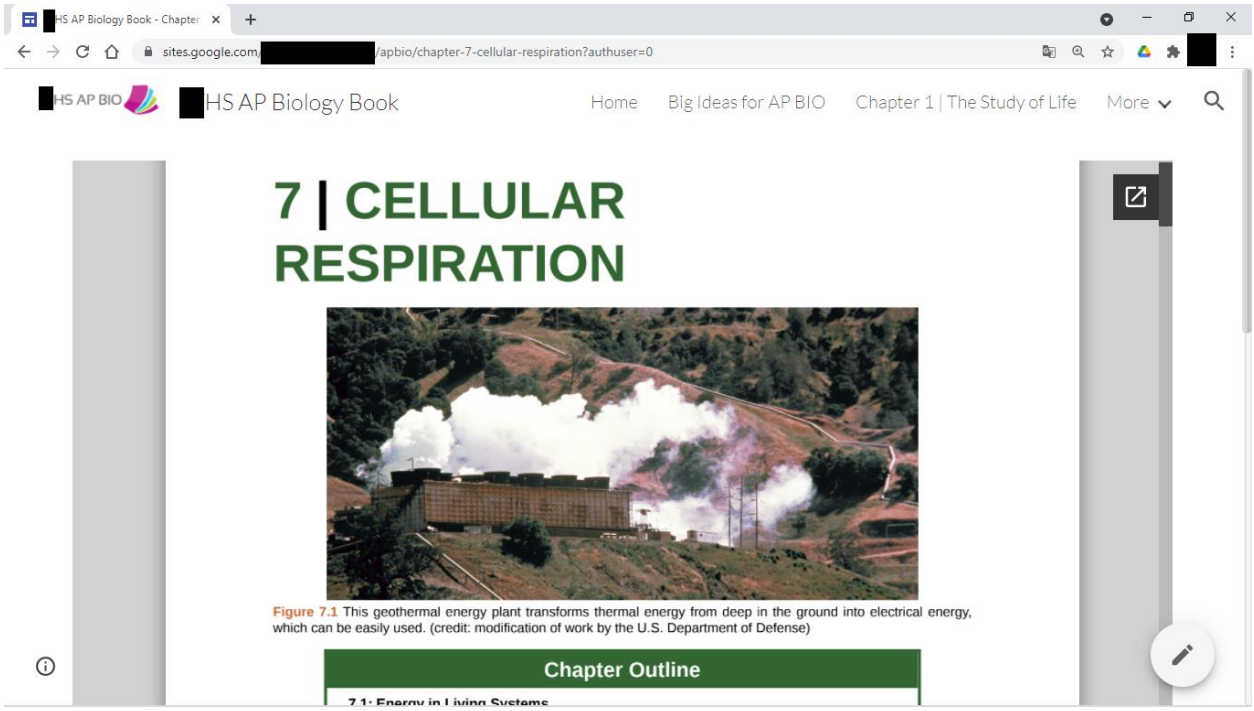


Figure 3

Screenshot of Chapter 7 from the Class Textbook

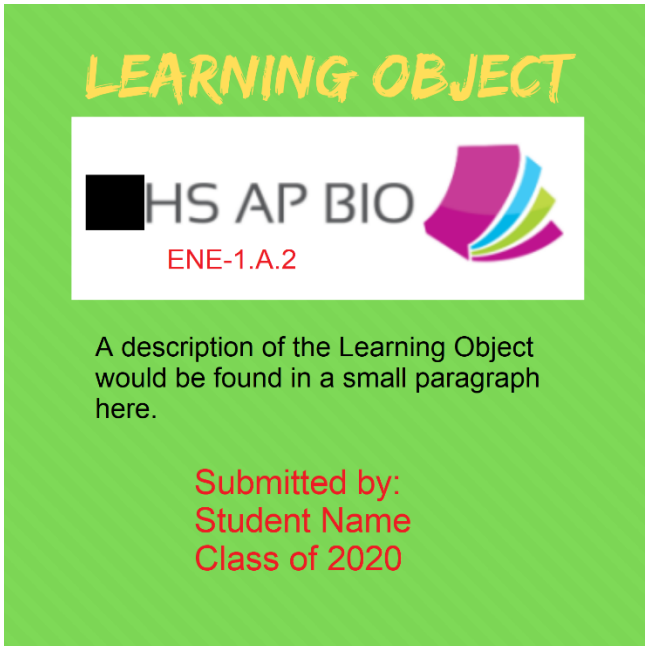


Editing the Class Textbook with Student Submissions

As the focus of this project centers around student contributions to a text book, I needed a way to include, and draw attention to, said contributions. Using the simple image processor, Paint, included with Microsoft Windows, I designed a square-shaped learning object indicator that could be pasted into the class textbook (Figure 4). This indicator includes the class textbook logo, the name of the student who submitted the learning object, the AP Big Idea standard that the learning object was related to, and a hyperlink to the object if needed.

Figure 4

Learning Object Indicator for Class Textbook



The Learning Object Indicator has a bright green background with yellow letters to indicate to readers that a Learning Object has been added to the textbook.

Under the Classroom Textbook Logo, the AP Big Idea standard that the Learning Object is aligned with can be added.

A brief description of the object can be entered.

The submitting students's name and class are entered at the bottom.

After experimenting with the learning object image, I found that having differently shaped formats allowed for more flexibility when adding the image to the textbook. I modified the original learning object indicator to some rectangular shapes that would fit better in certain sections of the book than the square image. As most of the submissions from students were not original work, most of the logos were hyperlinked so that clicking on the logo while reading would take students to the described learning object.

Description of Research Setting

This case study took place in a county high school with an enrollment of about 1400 students where I am employed as a science teacher. The AP Biology class, taught by another instructor, was the target group for this study. The instructor of this course was instrumental in providing me some of their valuable instruction time to explain the idea of a class textbook and to come into the class to explain each stage of the project. The instructor of the AP class

had been teaching the course for six years and regularly required students to read from a textbook as part of their weekly assignments. This instructor found the OpenStax textbook to be comparable with the one he had used in previous years.

This class consisted of 19 students who had registered to take the AP course in the 2019/2020 school year. Seventeen students, consisting of four juniors and 13 seniors, agreed to take part in the study and submitted the IRB-approved consent forms. I visited their classroom multiple times during the course of the semester to explain each step of the project and then invited the students to participate in semi-structured interviews to gauge their perceptions about this project.

The students in the class had participated in an information literacy training program as a regular part of the AP Biology curriculum. This training was done with the school librarian and they talked to students about research methods and evaluating the validity of the information you find. Students in AP Biology are required to write a number of research laboratory reports as a part of the course and the host teacher usually arranges these training sessions early in the year each time the class is taught.

Achieve OER Rubric

As discussed in the literature review, there are many different types of OER rubrics for evaluating OER learning objects. Yuan and Recker's review of available OER rubrics found that some of these focus on the reusability of OER, some on pedagogy, and some like the Achieve rubric concentrate on alignment with existing standards (2015). I decided to utilize the Achieve OER rubric because of my desire to have learning objects that correspond to the objectives of CollegeBoard for AP Biology.

The Achieve OER rubric was released in 2011 to "help states, districts, teachers, and other users determine the degree of alignment of Open Educational Resources (OER) to college- and career-ready standards and to determine other aspects of quality of OER" (Achieve, 2011, p. 1). As discussed earlier, one concern with students submitting OER materials to a textbook, is whether the learning object they submit represents the conclusions of mainstream science. Students might be able to find a web page or story that purports the age of the Earth as 6,000 years old; this 'information' is not represented among the standards presented by the College Board for AP Biology. By requiring that learning objects that are recommended for the AP Biology textbook inclusion match one of the standards for AP Biology, a great deal of misinformation can be eliminated from making its way into the textbook.

The original Achieve OER Rubric contains eight separate rubrics that can be evaluated for each learning object that is considered for inclusion in an OER publication. These eight are listed below (Achieve, 2011).

I. Degree of Alignment to Standards

II. Quality of Explanation of the Subject Matter

III. Utility of Materials Designed to Support Teaching

IV. Quality of Assessment

V. Quality of Technological Interactivity

VI. Quality of Instructional and Practice Exercises

VII. Opportunities for Deeper Learning

VIII. Assurance of Accessibility

Each of the eight rubrics prepared by Achieve is scored independently of one another and can be assigned one of five scores. For example, applying *Rubric I – Degree of Alignment to Standards* to a learning object, can result in a score of three for superior alignment, two for strong alignment, one for limited alignment, and a zero for poor alignment. A fifth score, N/A, deems that the rubric is not applicable to that metric. For example, *Rubric IV - Quality of Assessment*, would not be applicable if a learning object does not contain an assessment component. Achieve provides detailed explanations of how to apply a rating to each of its 8 rubrics (Achieve, 2011). The entire rubric is provided in Appendix A.

I decided to adapt the Achieve OER tools by choosing 4 rubrics that would be utilized by students as they evaluated each other's learning objects. The four that I felt would be most useful for this study were (1) alignment to standards, (2) explanation of subject matter, (3) quality of technological interactivity and (4) opportunity for deeper learning. To allow for students to evaluate the submissions of other students, an online survey was designed that allowed students to view the criteria for each of four rubrics.

Students could then examine the learning object and enter a score from three to zero, or N/A, to the learning object on the four chosen rubrics. Two open-ended questions at the end of the survey asked students what they liked the most about the learning object and what they liked the least. This allowed for the compilation and evaluation of the ratings and comments about each submission.

Categories of Student Submissions

As I reviewed the student submissions that were being suggested for inclusion in the class textbook, I started to sort the submissions into groups. I initially assigned each

submission one of five broad categories (1) video, (2) reading, (3) interactive, (4) audio/music, and (5) original work. I found that I needed to expand the first two categories to account for the different types of videos and reading formats that students submitted. Videos could be divided into different groups such as lecture videos (those with a teacher/professor visible on the screen using a presentation), or narrated videos (those with animations or live images overlaid with a voiceover explanation).

The readings category included submissions that were either encyclopedia-like entries, journal/news articles, or textbook-like explanations of particular subjects. Some readings were embedded with short videos to supplement the text, while others contained interactive questions about the text, and some readings contained both. After the project was complete, I classified all of the student submitted learning objects into the categories presented in Table 1.

Table 1
Categories of Learning Objects Submitted by Students

Categories	Description
Video	**A learning object in any video format**
Lecture (VL)	A video with a professor/teacher/lecturer with a presentation
Narrated (VN)	A scripted video that has a voice-over narration
Reading	**A learning object that is primarily text and images**
Article (RA)	An article or news story with no additional functionality
Article with video (RV)	An article that is accompanied by video(s) supplements
Article with questions (RQ)	An article that is accompanied by interactive comprehension questions
Article with video and questions (RVQ)	An article that is accompanied by video(s) and comprehension questions
Interactive	**A learning object that requires input from the user**
Games (IG)	An educational video game
Simulations (IS)	An object that allows the user to change variables, label parts, or similar interactivity
Audio	**A learning object that is musical format**
Audio only (AO)	An audio file
Music video (AM)	A song presented with accompanying video
Original work	**A learning object made by the student**
Illustrations (OI)	A drawing to illustrate a component being studied

First Student Submissions

I was eager to continue with the project in the early fall by introducing the project to the case study class. The class textbook was ready and waiting for the first submissions which would truly make our unique. For the first round of submissions, I went to the students' classroom and did a small presentation to explain what I was asking them to do.

I defined OER for the students and explained how the 5R permissions work. The students had already been required to read three chapters in the course and were preparing to

start a unit on the structure of the cell. They were instructed to read the chapter in the text as they usually did, but to think about anything they could add to "make the textbook better" by adding learning objects into the book. During this initial meeting I had several points I wanted to make clear to the students.

I explained how the CC-BY license that allowed me to set up the base class textbook would also allow the class to modify the textbook by adding content to it. It was clarified that anything that was added to the textbook must directly relate to the AP Biology Big Ideas, or standards, for the course. I told students that anything that also was published with the CC-BY license, could be directly added to our book under the reuse and remix principles of OER. The students were informed that any learning object they produced themselves could be copyrighted under a CC-BY license to become part of our book.

Students learned that some resources they might find useful would not be covered by a free use copyright. Items such as these could not be directly pasted into our book, but could be included as hyperlinks. They were also told that they would review each other's submissions to decide as a class which ones should be added. I explained that the rubric we would use would measure their submission for (1) alignment to standards, (2) explanation of subject matter, (3) quality of technological interactivity and (4) opportunity for deeper learning and provided a link with the full description of each. Lastly, I reminded the class that any learning objects submitted must be aligned with one of the AP Biology big ideas in order to be considered for publication in the class textbook.

With those considerations in mind, students set off to read the cell structure chapter and to think about and find items worthy of inclusion in our textbook, for not only their class but future ones as well. Students were then given three days to review or design learning

objects that would make worthwhile additions to the textbook. They submitted their learning object along with the AP Biology learning target that aligned with their submission.

First round of learning objects

After the due date for the submissions, I rated each object using the Achieve Rubric to determine if my ratings would align with student ratings. I compiled a list with hyperlinks to each learning object offered by students and returned to the class to explain how the items would be evaluated using the four rubrics. Students were divided into eight groups of two to three students and worked together to evaluate either eight or nine submissions using the modified rubric. Each student group reviewed learning objects and assigned scores for each of the four rubrics taken from the Achieve OER evaluation tool. Those were (1) alignment to standards, (2) explanation of subject matter, (3) quality of technological interactivity, and (4) opportunity for deeper learning. Students were also given the opportunity to declare what they liked the most about the submission and what they liked the least. I remained in the room to observe students as they worked on their evaluations to answer any questions about the rubric that they might have.

As students were working through the rubrics, two groups asked about rubric 3, quality of technological interactivity, as it related to links that directed the reader directly to a video. I then explained to the entire class that while a video does have some interactivity in terms of being able to pause or rewind, the rubric's explanation would lead to a rating of one, or limited, because the interactivity is not directly related to the subject matter. I did not receive any questions about how to score using the remaining three rubrics. I noted that the students appeared to be engaged in this activity and were having serious discussions in their

small groups as they progressed through the rubric for the learning objects they were reviewing.

Results of First Submissions

All seventeen students submitted learning objects for the class to evaluate. Using the categories of submissions presented earlier, students submitted four *videos*, eight *readings*, two *interactives*, an *audio* submission, and one *original work*. A brief summary of these learning objects is presented in Table 2.

Table 2

First round of student submissions by category of Learning Object

Categories	Number of submissions
Video	**Total 6**
Lecture (VL)	2
Narrated (VN)	4
Reading	**Total 8**
Article (RA)	1
Article with video (RV)	2
Article with questions (RQ)	3
Article with video and questions (RVQ)	2
Interactive	**Total 1**
Games (IG)	0
Simulations (IS)	1
Audio	**Total 1**
Audio only (AO)	0
Music video (AM)	1
Original work	**Total 1**
Illustrations (OI)	1

There were two learning objects that students were unable to access and evaluate. One of these was submitted from a website, study.com, which requires a subscription to use. This website lets users access the first parts of articles and videos, but requires the user to register and pay a subscription to view the rest. The other item that could not be evaluated by students was due to our school's internet service provider. The learning object led to an

interactive labeling exercise that I was able to access at my home when I was rating student submissions, but was blocked by our school as containing a malicious URL. This alarmed me as I had viewed the resource on my home computer, but I was never able to find out what the issue with this website was. The submitting student had completed the assignment on their own computer rather than the school issued Chromebook and their resource was not blocked at home.

Each learning object was evaluated by at least four student groups, generating four scores for each rubric. I averaged these scores to generate a ranking of learning objects. After student groups evaluated the submissions, I compiled the results and assigned each item an average score taken from the four rubrics. The average student scores were all with in a half point of the ratings I had assigned to each object. The scores for items suggested for the class textbook ranged from 1.3 to 2.9 and two items that were unable to be evaluated. These results are reported in Table 3.

Table 3

First Round of Student Submitted Learning Objects with Rubric Scores

Publishers of submitted learning objects with brief description of item	AP Bio Big Idea	Rubrics				Avg. score
		#1	#2	#3	#4	
Bioman Biology - flash simulation that lets students label the parts of a cell and answer questions (IS)	ENE-2.K.1	3.0	2.8	3.0	2.5	2.8
Britannica - encyclopedia entry about cells with supplemental questions and videos (RQ)	EVO-1.A.2	3.0	2.8	2.3	3.0	2.8
Lumen Learning - article about types of cells with micrographs and practice questions (RQ)[a]	EVO-1.A.2	3.0	2.8	2.0	2.8	2.7
Khan Academy – complete lesson covering RNA with reading, videos, and questions (RVQ) [a]	EVO-1.A	3.0	2.8	2.0	2.8	2.7

Publishers of submitted learning objects with brief description of item	AP Bio Big Idea	Rubrics				Avg. score
		#1	#2	#3	#4	
Biology Dictionary - article about mitochondria with videos and questions (RVQ)	EVO-1.B.1	3.0	3.0	2.0	2.5	2.6
Molecular and Cellular Biology Learning Center - flash animations of how the Golgi works (RV)[a]	SYI-1.D.4	3.0	2.5	2.0	2.8	2.6
Leaving Certificate Biology – cell structure article with supplemental videos (RV)	ENE-2.K.1	3.0	2.5	2.0	2.5	2.5
Khan Academy – video lesson covering cellular respiration (VN) [a]	ENE-1.K.1	2.8	2.8	1.0	2.8	2.4
Nucleus Medical Media - computer animation of the cell organelles with voice over narrator (VN)	ENE-2.K.1	3.0	3.0	1.0	2.0	2.3
Bozeman Science – a video enhanced lecture covering the organelles of the cell (VL)	ENE-2.K.1	3.0	3.0	1.0	2.3	2.3
PBS - flash animation covering DNA and the nucleus (VN)	EVO-1.A.3	3.0	2.5	1.0	2.8	2.3
Student 8 – a drawing of a generic cell with the opportunity to label organelles (OI)[a]	ENE-2.K.1	3.0	2.5	1.0	2.0	2.1
Emily Crapnell - a rap video featuring organelles and functions in the lyrics (AM)	ENE-2.K.1	2	2.8	1.0	1.0	1.7
TED Talk- an animator talks about the process of producing aesthetic videos for science (VL)	ENE-2.K	1.8	1.3	1.0	2.5	1.7
NIH – abstract for an article about the cell cycle (RA)	IST-1.D.2	1.5	1.0	1.0	1.8	1.3
Exammasters – a review of cell structure (RQ)	ENE-2.K.1	n/a	n/a	n/a	n/a	n/a
Study.com – video featuring types of lipids (VN)	ENE-1.A	n/a	n/a	n/a	n/a	n/a

Publishers of submitted learning objects with brief description of item	AP Bio Big Idea	Rubrics				Avg. score
		#1	#2	#3	#4	

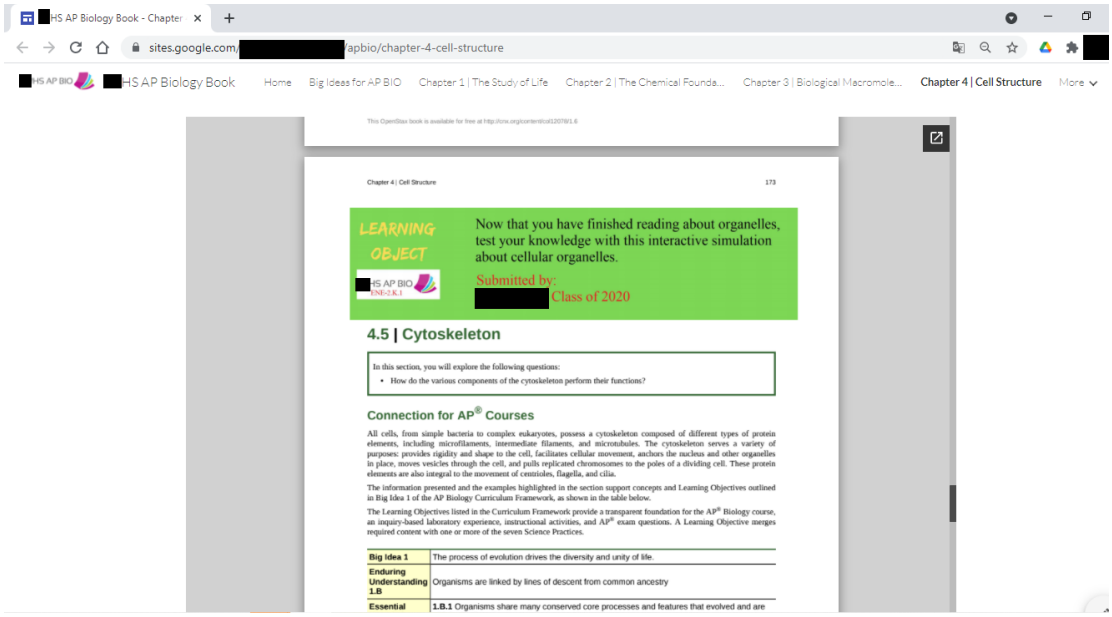
Note. Two items were not able to be evaluated in the class. Rubrics used- (1) alignment to standards, (2) explanation of subject matter, (3) quality of technological interactivity and (4) opportunity for deeper learning.

[a] Reflects a submission published with a CC-BY license.

I added the 12 learning objects that received an average score of two or better to the textbook. Adding each object required me to make a logo with the students' names, the AP Big Idea the submission was aligned with, format the logo with the hyperlink, come up with a description of the item, and then to find a space to place the logo in the text. I had not previously had experience with editing PDF documents and it took some time for me to figure out how best to add these items in. In most cases I found that I could simply shift existing entries, like images or blocks of text, around on the page to add the learning object. For example, I was able to insert the highest scoring learning object at the top of page 173 in the textbook, by shifting all of the existing content on the page down, as there was empty space at the bottom of the page (Figure 5). One of my goals was to add items into the book without adding additional pages as I did not want to have to edit page numbers in the textbook. I then returned the scores and comments about each submission to the students so they could see how their submission was rated.

Figure 5

Class Textbook Chapter Four with New Learning Object Embedded



The original work submitted was a hand drawn image with a plant cell on one side and an animal cell on the other. In the middle of the two cells were blank labels that pointed to the various organelles that allowed students to identify each organelle based on its shape and then check their answers against a key. This image was too large to fit into the middle of the chapter, but I found an appropriate location for it at the end of the chapter after the practice questions that were already there.

Second round of learning objects

I returned to the AP Biology class to share the new entries in the textbook with them. The students were shown the additions on the projector. Students learned that learning objects that had scored higher than an average score of two points had been added to the text. I made sure to remind students to make sure their resources worked using their school issued Chromebook and that they did not have a paywall or subscription associated with them. The students were then asked to submit a learning object for their chapter covering cell division.

The submissions this time included two instances of the same learning object being submitted by separate students and one student in the class did not make a submission. The students reviewed the additions like they did for the first round and all 14 unique learning objects were rated highly enough to be added to the class textbook. A summary and results of this round of submissions are found in Tables 4 and 5.

Table 4

Second round of student submissions by category of Learning Object

Categories	Number of submissions
Video	**Total 5**
Lecture (VL)	2
Narrated (VN)	3
Reading	**Total 4**
Article (RA)	1
Article with video (RV)	2
Article with questions (RQ)	0
Article with video and questions (RVQ)	1
Interactive	**Total 6**
Games (IG)	1
Simulations (IS)	5
Audio	**Total 0**
Audio only (AO)	0
Music video (AM)	0
Original work	**Total 0**
Illustrations (OI)	0

Note. One student did not submit a learning object. Two objects were submitted twice by students.

Table 5

Second Round of Student Submitted Learning Objects with Rubric Scores

Publishers of submitted learning objects with brief description of item	AP Bio Big Idea	Rubrics				Avg. score
		#1	#2	#3	#4	
Emory University – An interactive web page that allows students to explore the process of chromosomal sorting during meiosis (IS)	IST-1.F-1	3	3	3	2.5	2.9
Bioman Biology – An interactive mitosis activity with questions as you move through stages (IS)[b]	IST-1.B	3	2.8	2.8	3	2.9

Publishers of submitted learning objects with brief description of item	AP Bio Big Idea	Rubrics				Avg. score
		#1	#2	#3	#4	
NobelPrize.org - A flash video game that lets you control the cell cycle (IG)[b]	IST-1.C.1	3	2.8	3	2.5	2.8
Cellsalive.com – This is an animated interactive that lets one see the stages of meiosis with info on each discrete stage (IS)[b]	IST-1.F	3	2.8	2.5	2.3	2.7
Khan Academy - A full lesson over DNA mutations with videos and practice questions (RVQ)[a]	IST-2.E.2	3	2.5	2	2.8	2.6
PHSchool.com - This flash animation lets students manipulate stages of meiosis (IS)	IST-1.B.2	3	3	2	2.3	2.6
Georgia Tech Biology – An OER textbook section covering cell division and development (RV)[a]	EVO-3.D.2	3	2	2	2.8	2.5
ThoughtCo.-A hyperlinked article with videos discussing differences in mitosis and meiosis (RV)	IST-1.G	3	2.3	2	2.5	2.5
TED talk – animated video on cancer and cell division (VN)	IST-1.B	3	2.5	1	3	2.4
Bozeman Science – A lecture video with presentation that covers key stages of meiosis (VL)	IST-1.F	3	2.8	1	2.8	2.4
Virtual Cell Animation Collection -This video that animates the stages of meiosis and provides detailed still shots from the animation (VN)[a]	IST-1.F	3	2.5	1	2.8	2.3
Treehugger.com - This article shows 12 examples of asexual reproduction in animals (RA)	IST-1.C.1	3	2.3	1	2.8	2.3
DontMemorize.com – An animated video to present the differences between mitosis and meiosis (VN)	IST-1.G	3	2.8	1	2	2.2

Publishers of submitted learning objects with brief description of item	AP Bio Big Idea	Rubrics				Avg. score
		#1	#2	#3	#4	
Crash Course - A lecture video with presentation that covers key stages of meiosis (VL)	IST-1.H	3	2.3	1	2	2.1

Note. One student did not submit a learning object. Rubrics used- (1) alignment to standards, (2) explanation of subject matter, (3) quality of technological interactivity and (4) opportunity for deeper learning.

[a] Reflects a submission published with a CC-BY license.

[b] Indicates learning objects submitted twice by different students.

Third round of learning objects

The process of asking students to submit learning objects was changed slightly because of the duplicate submissions in the second round and because students were using different levels of the AP Biology Big Ideas. These standards are grouped under the four Big Ideas. Each Big Idea is further defined by the CollegeBoard in an outline type format with sublevels of enduring understanding, learning objective, and essential knowledge (CollegeBoard, 2020). On previous rounds of submissions, students were asked to match their submissions to one of the big ideas. Some students were submitting their standard at the enduring understanding level, while others were using the essential knowledge level. One example of these levels with associated codes is presented in Figure 6.

Figure 6
An Example of the Hierarchy of AP Big Ideas

- *Big Idea 2* – ENE Biological systems use energy and molecular building blocks to grow, reproduce, and maintain dynamic homeostasis.
    - *Enduring Understanding* - ENE-1 The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules.
        - *Learning Objective* - ENE-1.A Describe the composition of macromolecules required by living organisms.
            - *Essential Knowledge* - ENE-1.A.1 Organisms must exchange matter with the environment to grow, reproduce, and maintain organization.

Note- Adapted from Appendix A

Looking ahead, the students would soon be tackling ecology with four chapters in the class textbook. To try to avoid some of the duplicate learning objects I had seen in the second round submissions, students were asked to sign up for one of 24 essential knowledge components that the teacher of the course was covering for the ecology unit. In addition to hopefully lowering the possibility of students submitting the same learning object, I hoped this change would also allow me to disperse the learning objects amongst more than just one chapter.

The last round of submissions was complete near the end of the first semester of class. Even with having students work on separate essential knowledge components, two learning objects were submitted twice by different students. The results for the third round of student submissions are presented in Tables 6 and 7.

Table 6

Third round of student submissions by category of Learning Object

Categories	Number of submissions
Video	**Total 7**
Lecture (VL)	6
Narrated (VN)	1
Reading	**Total 2**
Article (RA)	0
Article with video (RV)	2
Article with questions (RQ)	0
Article with video and questions (RVQ)	0
Interactive	**Total 4**
Games (IG)	1
Simulations (IS)	3
Audio	**Total 1**
Audio only (AO)	1
Music video (AM)	0
Original work	**Total 0**
Illustrations (OI)	0

Note. Two students submitted the same learning object.

Table 7

Third Round of Student Submitted Learning Objects with Rubric Scores

Publishers of submitted learning objects with brief description of item	AP Bio Big Idea	Rubrics #1	#2	#3	#4	Avg. score
Virtual biology Lab - This is an interactive that allows for user to investigate island populations dynamics (IS)	SYI-3.G.1	3.0	3.0	3.0	3.0	3.0
HHMI - This interactive allows users to simulate population growth curves by manipulating variables (IS)	IST-5.A.3	3.0	2.5	3.0	3.0	2.9
Khan Academy – A full lesson on population ecology (VL)[a]	ENE-4.D.1	3.0	2.8	2.0	2.8	2.6
Biology Dictionary - An article on abiotic factors with review questions (RQ)	SYI-3.F.2	3.0	2.8	2.0	2.8	2.6
Prophet - A video showing how scientists perform experiments with ant communication (VN)	IST-5.A.1	3.0	3.0	1.0	3.0	2.5

Publishers of submitted learning objects with brief description of item	AP Bio Big Idea	Rubrics				Avg. score
		#1	#2	#3	#4	
Bozeman Science - A lecture video with presentation that covers behavior and natural selection (VL) [a]	IST-5.A.3	3.0	2.8	1.0	3.0	2.5
Bozeman Science – A lecture video with presentation that covers population ecology (VL)	ENE.1.N.2	3.0	3.0	1.0	2.8	2.4
APBiology-solorzano - This article contains information about animal interactions with videos and graphs (RV)	ENE-4.B.1	3.0	2.8	1.0	2.8	2.4
PennState- Article about biodiversity with video (RV)	SYI-3.F.1	3.0	2.8	1.0	2.8	2.4
Factile - This website lets you play a jeopardy style game as a review (IG)	ENE-1.M.1	2.0	1.5	3.0	2.5	2.3
Khan Academy – A video only lesson on Simpson's diversity index (VL)	ENE-4.A.1	2.8	2.8	1.0	2.8	2.3
PBS- This is a short interactive with questions about energy flow (IS)	ENE-4.C.1	3.0	2.0	2.0	2.0	2.3
RadioLab – This podcast is a conversation between hosts and experts as they ponder if science should be used to kill all mosquitos (AO)	EVO-3.H.1	3.0	2.3	1.0	2.8	2.3
DeBacco University - A lecture/presentation video covering predator/prey relationships (VL)	ENE-4.B.3	3.0	2.3	1.0	2.0	2.1
Crash Course - A lecture video with presentation discussing limiting-factors (VL)	SYI-1.H.2	3.0	2.3	1.0	2.0	2.1

Note. Rubrics used- (1) alignment to standards, (2) explanation of subject matter, (3) quality of technological interactivity and (4) opportunity for deeper learning

[a] Indicates learning objects submitted by two different students

Interviews

Once the three rounds of submissions were complete, I started thinking about the questions I would want to ask students during their interviews. I established a list of four basic questions I would ask each student to learn what students thought about the project. I included some additional prompts for each of the questions in case I felt I needed to draw more information from a student. The interview questions can be found in Appendix C.

Students were scheduled to come to my office for their interviews. I utilized the semi-structured interview style with four main questions. The students were familiar with me from my visits to their classroom to describe the various stages of the project, but I wanted them to feel at ease about the upcoming interview. I assured each student that there were no right or wrong answers to the questions I was going to ask them. I reminded them the purpose of the interview was to gauge their memories and ask about their feelings of the textbook project completed in the prior semester. I reminded each student that I after I transcribed the recoding of the interview, I would delete the audio file as described in the assent and consent forms they signed at the beginning of the study.

The first question I asked students was to simply tell me about the submissions they made over the course of the previous semester. If the student did not allude to how they found the resources and decided what they wanted to submit, I would ask follow up questions to provide more illumination on their thought processes. I then asked students to compare an OER project like this one to other projects and assignments they have completed in high school. I also asked them if they remembered what OER stood for. I asked students to then tell me about the peer-review process and their experiences with both evaluating other students and being evaluated themselves. I ended the interviews by asking students how they felt about next year's students seeing their contribution.

I transcribed each interview as quickly as possible after each one occurred. This allowed me to annotate each interview with context that would be missing from a simple transcript. I put in notes about mood and engagement for each interviewee, and added in other descriptors such as when a student mimed the process she was describing. In all cases, I transcribed an interview before starting a new one. After all interviews were complete, I began the process of coding the information. As interviews are an important component of my research, I needed a way to examine the raw qualitative data and turn it into the "story" that this project is producing. Coding is considered a central part of qualitative analysis that reduces large amounts of empirical data to code words or phrases that are more readily available for analysis (Linneberg & Korsgaard, 2019). I then used a coding program, Quirkos, to help through the process of creating an inventory of my data.

There are two main directions one can choose when starting the coding process, inductive or deductive coding (Linneberg & Korsgaard, 2019). Inductive coding starts with the idea that the codes developed by the researcher come directly from the data. The codes originate from the participants directly by using the words and phrases they have spoken or written. This type of coding is often used for exploratory studies if there are no theoretical concepts developed for the phenomenon being observed (Giora et al., 2013). While inductive coding has the advantage of being more true to the collected data, there is the possible pitfall of the process becoming overly complicated and being insufficient in its focus (Linneberg & Korsgaard, 2019).

Deductive coding, on the other hand, allows for a more narrow focus during the coding process (Miles et al., 2013). The researcher starts with a pre-defined list of codes based upon the research questions being explored. Generally, theoretical concepts or themes

from existing literature are the sources of these pre-defined codes. My research question, "How are the cognitive concepts of attention, memory, and motivation impacted by the production and evaluation of Open Resources?" was developed from Bandura's Social Learning Theory, I created codes for *attention*, *memory* and *motivation* for my first cycle of coding. For my question, "Why do students choose the resources and processes they use when reviewing and designing their own OER contributions?" I created a code for *process*.

It is suggested that coding occurs in multiple cycles (Linneberg & Korsgaard, 2019). The first cycle of coding should focus on descriptive coding and attribute coding. Descriptive coding assigns segments of data based on what the segment is about. In this way, I can find portions of interviews that directly relate to the processes students used in this study and group them for easier analysis. Attribute coding for this study is simply defining the grade and gender of the participants. The second cycle of coding allows a researcher to refine the first-cycle choices and explore patterns that develop from the first cycle codes. Saldaña suggests the second cycle of coding should entail "classifying, prioritizing, integrating, synthesizing, abstracting and conceptualizing, and theory building" (2015, p. 58). As I was interviewing students and studying their responses to my questions, I began to believe that I was reaching data saturation with about the tenth interview. Shortly after the twelfth interview, the Covid-19 pandemic caused the school to be closed for in-person attendance and effectively brought the active portion of my study to an end. In the end, I had interviewed 12 of the 17 students involved in the study.

I used an evaluative program known as Quirkos to examine the interviews and perform both content and thematic analysis. Quirkos is a tool for the qualitative analysis of text that works by creating "quirks" or tags for content or themes. Researchers are then able

to highlight portions of text and drag and drop excerpts into the created quirks. This tool allows for visual analysis as each quirk grows in size as content is added to it.

Summary

Open educational resources and their CC-BY license offer many unique opportunities for learning. I believe that constructing a textbook as part of a class project to be at the forefront of these possibilities. However, very little research has been published on student contributions to OER. To tackle this lack of research, I set this project up as a case study to provide a foundation to build future research upon. The case study approach works well to answer my research questions within the small group of students available for my project. Case studies, being qualitative in nature, should be planned carefully to provide trustworthiness in the results of the study.

Interpreting the results of a case study requires an appropriate lens with which to view the data collected. The project is largely a community effort in which students will work and learn together, so the framework of Social Learning Theory and Self-Efficacy Theory was applied when interpreting the results. Albert Bandura believed that memory, attention and motivation were key aspects of learning and my proposition at the beginning of the study was that these key cognitive aspects would be stimulated in students participating in a class textbook project. This project was started by downloading an existing OER textbook and then asking students to add material to it to make the textbook better. To help ensure that learning objects added to the textbook are worthwhile additions, students peer-reviewed each other's submissions to make sure they matched the learning targets of the course. They also evaluated each object for its clearness in explaining a topic, how interactive the addition was,

and if it would provide opportunities for deeper learning. In the next chapter, the findings of this research project will be presented.

Chapter 4

Findings

The purpose of this research was to find what students would contribute to an OER textbook being used by not only their class, but also by future classes as well. The processes used by students to decide what learning objects to add to the textbook will be examined along with student perceptions of their work, the evaluative process, and their feelings about their name and work being carried forward to future classes.

Research Question One

My first research question, "Given the opportunity, what resources will a class of AP Biology students add to an existing OER biology textbook?" is the easiest question to quantify. Students in the class submitted 3 objects to the text book over a period of 10 weeks. After students submitted each round of learning objects, the class evaluated those objects by using the Achieve OER rubric. This generated a composite score for each object ranging from 0 to 3. This was the criteria used for deciding which items would actually be added to the class textbook. Objects that received a score of at least 2 out of 3 were added to the textbook along with a brief description of the resource and the name of the submitting student. The first round of student submissions was the only round in which submissions were evaluated with scores that were too low to be included in the textbook.

I found the peer-review process to be immensely useful in this project. Peer-review is a peer-learning practice in which students evaluate the products and performance of their classmates (Liu, et al., 2002). Liu et al. (2002) also convey that exposure to peer-review in the science classroom can be used to illustrate the processes that occur when scientists are publishing their findings. Through peer-review, students gain higher levels of accuracy,

logical thinking, and a clear sense of purpose when both completing assignments and being exposed to the work of their classmates (Matherly & Burney, 2009). I think reviewing the submissions of their classmates led to better overall submissions from the class. When compared to their initial submission's peer-review score, in later rounds sixteen of the seventeen students in the study submitted at least one more learning object that scored higher their than first.

Summaries of student submissions for each round were presented in Tables 2, 4 and 6 in Chapter 3. The most popular category of submission was Video, with submissions being close to evenly split between the sub-categories of lecture video and narrated video. To my disappointment, the category that received the fewest submissions was the original work category. Only one student in the study produced a learning object that was their own creation. Below in Table 8 is a summary of all the 46 unique learning objects submitted over the course of the semester.

Table 8

Summary of all Student Submissions by Category of Learning Object

Categories	Number of submissions
Video	**Total 18**
Lecture (VL)	10
Narrated (VN)	8
Reading	**Total 14**
Article (RA)	2
Article with video (RV)	6
Article with questions (RQ)	3
Article with video and questions (RVQ)	3
Interactive	**Total 11**
Games (IG)	2
Simulations (IS)	9
Audio	**Total 2**
Audio only (AO)	1
Music video (AM)	1
Original work	**Total 1**
Illustrations (OI)	1

Videos as Learning Objects

Videos proved to be the most popular of student submissions with a total of 18 stand-alone videos. An additional nine articles that included video content were also submitted, for a total of 27 entries that contained some type of video. Students' preference for video instruction, as well as the types of videos they picked, is supported by several studies. A study in the UK found that students felt that short lecture videos and key concept videos were the most helpful resources in a virtual learning environment (Hamutoglu et al., 2020). Guo et al. (2014) studied the data from over 6 million video watching sessions across multiple Massive Open Online Courses (MOOC) platforms. Their main findings indicate that shorter videos like talking-head videos, and Khan Academy tablet drawing videos are the most engaging for students (Guo et al., 2014). Echoing this finding, an Australian study found that 85% of students surveyed found short "premium videos", described as videos with

animations that only show text on screen to highlight key principles presented with an informal conversation style, to be more beneficial than longer lecture-type videos (Patterson et al., 2020). The authors measured engagement, in part, by how long viewers watched educational videos. The Breakthrough Junior Challenge, sponsored in part by Khan Academy, offers students the chance to win a $250,000 scholarship for producing a three-minute video explaining a difficult science concept (Breakthrough Junior Challenge, 2021).

The videos that students in this study submitted averaged just over 10 minutes in length. The most popular source of videos selected was Bozeman Science, which produces videos similar to the "premium video" described earlier. Five different videos from this YouTube channel were selected by students. One student submitted Bozeman videos for all three of their submissions, with two additional students submitting Bozeman videos during the third round of submissions. In their interview with me, the first student expressed that they really liked those videos from their chemistry class. "He explained everything better than my chemistry teacher," the student said of Paul Anderson, a high-school teacher and founder of Bozeman Science. This student thought that other students would like Mr. Anderson's style of explaining hard concepts.

Mr. Anderson's hundreds of videos all include him talking to students with various pictures, animations, and tablet-style annotations. When asked during the evaluations what they liked the most about the learning objects they had just rated, responses to Bozeman Science videos included such statements as "this teacher is awesome" and "he is easy to understand." The comments answering what was least liked about Bozeman Science videos tended to relate to the length of some of his videos, with one student simply replying "14 minutes!" to that query.

Khan Academy was also a popular source for students submitting to the textbook. Some Khan Academy learning objects were simply videos, but other submissions took students to an entire lesson with videos and interactive questions. With thousands of videos and over 1.8 billion views on YouTube (YouTube, 2021), it is not surprising that students in this study were familiar with Khan Academy's offerings. Khan Academy also makes it easier for AP Biology students to ensure their materials match the learning objectives for the course. Videos hosted by Khan Academy are labeled with The AP Big Idea codes, like ENE-1.A.2, to help students know that the object they are submitting matches with the goals of the College Board. One student reported finding their Khan Academy lesson by performing an internet search of their Big Idea code.

Videos: Purpose and Conflicts

I believe that the inclusion of videos is great for the textbook. One quote that I reflected on as I realized that video submissions were going to be a big part of student submissions was from a study of video as a mediating artefact of science learning. The authors of this paper, who endeavored to discern what helps students learn from watching video in science classes, said:

> Perhaps the most important criteria teachers could use to identify and select video to mediate science learning is to be purposeful in their selection and to assess whether the video designers' purposes conflicts with their own as teachers; that is an imperative is being clear about reasons for showing a particular video and knowing how it connects to curriculum goals. (Higgins et al., 2018, p. 15)

Two points made here are important to consider with a project like the class textbook. Being clear about reasons for showing a video, or in this case, adding it to a textbook, is

knowing how it connects to curriculum goals. For an AP Biology class, the Big Ideas are the foundation for curriculum goals. Having students identify the specific learning objective associated with their submission does help to answer the questions of how the included video will connect to the curriculum.

The other point made in the above quote, was to know the purpose of the designer of a video, and to discern if that purpose matches your own as an instructor. This is something I struggled with as I decided about the ultimate inclusion of one video to the class textbook. When I first watched this particular video upon its submission, I loved it and thought it was one of the better videos that had been found for the textbook. It was certainly one of the more fascinating animal communication videos I have viewed. This short video shows ants using pheromones to communicate and has very neat footage of the laboratory equipment that the scientists are using in the study. As mentioned earlier, I was very excited about the video and added its URL to the list of resources that students were to evaluate after the third round of submissions. The video was highly rated by students and scored high enough to be included. During the evaluation, students noted positive aspects of the video as "very cool" and "short but very informative" and no students listed anything they disliked about the video. Yet, after noticing one aspect of the video that I missed initially, I was unsure if I should allow it to stay in the textbook.

As I was compiling the information for this project, I finally noticed the name of the YouTube channel that uploaded the video. This channel, *Prophet Muhammad an Excellent Pattern to Follow*, hosts numerous videos relating to science and the Qur'an. The ant communication video itself had no mention of Islam or the Qur'an, but if one scrolls down to the video description, one finds an essay about the beauty of ants and the times they are

mentioned in the Qur'an. There is particular emphasis on an Ayah (similar to a Bible Verse) that describes a story in which an ant verbally addresses the Prophet Sulamain. The author of the essay implies that some would dismiss the Qur'an as a fairy tale for mentioning ant communication, and then implies that the ant communication video proves that the Qur'an is factual. Many of the other videos hosted on this channel attempt to draw similar conclusions. My purpose for making the ant communication video available to students is certainly not the same purpose as the host of the channel.

In the literature review, I discussed challenges for OER. One challenge that remains at the forefront of my thoughts about this project is the inclusion of ideas such as the Flat Earth Theory. I cited some important court cases that were relevant to science textbooks and religious belief. *Willoughby v. Stever* found that public science textbooks cannot be tailored toward a particular religious belief (1973). *Edwards v. Aguillard* held that the teaching of creation science violates the establishment clause (1987). The YouTube channel, *Prophet Muhammad an Excellent Pattern to Follow*, does host videos that purport creation science as true and evolution as false.

I ultimately decided to not include this video as a part of the textbook. As I have established, the video itself seemed very suitable for inclusion into the textbook. Unfortunately, the video is not covered by the CC-BY license so the only way to include it was as a link. The link would take students to a location that presents resources that do not align with scientific thought on evolution, thus rendering it unusable.

I was unable to relay my concerns about this learning object to the class as I had not noticed the purpose of the channel until the majority of them had graduated. I am inclined to believe that the student that contributed the video was not aware of the name of the channel

or its religious affiliation and received no indication that any students noticed the name of this YouTube channel. Deciding to exclude this learning object from the class textbook was a struggle for me because the students believed that we as a class had already vetted the video for inclusion. In hindsight, I should have asked for students to identify the online hosts for Learning Objects as they submitted them. Requiring this additional information would have brought attention to the channel sooner rather than later as well as serving as a reminder for students of their information literacy training.

Readings as Learning Objects

The second largest category of submitted learning objects was readings. There were a total of 14 learning objects submitted for the textbook that I classified as readings. There were four distinct categories of readings. Two submissions were stand-alone texts, containing only text and images. Three of the readings were accompanied by interactive comprehension questions students could attempt as they read through the articles. Five of the articles were accompanied by video supplements to the reading, and four contained both video and interactive questions.

One of the best received readings in terms of positive comments by the students, was an article that reviewed 12 animals that reproduce asexually. This article was submitted for the reproduction chapter. The source textbook had only mentioned the hydra and yeast as examples of organisms that could reproduce asexually. The included link now takes readers to an article with color photographs and a blurb about how each of the 12 species reproduce without the need for a mate. “Real-life examples are great!”, “I had no idea snakes and lizards could do that.”, and “very interesting” are representative of the comments students made when evaluating the resource.

Readings with Questions

Six of the reading category submissions contained embedded questions in the text that students could answer to gauge their understanding. Inclusion of these types of readings is supported by literature and positively enhances the class textbook. Carmine and Carmine report the use of embedded questions to enhance retention and comprehension in science texts (Carmine & Carmine, 2004). Most textbooks, including the OpenStax AP Biology textbook that was used as the main source for the project, include questions already embedded. However, these questions are not interactive and require looking as the end of the chapter to find the answers. Importantly for this project, interactive questions tend to be more beneficial to students reading e-texts when compared to traditional textbooks (Sommers et al., 2019). In a two-part study, Sommers et al. (2019) first found that freshman college students using an interactive e-text report spending significantly more time on embedded questions than those using an identical print copy. In the second part of the study, students were randomly given a section of a psychology text to read as either a printed book, a portable document format (PDF), or as an interactive e-text. Once again, students using the interactive e-text reported higher use and perceived value of embedded questions versus the other two formats. On a post reading test, students who read the interactive text also performed better when answering questions that were similar to those presented in the text (Sommers et al., 2019). In five of the seven cases, student evaluations mentioned the questions as being the aspect they liked the most about these particular learning objects. These additions to the text will hopefully benefit students who are more likely to make use of these types of questions when they are presented as an interactive.

Readings with Videos

A total of nine readings that were submitted for the textbook were articles that included video or videos interspersed through the reading. Students have shown in this case study that adding videos to a textbook makes the textbook better, so it is not surprising that they were more likely to submit an article if it also had a video element. An example of one of these was a chapter from an OER textbook that was published by the University of Georgia's Department of Biology that was submitted as a supplement to our book. This OER textbook was designed by faculty for their Organismal Biology course and had a lot of the look that our class textbook was developing. The authors of the chapter had taken full advantage of remix permission granted by the CC-BY license, as it contained information from Khan Academy, OpenStax Biology, and relevant videos to enhance the student's reading of the material. This was a nice learning object for the class to see as it gave them an idea of what our book could resemble when we had all of our additions linked in.

I found that many students enjoyed all types of articles if the reading was hyper-linked with definitions. For example, one article that was submitted covers similarities and differences in the cell reproduction methods of mitosis and meiosis. In the reading, the article mentions that both processes use chromosomes. The word chromosome is hyperlinked to a definition of that term for students who may need a reminder. It is possible that students perceive this functionality as beneficial, because the answer is a click away. If they had forgotten the definition of the word in a traditional text, they could easily look it up in the same textbook. However, this may be like the functionality of interactive questions in that they are more likely to be used when it is quick and easy for the user to access. However, this particular website received negative comments about its proliferation of advertisements..

This is definitely a pitfall of learning objects that are not CC-BY licensed. In order to access the information on that website, one must endure, or ignore, the advertisements that supply income to the site's hosts.

Interactive Games and Simulations

Students submitted 11 interactive games and simulations. The basic difference between these is that games return a score for you based on performance. Both simulations and games required student input, usually by using a mouse and keyboard. This category only received one submission during the first round of submissions, but it seemed to have inspired students to turn in similar offerings during subsequent rounds as ten more items in this category were submitted in the second and third round. The first item that was submitted was a simulation that let the user label the organelles of the cell and then asked multiple choice questions about each. That particular submission was the highest rated submission during the first round of submissions and students liked the interactivity of the labeling, with one student commenting that it was a "good way to learn the parts of the cell."

The second round of submissions contained one type of simulation that was a popular choice among students. The chapter was covering cell division and students submitted four different simulations that would allow the user to move step-by-step through the processes of mitosis and meiosis. One simulation allowed users to stop at each stage of an animation and zoom in for detail. One simulation would allow students to decide if nondisjunction would occur and at which stage it would occur. Students could then combine the produced gametes from each parent to determine if any abnormalities in chromosome number would occur. One of these simulations allowed users to watch the division process occur stepwise and answer questions about the process as they went. One thing they all had in common was the need for

some type of interaction from the user. These types of simulations brought positive comments like “good for practice,” “allows you to see detail,” and “it’s fun.” As a parent of two teenage boys, I know that if there’s one thing that younger video game players are used to, it is repetition. One student mentioned this aspect of games as a reason for submitting two of them to the book, “It's been more like stuff that has repetition so you can get more familiar with the concepts.”

One student turned in a Jeopardy-style review game for thermoregulation during the ecology unit. This game was a good review and many students expressed their love of Jeopardy. The host for this review game, Factile, allows students to easily build their own Jeopardy-styled review or they can play from one million different review games that have been submitted by other users (Factile, 2021). It is important to note that a submission from this resource should require a vetting of the questions asked during the game, as any user can upload questions. One simulation allowed students to explore island biogeography by manipulating the type of habitat, the size and distance of the island from the mainland, the types of animals, and migration and mortality rates. The animation shows how animals will migrate and produces a data log for the students to examine. Another simulation added to the textbook allows for students to input variables such as population size, the per capita growth rate, and time to generate different growth curves.

It is not surprising that more games and simulations were turned in for this project. Pew Research reports that, among 13-17 year olds in the United States, 97% of male students and 83% of female students play video games on some type of device (Perrin, 2018). There is ample research on video games and science education. Science games can increase conceptual understanding, an understanding for the process of science, and can help students

understand the nature of science (Honey & Hilton, 2011). Science based video games can engage students in the *doing* of science, rather than being focused on the memorization of facts (Marino et al., 2013). Educational video games help keep students motivated and can challenge them at their own level (Blumberg, 2014).

Technology changes

The video games and simulations all made nice additions to the class textbook. Many of the games relied on the Adobe Flash Player for animations and interactivity. Of the 11 learning objects in the interactive category that were added to the book, seven of them relied on the Flash Player. Unfortunately, Flash, as a web plugin for browsers, was a security risk. Adobe was unable to fix the security flaws so the company decided to discontinue support for Flash and effectively killed the program at the end of 2020 (Brookes, 2021). This means that all of these additions to the textbook had to be removed as web browsers are now unable to play these resources.

Audio as a Learning Object

Two learning objects that were submitted were classified as audio. During the first round of submissions, a video titled "Cells Cells – Parts of the Cell Rap" was submitted. This video was animated showing parts of the cell with the lyrics of the song describing the organelles of the cell with an image of each on the screen as it is mentioned. This video was not as well received by the class as being "too childish" or some variation of that sentiment. It was also rated very low on its opportunities for deeper learning.

The second audio submission was a podcast from the series "RadioLab." Radiolab is produced by WNYC and is broadcast on public radio stations and is available on their website. An episode entitled "Kill 'Em All" was submitted to the textbook for the ecology

section. This 22-minute episode talks with ecologists and genetic engineers about the problems with mosquitoes and the diseases they spread, primarily malaria. The focus of the program is exploring that humans have the biological technology to kill all mosquitoes and contemplating what would happen if we did. I thought this a marvelous program and if students listen to the entire program, a great classroom discussion could be had. I thought, like many of the student reviewers, that the addition was a little too lengthy for a textbook, but agreed with students that the opportunity for deeper learning was strong.

Original Works

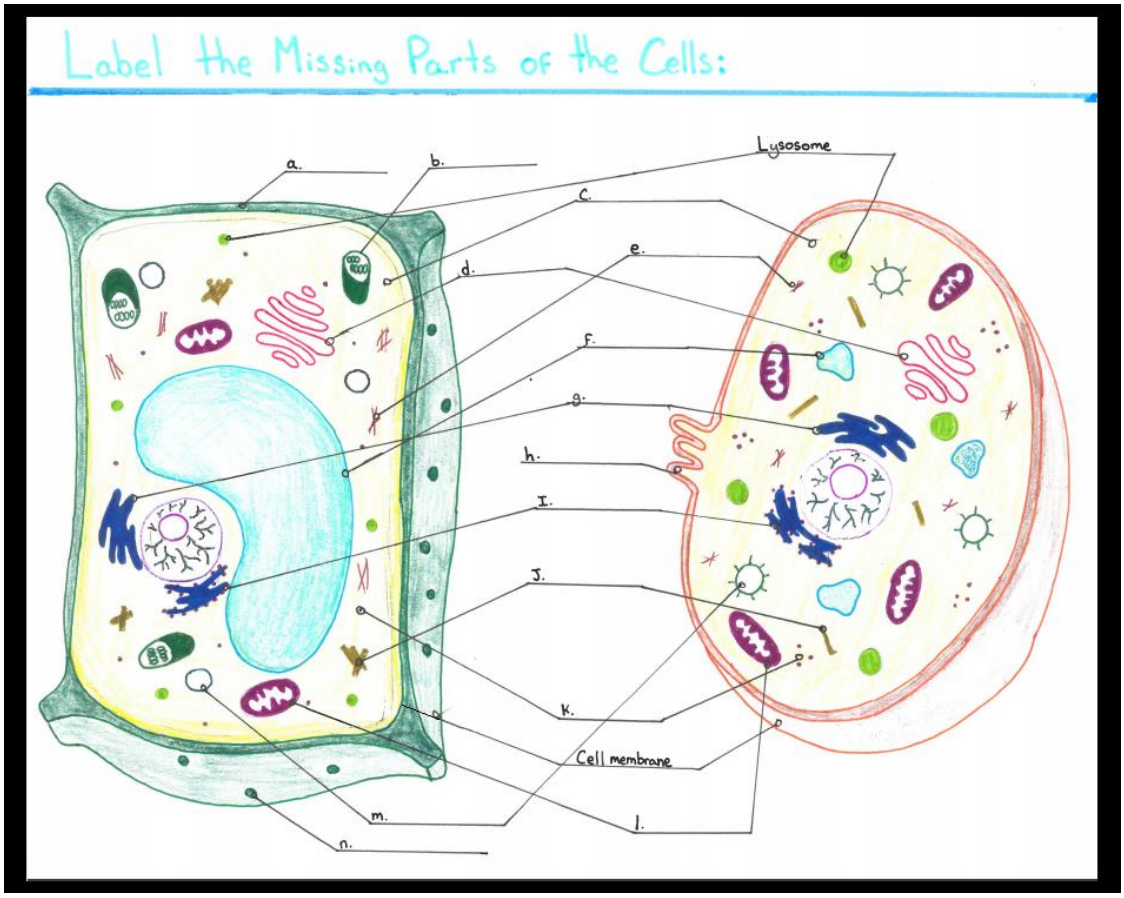
Only one student turned in an original work for this project. This student made a review illustration for the naming of animal and cell parts. Student review of this work was very positive. This student was apparently well known as an artist by their classmates as several comments were variations of, "*Student 8* is creative/talented". One student wrote "it's handmade" as their favorite thing about the learning object. This student submission can be seen in Figure 7.

Summary

Students preferred videos and simulations over all other types of learning objects. The student participants overwhelmingly chose to find existing learning objects to add to their class textbook rather than making their own original learning objects. Most learning objects aligned well with the AP Bio Big Ideas, but one submission, while appropriate for the textbook on its own, was hosted on a YouTube channel that did not align with the purposes of the textbook. Changing technology can have an effect on submissions as many of the simulations that were added are no longer functional with the discontinuation of Flash based websites.

Figure 7

Practice Cell Labeling Exercise Submitted to Textbook



Research Questions Two and Three

As I outlined in the methodology section, the student participants in this study are the real focus of this research. Their feelings and perceptions of this project will help me address my remaining research questions. During interviews, I needed to get more information about how students were choosing the resources they were submitting, how the peer-review process affected them and their choices, and their perceptions of their names being listed in the textbook as the student who thought this resource would be helpful to future students. Students had turned in materials over the Fall 2019 semester and I interviewed 12 students two months after their last submissions to the textbook.

The teacher of the class keeps a cup full of Popsicle sticks with student names written on them that he uses to randomly choose students to ask questions or continue a discussion. The teacher drew a name from the cup for me each time that I was ready to start a new interview. I interviewed five senior males, five senior females, and two junior females. I had completed 12 interviews from the 17 students when the pandemic caused schools to be closed to in-person attendance for students. This was not tragic to my research because after I had spoken with ten students, I was considering discontinuing the interviews as I felt I was reaching saturation with the responses I was receiving.

One thing I tried to gauge about each interview was how seriously the student took the project. I know that there was some possibility that students submitted a learning resource without much thought other than to complete another assignment. And, in fact, during the first round of assignments, a student submitted an abstract from a scientific journal. The abstract submitted had some key words about the cell cycle. Beyond that, the abstract had very little to do with the material that the students were studying and was published in a Veterinary Pathology journal. Only the abstract from the article was available online, and to me it indicated the paper was too technical for the class, even if there had been a full copy of the paper available. It was obvious that the student had put very little effort and thought into their first submission. Overall, I found that seven of the students had very good recall about the three submissions they had made during the previous semester, three that were able to describe some of the submissions they had made, and two that could not recall much detail about the submissions they had made. Having some students thoughtlessly rush through an assignment just to get it done is unfortunately not a new phenomenon in my experience as a teacher.

Research Question Two

My second research question, "Why do students choose the resources and processes they use when reviewing and designing their own OER contributions?" is one that is not as easy to quantify as my first research question was. Students employed multiple strategies as they searched for learning objects to submit to the class textbook.

Several students were eager to share resources that they were already familiar with and had established some level of trust with. One student brought experiences with her family to the text book. She told me that she and her mom liked to listen to podcasts and watch TED Talks. She also told me that she felt, compared to other assignments, that this project "… is more impactful. It made me think a little bit more about what I was submitting, just to think that it could be in the textbook one day." For her, she already knew about sources that she valued and apparently trusted and reported that she navigated to the TED Talks website to search for engaging talks that were appropriate for the topic at hand. For her last submission, she had previously listened to a podcast with her mom about mosquitos that she thought "was perfect for ecology."

Other students followed similar approaches of submitting resources they were already familiar with. One student seems to have started a trend with their trusted resource when they added a video by Bozeman Science. This student told me that those videos helped him make it through chemistry and submitted one during the first round of submissions. It is apparent that students liked this addition to the text, as five more submissions were made from the Bozeman Science channel. One student who submitted a Bozeman video for his last submission reported specifically searching for "Mr. Anderson ecology," ostensibly after reviewing several of his videos during the first rounds of submissions.

This pattern of students altering their searches due to what they had seen other students turn in was evident in other situations as well. A male senior student, in recalling what he had turned in, recalled that his first submission couldn't be viewed at the school, but that he thought he had "done better on the other two". When I asked what he did different, he said that he "paid more attention to the grading procedures and picked more interactive ones for the other two". There was a sharp upturn in the number of students who reported adding the term interactive to their search queries in the last round of submissions.

Students described searching for items to add to the textbook because they were personally having trouble with a particular topic. A senior female student related this to me: "I tried to see what would help me personally. So anything that I personally had kind of been confused about, I tried to look for something that explained that question or concept more thoroughly." A number of other students employed this strategy and also seemed to consign the ability of the source to help them to other students. A female senior stated, "I would find things that help me understand it better just because I thought other kids struggle with that, too." A different female senior backed this idea up, saying, "you could like pick whatever topic you either struggle with or felt comfortable with to help explain it to (other) kids."

A number of students seemed to be influenced in their choice of submission by the thought of it being viewed by future students. During his interview, a senior student told me: Doing something like this definitely made me think a lot more about what I was trying to find and maybe put in a lot more effort for it because it was for someone else, rather than just getting an understanding of my own. I had to think about how other people would read it. Another male senior told me "I guess that also just puts more pressure on me to make sure that it's right. And it's actually useful information….. I don't want to seem like stupid to the

kids next year." A senior female said of her submissions, "I think if (my submissions) are helpful to someone they can think of me!" with a big smile on her face. One of the juniors involved with the project was already anticipating the next academic year saying, "I think that'll be awesome because I've a lot of friends going into AP Bio next year. Something like 'that's mine!'" she laughed as she mimed pointing to one of her friend's computers.

Research Question Three

The last of my research questions was written with both Bandura's Social Learning Theory and Self Efficacy Theory in mind. Albert Bandura was a social cognitive psychologist who is best known for the above theories and his famous Bobo doll experiments (Grusec, 1992). He believed that the underlying components of observational learning are attention, retention, and motivation. My third and final research question also contains three sub-questions:

3. How are the cognitive concepts of attention, memory, and motivation impacted by the production and evaluation of Open Resources?
    a. How can online interaction help reinforce subject specific stimuli in the form of peer evaluations and peer comments to enhance memory creation and retention?
    b. How does creating an educational resource that will be viewed by future students affect student perception of work they produce?
    c. How does contributing OER material help students meet learning targets in a biology class?

Research Question 3a: Attention from OER

As I discussed the processes students use when selecting materials for a class OER textbook, I partially addressed how attention was playing a role in the students' processes.

Attention is the process of taking notice of something and regarding it as interesting or important (Grusec, 1992). A senior student that had his first submission rejected because it would not play on the school network attributed his success on his later submissions to paying closer attention to the details of the assignment. A senior female participant stated that this type of project requires students to "make sure everything is right" as it could be in the textbook forever.

Student Choice

One theme I noticed as I was into my second round of coding was the number of students who appreciated the aspect of this project that let them choose what they thought would be the most beneficial for the textbook. This often came up in the interviews when I asked students how they would compare this project to projects assigned in their other classes. One female senior student responded that she found it easier to complete this assignment because students got to choose what would benefit the book "I thought that was pretty good, that we just got to choose." Another student replied similarly, "I did like the aspect of having control over what you create. I like that." Another senior female student told me that this project was better than most and "…doubly more informational than just a big PowerPoint that most teachers will have to do and stuff like that. In fact, they've decided what your project is about." I believe providing the student with the range of choices they had on the project helped them to pay attention and remain engaged with the project.

Student choice in completing science learning activities has positive impacts to the student's engagement in their work (Schmidt et al., 2017). In their study of high school students, Schmidt et al., generated *momentary engagement profiles* measuring different dimensions of student engagement and reported that student choice in completing

assignments was generally associated with the study's more optimal engagement profiles (2017). The authors conclude their article stating:

> our study demonstrates that student choice matters in general, and that particular choices—such as those around framing the task—have more positive impacts on engagement than others like choosing who to work with or how much time to take to complete a task (2017, p. 38)

The act of building an OER textbook with classmates provides an environment in which attention and engagement are thoroughly entwined. When student engagement is stimulated by their choice in the style and type of resource they choose, as in this research, they will likely be more focused and deliberate in the submissions they offer to the class. The peer-review process is akin to social media, in which students get to post an item, like or dislike other posts, and make comments. Shannon Deaton reports in their review of social media and learning "The very nature of online social interaction requires that attention be maintained in order to engage with the content" (2015, p. 2). By engaging in peer-review and being peer-reviewed in return, the persistent call for attention can improve learning processes and increases the student's ability to maintain focus throughout the completion of the learning activity (Deaton, 2015). I think evidences of attention being positively encouraged by this project is the fact that students average ratings of the learning objects was closely aligned with my ratings.

During interviews, I heard multiple student statements that led me to believe that student ratings and comments were perceived by other students to be honestly and thoughtfully given. One senior student appreciated the effort that her classmates made as they evaluated her learning objects. She said "I was kind of nervous about it… sometimes I feel

like I don't understand things that other kids do. But I mean, like, like no one was like mean about it. They just read it and evaluated it." A male senior said "I thought it was good because we could really give each other honest feedback. And I mean, with our class size, it's easier to because we can be more honest about it. So I thought it was good that we could just be real about it." I think these perceptions of the peer-review process indicates that students believed their classmates were closely paying attention to each other's submissions and giving their true impressions of each learning object.

Research Question 3b: Motivation from OER

Self-efficacy, or what the layman may call 'believing in yourself', is a central tenet in Bandura's theories on learning. A student's belief in their own abilities plays a role in what we do, how we act, and how we perceive our place in society (Grusec, 1992). At the onset of this project, I had stated that I thought as students viewed and critiqued each other's work, they would learn from each other what they like about resources and use that to improve their own work. I found the peer-review portion of this exercise to be critical to answering the question of how submitting OER materials affects motivation in the learning process. Albert Bandura said this of learning:

> Learning would be exceedingly laborious, not to mention hazardous, if people had to rely solely on the effects of their own actions to inform them what to do. Fortunately, most human behavior is learned observationally through modeling: from observing others one forms an idea of how new behaviors are performed, and on later occasions this coded information serves as a guide for action. (1977, p. 22)

Students could have easily submitted work for this project and I could have graded it and decided what should be included. A student who received a poor grade, or found their

submission rejected, might not believe that they could succeed in later attempts. When small groups of students reviewed the submissions of their classmates they were able to learn what other items might be contributed and what their classmates thought made learning objects useful or not. They also got to see their names in the book, which many students indicated was a favorable outcome during their interviews. With these conditions set in the class, students were surrounded with a lot of motivation to find quality materials. The quality of submissions increased as a whole for the class through the three rounds of submissions. The first round of submissions had an average score of 2.3, while the latter two both rose to an average of 2.5. Similarly, student performance was enhanced in a study that provided peer-review for a screencast assignment (Sudhakar et al., 2016). The study attributed the increase in performance to student viewing the exemplar screencasts of their fellow students during a peer-review process.

I found evidence in student responses that indicate this approach did improve not only the quality of the work, but the efforts of the students. A male student said of students reviewing his work, “it didn't really pressure me too much because I knew, you know, if it's good, get at it. If it isn't, then it won't sell.” One student described the AP Biology class as being really close to one another so he felt positive about peer-review, “we already intentionally pick on each other and critique each other to make each other better, so we took it pretty seriously…we had to be intentional about making sure these are solid things for the book.”

Students were motivated as well by thinking about future students. The student that made the cell drawing submission said that she was very proud of her work and was happy that other students would get to use it. Many students expressed positive remarks that their

effort on this project would help students in the future and not simply be forgotten. “You feel more purpose doing it cause you're helping other kids who are going to learn about this stuff in the future other than like just making a poster that you're never gonna look at again” remarked one of the female seniors in the study. Echoing this, a male senior said “It's going to be something that future kids are going to be using and looking at and learning from. Definitely a lot more sense of accomplishment. Yeah, it felt very accomplishing to be a part of it.”

Research Question 3c: Memory from OER

There are many theories surrounding the formation of long-term memory. Behaviorists underline the role that external factors play, while a cognitive approach will point to the process that occurs in the brain (McLeod, 2017). Social learning theory connects these two theories, attributing memory formation to a combination of both. From the interviews of the participants in the study, I think for some students that is definitely the case. Some students were able to recall precisely what they had turned in, while some were only able to partially describe what they had found. I would hope this translates into remembering something about the Big Idea they were studying. For example, the student who produced the hand-drawn study sheet for cell organelles, indicated that she had to examine several different cell illustrations before making hers, because some of those reference diagrams lacked the presence of ribosomes. Noting the differences in the source diagrams and remarking on it to me several months later suggests that designing an OER submission can aid in memory formation.

One senior female, as I questioned her thoughts about the class peer-review process specifically mentioned a comment that she made about a learning object “*Student 10* did, like

it was a game that she linked that let you control cell division. And then I thought it was a really good. So I think that's pretty much what I said". This student had not only recalled her own submissions, but off-handedly revealed that she remembered another student's contribution as well. Of course, there were some students who couldn't recall any specifics about the submissions they made, which leads me to believe that students who were not engaged in the project made choices that they soon forgot all about. While I found most of these students' submissions useful for the class textbook, I suspect that the passive learning achieved in merely finding those resources did not lead to any specific long term memories. Many studies conclude that active learning, such as designing your own learning object, supplements student learning and can increase subject knowledge (Braxton et al., 2000; Kilgo et al., 2015; Kitchens et al., 2018).

The biggest impact the Covid-19 pandemic had on my research was the last component for the study I had planned. I realized that my last research question, "How does contributing OER material help students meet learning targets in a biology class?" was not being answered sufficiently in the interviews. I started to design a practice study question sheet for the students by choosing questions from a databank in which the learning objectives were marked on each question. My idea was that I could examine results from this practice test and compare student correct responses against the learning objectives they had submitted. Unfortunately, with the chaos that came from school being cancelled and the switching of all of my own classes to online work coupled with the fact that students were not coming to campus anymore, this part of my study was abandoned.

With this approach to gauge the effect of memory development from this project unavailable, I instead examined the average scores of ten tests the host teacher administered

through the fall semester. These ten tests were designed as 20 points tests by the host teacher. Four of the tests covered topics in which students chose and evaluated each other's learning objects. The average score on these four tests was 17.4 compared to a 16.3 average for the remaining six tests. Three of the top four averages on these tests were from chapters that the student's weekly assignments included the OER project. However, one of these four tests ranked as the third worst average. While not conclusive, I think that the overall increase in scores on tests during the units with active OER participation does add to my impression that this project positively impacted memory in these students. The average test scores are presented in Table 9.

Table 9

AP Biology Test Scores through the First Semester

Tests										
#1	#2	**#3**	#4	#5	**#6**	#7	#8	**#9**	**#10**	Average of all tests
17.1	13.4	**17.2**	17.5	17.9	**17.7**	15.7	16.5	**18.5**	**16.1**	16.9

Note. The boldfaced scores are tests that covered topics in which students participated in class textbook activities.

Learning

This project was not designed to just make a custom textbook for a class. The hope at the outset of this endeavor was that if would also aid students in mastering the learning objectives of AP Biology. This study shows that memory, attention, and motivation were each stimulated as students went through the process of finding and designing learning objects. Students paid more attention to their work as they knew their peers would be able to view their contributions in the future. Students were more engaged because they had a choice

in the type of learning objects they could submit. They were motivated by their desire to help other students and making certain their submissions would be favorably evaluated by the rest of the class. Many students could remember their submissions months later and scores on quizzes showed improvement when students were actively participating in the design of the class textbook.

Trustworthiness of these Findings

In the methodology section of this dissertation, the differences between trustworthiness in qualitative and quantitative works were discussed. Recommendations presented for ensuring trustworthiness in qualitative work included exploring alternative theories and attention to several constructs that can be employed during a case study to bolster confidence in the research. This work was designed and viewed through Bandura's social learning theories. The leading competing theories for learning would be from a behaviorist or developmentalist point of view. A behaviorist could argue that students would submit learning objects that simply meet the requirements needed to receive a passing grade. This theory cannot be ruled out for all students in this study, as some students did seem to submit learning objects that would simply satisfy the requirements of this assignment so that they could move to the next. Behaviorists would describe this as a type of conditioning and postulate that students have not learned anything, but were simply seeking reinforcement for a learned behavior. However, based on interviews with students that could not recall many of the details of their submissions, I believe that Bandura is correct with his notion that reinforcement does play a role in learning, but is more a predecessor than a consequential learning activity (Bandura, 1977). These students still demonstrated an understanding for the

reasons why the project was taking place and the consequences of their submissions for future students as the underlying reason for their choices.

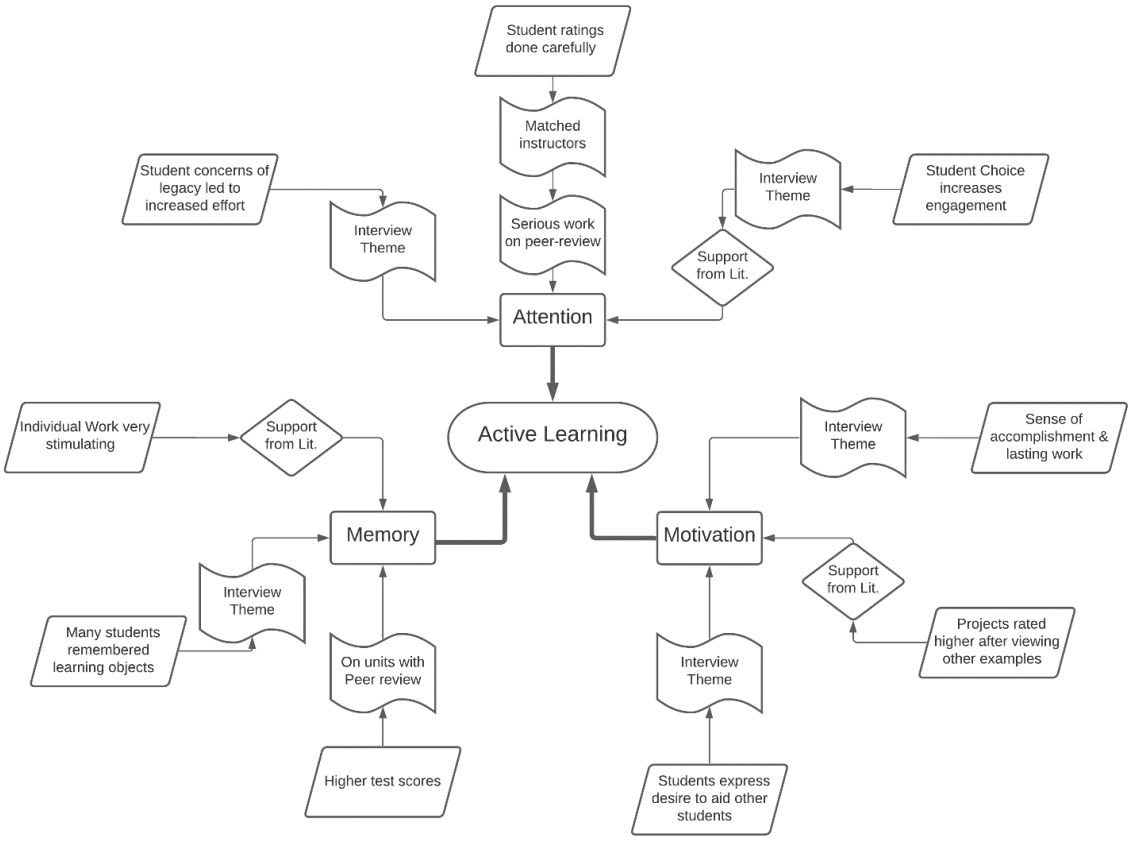
The constructs reviewed in the methods chapter for maintaining trustworthiness in a case study were credibility, transferability, dependability, and confirmability (Shenton, 2004). These five items, first proposed by Egon Guba, are areas where the researcher can work to increase the integrity of their work (1981). Below I will review each of these and how they have been employed throughout this study. The first issue to address is credibility, and a suggested way to accomplish this in a case study is to emulate the work of previous successful projects (Yin, 2014). As this case study is the first to examine student contribution to OER, I concentrated on Yin's suggestion to triangulate the data I collected from different sources. Much of my project relied on the peer-review process and the ratings and comments generated there. My observation of students during the peer-review process, followed by examining comments on student submissions, using the rubric on each entry myself, contributed to the credibility of the submissions and ratings reported by students. The students' ratings reported in this study might not be held up by just one of these methods, but observing the seriousness of the students during the peer-review process, coupled with student ratings closely coinciding with my own, and their comments complementing the scores of each learning object, I feel that these ratings are accurate.

I believe this project has shown positive impacts to learning, memory and attention, three key aspects of learning. Without a quantitative means to measure these cognitive aspects of learning, I have relied on reporting multiple sources of data that have impacted these three aspects. Figure 8 is attempt to graphically represent how my study converges on

the notion that AP Biology students are actively learning material when participating in building an OER class textbook.

Figure 8

Support that Building a Class Textbook Stimulates Learning



Credibility can also be enhanced by taking steps to ensure honest responses from participating subjects (Shenton, 2004). To help assure that the study participants were honest, I provided all students with the choice to participate, noting there was no penalty for not enrolling in the study. This step can help ensure that only students willing to talk to me would participate and no one would feel pressured into consenting to the study. Two students in the AP Biology class chose not to participate in this study. I also took care to remind each

student during their individual interviews that there were no correct answers to the questions I asked of them and that they would not be penalized in any way for any answers they gave.

The transferability of this study should be addressed as well. Merriam stresses the importance of transferability and determining how the results of a study can be applied to other situations (1998). Through my descriptions of the case study, I have worked to inform readers of the demographics of the participating students, the materials and resources they had available, and all of the contextual information they would need to recreate this study. However, the size and specific environment of my study precludes a direct transfer to a different population (Shenton, 2004). As Shenton also suggests, through noting the boundaries of my study and reporting the methods and timing of its execution, I have provided enough detail that another researcher could make the transfer themselves (Shenton, 2004).

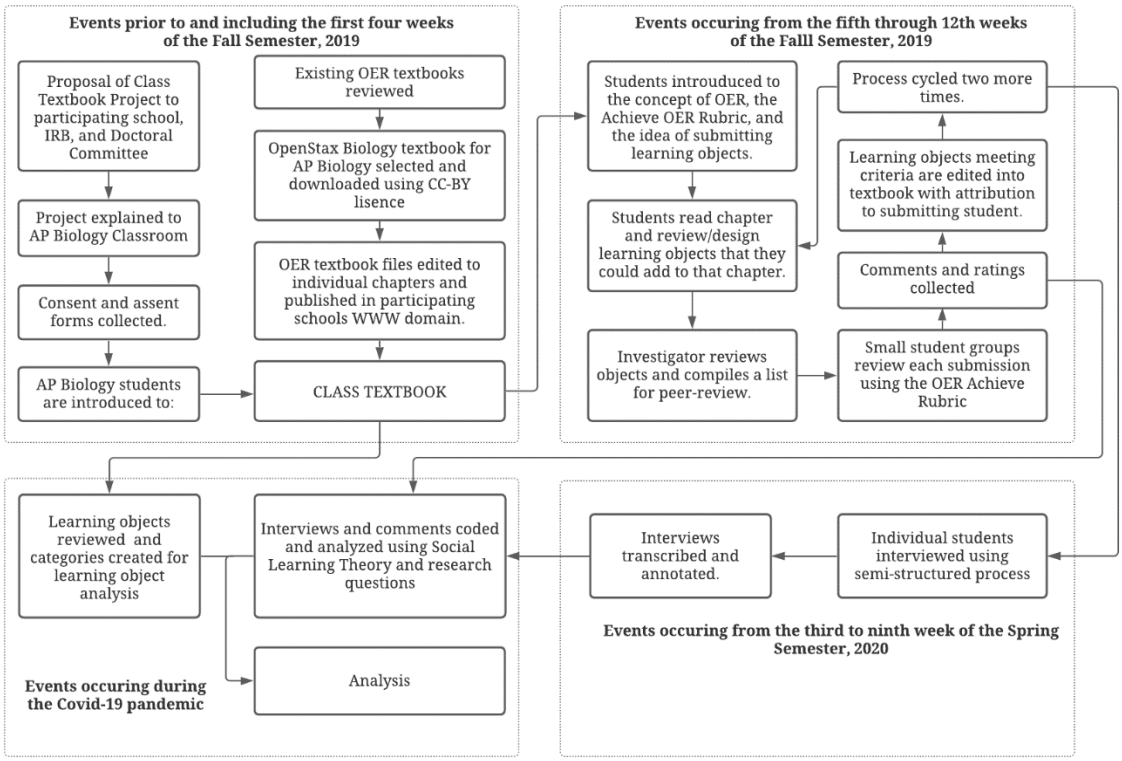
Dependability in quantitative work can be demonstrated by detailing the processes utilized in the design and implantation of the study (Florio-Ruane, 1991). I have provided a great deal of detail about the processes undertaken to publish the class textbook, how students made submissions, and how the peer-review ultimately led to inclusion in the textbook. This will serve to allow the reader to gauge the effectiveness of the actions taken to complete this project (Shenton, 2004). Guba noted that credibility and dependability are somewhat entwined, as a thorough exhibition of the first in a naturalistic study can give weight to the second (1981).

Confirmability in quantitative work can often be shown with instruments of measure. In my qualitative work, however, there is a greater danger that my biases and predilections could find their way into my work (Shenton, 2004). I previously described the types of

learning objects I thought might be submitted to a class textbook. In order to not influence student choice, I made the decision to perform this research in another teacher's class, rather than one of my own. I wanted to have as little influence on their decisions about learning objects as possible. A graphical *audit trail* has been suggested as a way for the researcher to show the step-by-step processes and timeline that was employed in the study with an explanation of why that scheme was followed (Shenton, 2004). In Figure 9, I have outlined the steps and timeline of this project.

Figure 9

An Audit Trail of this Case Study



This project had four main phases. At the upper left of Figure 9, the foundations of the project are shown. I had to prepare and defend my study with the Graduate School, I had to gain acceptance of the participating high school, and prepare a base-line OER textbook

that the class could modify. Once the class textbook was in place, I gave the students parameters for submitting learning objects to the textbook and allowed them three days to make their choices. After I collected the submissions, I took them to the class for peer-review. I collected the ratings and comments made by students and edited the textbook to reflect the student contributions. This basic pattern of submissions and peer-review was completed two more times. After the last round of submissions, I started the interviews with the student participants, transcribing and annotating each interview. At this time, the Covid-19 pandemic was sweeping across North Carolina, and all further work on the project was suspended. During the pandemic, the answers to the research questions presented in this dissertation were synthesized from a thorough examination of student submissions, student comments from peer-review, and transcripts of individual interviews.

Chapter 5

Summary and Future Research

I gained an interest in OER textbooks initially to help save my college students money on their education. When I transitioned to teaching secondary students, I thought that OER textbooks could not only save the district money, but also that there were some opportunities to make something unique that has a positive impact on science education. Students could easily become active participants in their education, not simply passive recipients, by working on a project that would not only help them meet learning goals, but would also help future students as well. I also felt very accomplished as I watched our class textbook grow in size and different types of resources. Knowing that the project completed is one of the first attempts of its kind is rewarding in itself. Believing that the project has true merit and can be used as an effective teaching strategy has me excited about the future of OER. I have plans to modify my initial approach with the AP Biology class in my own Anatomy and Physiology classes and I believe my current and future students will benefit from the effort.

I believe the using editable OER book in a class can foster learning through what Paolo Freire referred to as dialogical education (Freire, 2005). The construction of a class textbook employs the concepts of dialogical education because students aid in the co-construction of a new tool for learning. Rather than simply receiving information from a text book, they are actively involved in reversing the flow of information that exemplifies a banking concept approach to education. Working together on a community textbook turns students into co-creators of knowledge.

Review of Research Questions

1. Given the opportunity, what resources will a class of AP Biology students add to an existing OER biology textbook?

The digital age has made short videos and clips very popular in today's society. TikTok, a social network specializing in sharing videos, has over one billion daily users (Doyle, 2021). The United States has 130 million users, 33% of whom are under 19. It is no surprise that today's students found videos to be worthy additions to the textbook. Over half of student contributions contained some type of video. Students liked having videos that had the combination of a talking head and animations on the screen to help them understand topics better. Students will add supplemental readings to the textbook, most often when those readings contain interactive questions and/or videos accompanying the written explanations.

Video gaming is as popular as short videos for millennial students. So again, it is not surprising that video games and simulations were popular additions as well. Students commented positively about these submissions that offered something repetitive to help them remember key processes that occur in living things. Students also enjoy the interactivity that was present in many of the simulations and readings with embedded questions, allowing them to manipulate variables and observe the results. Audio submissions were not as popular, with only one ultimately making it into our class textbook. I also found that students in this case study were not eager to reinvent the wheel to make their own learning objects when there are so many resources already available.

2. Why do students choose the resources and processes they use when reviewing and designing their own OER contributions?

I found that students generally had one of two strategies when choosing resources for the class textbook. Students often shared resources that they had used previously and found success with. Some students had familiarity with sources before the project started, while others found sources they liked as they observed one another's contributions. The other strategy employed by students was identifying what they were having difficulty understanding and then searching for learning objects that would aid them with their own comprehension of problematic topics. Many students believed that if the resource could aid them, it could help their classmates and future students as well.

3. How are the cognitive concepts of attention, memory, and motivation impacted by the production and evaluation of Open Resources?
    a. How can online interaction help reinforce subject specific stimuli in the form of peer evaluations and peer comments to enhance memory creation and retention?
    b. How does creating an educational resource that will be viewed by future students affect student perception of work they produce?
    c. How does contributing OER material help students meet learning targets in a biology class?

Albert Bandura's theory of learning posits that a combination of attention, memory or retention, and motivations are the keys to successful learning. This research project shows that all three of these cognitive concepts can be engaged with the production of an OER textbook. Students felt they needed to pay special attention to details as their project would not only be seen by the teacher, but also to make sure the materials would be helpful to future students. The ability to choose what they felt would benefit the textbook also led to more engagement. Student choice of how to complete this assignment was highly valued.

Students were motivated to create or submit works that were acceptable to their classmates. The peer-review process allowed students to model their work on what their friends were doing, a key aspect of self-efficacy. Students were able to see that they could present acceptable learning objects by seeing the success of their classmates. Having their name associated with the learning object was also a motivational aspect for some students helping ensure that they believed their effort in offering contributions would be truly helpful for future students.

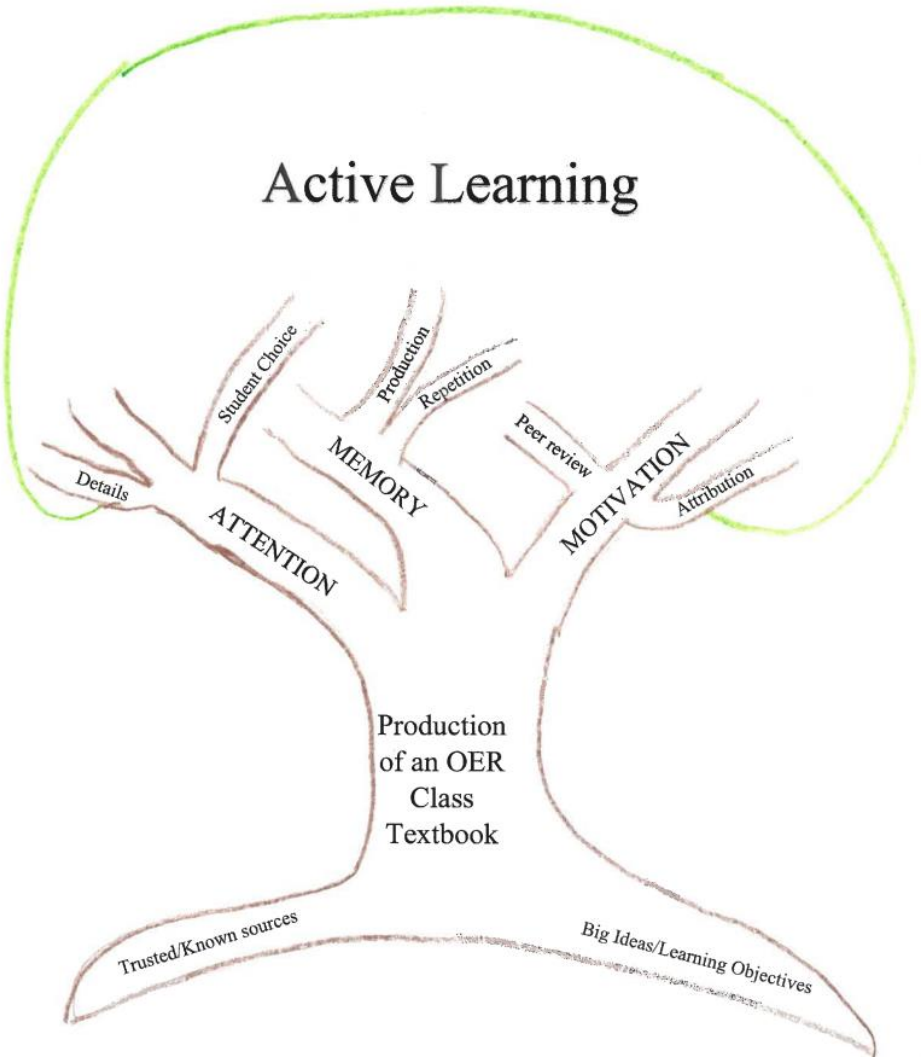
From this study, it is difficult to gauge the ability of contributing to OER toward memory formation. There were mixed results when students were asked to describe their contributions, as some obviously learned a lot as evidenced by their recall, but others clearly spent less time searching for resources as they were unable to recall specifics of their learning objects a few months later. I wrote earlier about students citing their submission of a video game to the textbook as a resource that would allow repetition to engage their memory.

My biggest deficiency in this case study was not requiring students to produce at least one round of original works. I do believe that if I had asked students to produce their own videos, design their own interactive questions, or any other form of original work, that it would have had a stronger impact on student memories. The student who recalled and relayed the most details about a learning object that they submitted was the student who created the drawing for the textbook. Multiple studies have pointed to the benefits of active learning and I believe that the time needed to design and complete a new learning object, as opposed to evaluating existing ones, would be more beneficial to a student's learning. Requiring students to design their own learning objects would be one of my top suggestions to any individual or group who decides to implement this project in their own setting.

I believe this work provides a good foundation for future research. To aid myself and future researchers who engage in this type of work, I have attempted to capture the organic spirit of a class designing their own OER textbook and how it can aid in learning (Figure 10). My hypothesis is that if students' efforts in building an OER textbook are rooted in the big ideas, or standards, for their class as well as using known and trusted sources, then they will be actively learning their content as the cognitive aspects of attention, memory, and motivation are stimulated.

Figure 10

Representation of how an OER Class Textbook Can Lead to Active Learning.



Student choice in both my work and in the literature has been shown to help grow student engagement and attention. The peer-review process employed before placing learning objects in the textbook can motivate students to do better work as they strive to mimic their more successful classmates' efforts. Additionally, students are motivated by the knowledge that their work will not be forgotten and that as part of the CC-BY license, their name will

remain attached to their learning object with the potential to be viewed by a far larger audience than most of their school work. I believe that memory will play a larger role in the process when students are producing their own works. Videos were very popular among my students and I wish I had had the opportunity to ask students to submit their own, even if very short. A partnership between Khan Academy, National Geographic, and Cold Springs Harbor Laboratory finds such enormous value in students producing their own videos, they are now offering a $250,000 scholarship as part of their yearly Breakthrough Junior Challenge (Breakthrough Junior Challenge, 2021). To enter this contest, students under 18 years of age may submit their own three-minute video explaining a concept in either physics, mathematics or life sciences. The Breakthrough Junior Challenge finds worth in these videos saying "An inventive video can get across complex material that would take pages of text to communicate" (2021).

Future Research

This study answered some questions about student participation in helping to design an OER textbook, but as it was one of the first studies investigating that topic, there are many opportunities to elucidate what other benefits might come from undertaking a project similar to this one. The first logical extension of this work would be to simply follow the progress of the book through a few cycles of classes adding materials to the textbook. The students in this study did not get to see examples of learning objects prior to the start of the study. Seeing their graduated classmates' names and learning objects already present in the book may have more of an effect as future students will be able to experience the learning objects as part of their textbook reading, rather than as a part of the peer-review process. To further address if contributing to an OER textbook will help students meet learning targets, a review

quiz, in which questions are designed to evaluate knowledge of particular learning objectives, could be compared against the submissions each student made.

In attempting a project on the scale similar to the class textbook, a teacher will need the support of other staff at the school. There needs to be buy-in from the school's administration and support from the other members of the faculty and staff. The school librarian would be a tremendous asset to constructing a new OER textbook. They can offer literacy training, such as the type students in my project completed, and offer technical assistance with hosting the materials online and making them freely available for use. Libraries often have the equipment that students might need to make their own videos to submit as learning objects. Schools that have classes in Internet Technology could be involve those students in the editing of the webpages hosting the textbook. Lastly, involving more teachers in the project can allow for the creation of an editorial board to make decisions on questionable material that may be submitted as opposed to giving complete editorial control to a single person.

On a larger scale, I see many other opportunities to test my ideas of how contributing to an OER textbook can help students grow their knowledge. There were many challenges to attempting this project as a solo effort. I am interested in working with partners that can make the process of adopting a class textbook easier and less time intensive. An advantageous choice for this partner could be a university library or education department that would offer tools and support to teachers wanting to do this type of project with their classes.

Many of the challenges that would face a teacher maintaining their own OER textbook are technical in nature. For example, I was knowledgeable of education practices

and had 25 years' experience as a biologist, but I did not know much about how to electronically host a textbook. The class textbook in this study was all in the form of PDF files. These files can be edited relatively easily and links and pictures added with basic knowledge of editing text documents. This is one reason why I adopted this approach as it was the only method I was familiar with. An unfortunate drawback to this approach is that animations, videos, and simulations must all be viewed outside of the textbook through a link, as these types of learning objects are not supported inside of PDFs.

A support partner could offer web hosting tools that would allow the textbook to be even more interactive and to keep students from having to navigate back and forth from the textbook to engage with learning objects. Offering an online space for hosting the textbook coupled with training and tools for adding learning objects directly into the textbook could encourage teachers who would like to adopt this type of project for their own classrooms. I have discussed the advantages that I believe producing video learning objects would bring to this project. A support partner could help provide resources to students to produce higher quality videos that would be possible using Chromebooks or smartphones. A green screen and the ability to add graphics or images to videos seems to be key among the producers of winning videos in the Junior Breakthrough Challenge.

If such a program were hosted by a university, many other opportunities for collaboration would become possible. Some schools, especially rural ones, have smaller AP classes. In this case, a support partner could host a *regional* textbook, rather than a *class* textbook. Students from multiple small classrooms could work with one another to build a custom textbook and participate with each other in the peer-review process. Another aspect of a regional textbook that is appealing, is having several instructors to serve as an overall

editorial team. This will allow decisions to exclude materials, like the ant communication video, to be approached more equitably instead of a single person controlling the content of the textbook. To answer questions about the efficacy of my hypothesis of how making an OER textbook can lead to learning, AP exam scores can be compared to schools with similar demographics. Success in a study like this could potentially lead to statewide adoption of an OER textbook, freeing up money to enhance laboratories and experiential learning.

My hope is that this project will stimulate teachers and education agencies to consider undertaking the production of an OER textbook. I believe this study has shown that there is great potential for enhanced learning through student participation in the remixing of textbooks. Students will be motivated to produce even greater works through the essential peer-review process needed for effective textbook building. In my experience, students are excited to help other students, and the possibility of their attributed work being viewed by future students will increase student engagement. Their memory formation will potentially be stimulated, especially if they are producing original work. Allowing students to choose the type of contribution they would make increases enthusiasm for the learning that comes from participating in a class textbook. Traditional textbooks may eventually become relics from the time before the digital revolution, but the future of OER textbooks is wide open.

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Appendix A
Achieve OER Rubric

Rubrics for Evaluating Open Education Resource (OER) Objects

The following rubrics represent an evaluation system for objects found within Open EducationResources. An object could include images, applets, lessons, units, assessments and more. Forthe purpose of this evaluation, any component that can exist as a stand-alone qualifies as an object. The rubrics in this packet can be applied across content areas and object types.

In general, the rubrics should be applied to the smallest meaningful unit. In some cases, this may be a single lesson or instructional support material, while in others it might be a completeunit of study or set of support materials. If multiple lessons are included in an OER, the reviewer needs to determine if all lessons will be examined, if only those lessons that deal withessential aspects of the curriculum are to be considered, or if it would be best to evaluate random lessons, looking at, for example, every third or fifth lesson.

These rubrics are typically used to rate the potential, not actual, effectiveness of a particular object in a learning environment. Each rubric should be scored independently of the others using the following five scores that describe levels of potential quality, usefulness, or alignmentto standards:

3: Superior
2: Strong
1: Limited
0: Very Weak /
None N/A: Rubric Not Applicable

The *not applicable* (*N/A*) rating should be used any time a particular rubric does not apply to the object being rated. This is not a pejorative score; it simply means it would be inappropriateto apply this rubric to this object. For example, Rubric IV: Quality of Assessment would not be applicable to an object that does not have an assessment component.

The following rubrics are included:

Rubric I. Degree of Alignment to Standards
Rubric II. Quality of Explanation of the Subject Matter Rubric III. Utility of Materials Designed to Support Teaching
Rubric IV. Quality of Assessment
Rubric V. Quality of Technological Interactivity
Rubric VI. Quality of Instructional and Practice Exercises
Rubric VII. Opportunities for Deeper Learning
Rubric VIII. Assurance of Accessibility

Rubric I: Degree of Alignment to Standards

This rubric is applied to learning objects that have suggested alignments to standards. It is usedto rate the degree to which an individual object actually aligns to each proposed standard. The rubric was designed specifically for the Common Core State Standards, but can be used with any set of standards. Before the rubric can be applied, the assumption is that a user has proposed an alignment between the object and the selected standard(s).

There are two major aspects of standards that are vital to a meaningful alignment review: content and performance expectations. It is important that the *content* addressed in the objectmatches the content addressed in each proposed standard. Evaluating the alignment of the *performances* required in both the object and the standard is equally essential and should be considered along with the content.

Rubric I Scoring Guide:

3: An object has *superior* alignment only if **both** of the following are true:

- All of the content and performance expectations in the identified standard are completely addressed by the object.
- The content and performance expectations of the identified standard are the focus ofthe object. While some objects may cover a range of standards that could potentially be aligned, for a superior alignment the content and performance expectations must not be a peripheral part of the object.

2: An object has *strong* alignment for either one of two reasons:

- Minor elements of the standard are not addressed in the object.
- The content and performance expectations of the standard align to a minor part of the object.

1: An object has *limited* alignment if a significant part of the content or performance expectations of the identified standard is not addressed in the object, as long as there is fidelity to the part it does cover. *For example, an object that aligns to CCSS 2.NBT.2, "Count within 1000; skip-count by 5s, 10s, and 100s," but only addresses counting numbers to 500, would be considered to have limited alignment. The object aligns very closely with a limited part of the standard.*

0: An object has *very weak* alignment for either one of two reasons:

- The object does not match the intended standards.
- The object matches only to minimally important aspects of a standard. These objects will not typically be useful for instruction of core concepts and performances coveredby the standard.

N/A: This rubric does not apply for an object that has no suggested standards for alignment. *For example, the rubric might not be applicable to a set of raw data.*

Rubric II: Quality of Explanation of the Subject Matter

This rubric is applied to objects designed to explain subject matter. It is used to rate how thoroughly the subject matter is explained or otherwise revealed in the object. Teachers mightuse this object with a whole class, a small group, or an individual student. Students might use the object to self-tutor. For objects that are primarily intended for teacher use, the rubric is applied to the explanation of the subject matter not to the planning instructions for the teacher.

Rubric II Scoring Guide:

3: An object is rated *superior* for explanation of subject matter only if **all** of the followingare true:

- The object provides comprehensive information so effectively that the target audienceshould be able to understand the subject matter.
- The object connects important associated concepts within the subject matter. *For example, a lesson on multi-digit addition makes connections with place value, rather than simply showing how to add multi-digit numbers*. *Or a lesson designed to analyzehow an author develops ideas across extended text would make connections among the various developmental steps and the various purposes the author has for the text.*
- The object does not need to be augmented with additional explanation or materials.
- The main ideas of the subject matter addressed in the object are clearly identified for the learner.

2: An object is rated *strong* for explanation of subject matter if it explains the subject matter in a way that makes skills, procedures, concepts, and/or information understandable. It falls short of *superior* in that it does not make connections among important associated concepts within the subject matter. *For example, a lesson on multi-digit addition may focus on the procedure and fail to connect it with place value*.

1: An object is rated *limited* for explanation of subject matter if it explains the subject matter correctly but in a limited way. This cursory treatment of the content is not sufficiently developed for a first-time learner of the content. The explanations are notthorough and would likely serve as a review for most learners.

0: An object is rated *very weak or no value* for explanation of subject matter if its explanations are confusing or contain errors. There is little likelihood that this objectwill contribute to understanding.

N/A: This rubric is *not applicable* (N/A) for an object that is not designed to explain subject matter, for example, a sheet of mathematical formulae or a map. It may be possible to apply the object in some way that aids a learner's understanding, but that is beyond anyobvious or described purpose of the object.

Rubric III: Utility of Materials Designed to Support Teaching

This rubric is applied to objects designed to support teachers in planning or presenting subjectmatter. The primary user would be a teacher. This rubric evaluates the potential utility of an object at the intended grade level for the majority of instructors.

Rubric III Scoring Guide:

3: An object is rated *superior* for the utility of materials designed to support teaching only if

all of the following are true:

- The object provides materials that are comprehensive and easy to understand and use.
- The object includes suggestions for ways to use the materials with a variety of

learners. These suggestions include materials such as "common error analysis tips" and "precursorskills and knowledge" that go beyond the basic lesson or unit elements.

- All objects and all components are provided and function as intended and described. Forexample, the time needed for lesson planning appears accurately estimated, materials lists are complete, and explanations make sense.
- For larger objects like units, materials facilitate the use of a mix of instructionalapproaches (direct instruction, group work, investigations, etc.).

2: An object is rated *strong* for the utility of materials designed to support teaching if it offers materials that are comprehensive and easy to understand and use but falls shortof "superior" for either one of two reasons:

- The object does not include suggestions for ways to use the materials with a variety oflearners (e.g., error analysis tips).
- Some core components (e.g., directions) are underdeveloped in the object.

1: An object is rated *limited* for the utility of materials designed to support teaching if it includes a useful approach or idea to teach an important topic but falls short of "strong"for either one of two reasons:

- The object is missing important elements (e.g. directions for some parts of a lesson arenot included).
- Important elements do not function as they are intended to (e.g. directions are unclear or practice exercises are missing or inadequate). Teachers would need tosupplement this object to use it effectively.

0: An object is rated *very weak or no value* for the utility of materials designed to supportteaching if it is confusing, contains errors, is missing important elements, or is for someother reason simply not useful, in spite of an intention to be used as a support for teachers in planning or preparation.

N/A: This rubric is *not applicable* (N/A) for an object that is not designed to support teachers inplanning and/or presenting subject matter. It may be possible that an educator could find an application for such an object during a lesson, but that would not be the intendeduse.

Rubric IV: Quality of Assessments

This rubric is applied to those objects designed to determine what a student knows before, during, or after a topic is taught. When many assessment items are included in one object, as isoften the case, the rubric is applied to the entire set.

Rubric IV Scoring Guide:

3: An object is rated *superior* for the quality of its assessments only if **all** of the following aretrue:

- All of the skills and knowledge assessed align clearly to the content and performanceexpectations intended, as stated or implied in the object.
- Nothing is assessed that is not included in the scope of intended material unless it isdifferentiated as extension material.
- The most important aspects of the expectations are targeted and are given appropriate weight/attention in the assessment.

- The assessment modes used in the object, such as selected response, long and short constructed response, or group work require the student to demonstrate proficiency in the intended concept/skill.
- The level of difficulty is a result of the complexity of the subject-area content and performance expectations and of the degree of cognitive demand, rather than a result of unrelated issues (e.g. overly complex vocabulary used in math word problems).

2: An object is rated *strong* for the quality of its assessments if it assesses all of the contentand performance expectations intended, but the assessment modes used do not consistently offer the student opportunities to demonstrate proficiency in the intended concept/skill.

1: An object is rated *limited* for the quality of its assessments if it assesses some of the content or performance expectations intended, as stated or implicit in the object, butomits some important content or performance expectations and/or fails to offer the student opportunities to demonstrate proficiency in the intended content/skills.

0: An object is rated *very weak or no value* for the quality of its assessments if its assessments contain significant errors, do not assess important content/skills, are writtenin a way that is confusing to students, or are unsound for other reasons.

N/A: This rubric is *not applicable* (N/A) for an object that is not designed to have an assessment component. Even if one might imagine ways an object could be used for assessment purposes, if it is not the intended purpose, *not applicable* is the appropriatescore.

Rubric V: Quality of Technological Interactivity

This rubric is applied to objects designed with a technology-based interactive component. It isused to rate the degree and quality of the interactivity of that component. "Interactivity" is used broadly to mean that the object responds to the user, in other words, it behaves differently based on what the user does. This is not a rating for technology in general, but for technological *interactivity*. The rubric does not apply to interaction between students, but rather to how the technology responds to the individual user.

Rubric V Scoring Guide:

3: An object, or interactive component of an object, is rated *superior* for the quality of itstechnological interactivity only if **all** of the following are true:

- The object is responsive to student input in a way that creates an individualized learning experience. This means the object adapts to the user based on what s/he does, or the object allows the user some flexibility or individual control during thelearning experience.
- The interactive element is purposeful and directly related to learning.
- The object is well-designed and easy to use, encouraging learner use.
- The object appears to function flawlessly on the intended platform.

2: An object, or interactive component of an object, is rated *strong* for the quality of its technological interactivity if it has an interactive feature that is purposeful and directly related to learning, but does not provide an individualized learning experience. Similarlyto the *superior* objects, *strong* interactive objects must be well designed, easy-to-use, and function flawlessly on the intended platform. Some

technological elements may notbe directly related to the content but for a *strong* rating they must not detract from the learning experience. These kinds of interactive elements, including earning points or achieving levels for correct answers, might be designed to increase student motivation and to build content understanding by rewarding or entertaining the learner, and may extend the time the user engages with the content.

1: An object, or interactive component of an object, is rated *limited* for the quality of its technological interactivity if its interactive element does not relate to the subject matterand may detract from the learning experience. These kinds of interactive elements may slightly increase motivation but do not provide strong support for understanding the subject matter addressed in the object. It is unlikely that this interactive feature will increase understanding or extend the time a user engages with the content.

0: An object, or interactive component of an object, is rated *very weak or no value* for thequality of its technological interactivity if it has interactive features that are poorly conceived and/or executed. The interactive features might fail to operate as intended,distract the user, or unnecessarily take up user time.

N/A: This rubric is *not applicable* (N/A) for an object that does not have an interactive technological element. *For example, the rubric does not apply if interaction with theobject is limited to, for example, opening a user-selected PDF.*

Rubric VI: Quality of Instructional and Practice Exercises

This rubric is applied to objects that contain exercises designed to provide an opportunity to practice and strengthen specific skills and knowledge. The purpose of these exercises is to deepen understanding of subject matter and to routinize foundational skills and procedures. When concepts and skills are introduced, providing a sufficient number of exercises to support skill acquisition is critical. However when integrating skills in complex tasks, the number of exercise problems is less important than their richness. These types of practice opportunities may include as few as one or two instructional exercises designed to provide practice applying specific concepts and/or skills. Sets of practice exercises are treated as a single object, with therubric applied to an entire group.

Rubric VI Scoring Guide:

3: An object is rated *superior* for the quality of its instructional and practice exercises only ifall of the following are true:

- The object offers more exercises than needed for the average student to facilitate mastery of the targeted skills, as stated or implied in the object. For complex tasks,one or two rich practice exercises may be considered more than enough.
- The exercises are clearly written and supported by accurate answer keys or scoringguidelines as applicable.
- There are a variety of exercise types **and/or** the exercises are available in a variety of formats, as appropriate to the targeted concepts and skills. For more complex practiceexercises the formats used provide an opportunity for the learner to integrate a variety of skills.

2: An object is rated *strong* for the quality of its instructional and practice exercises if

it offers only a sufficient number of well-written exercises to facilitate mastery of targetedskills, which are supported by accurate answer keys or scoring guidelines, but there is little variety of exercise types or formats.

1: An object is rated *limited* for the quality of its instructional and practice exercises if it has some, but too few exercises to facilitate mastery of the targeted skills, is without answerkeys, and provides no variation in type or format.

0: An object is rated *very weak or no value* for the quality of its instructional and practice exercises if the exercises provided do not facilitate mastery of the targeted skills, containerrors, or are unsound for other reasons.

N/A: This rubric is *not applicable* (N/A) to an object that does not include opportunities to practice targeted skills.

Rubric VII: Opportunities for Deeper Learning

This rubric is applied to objects designed to engage learners in at least one of the followingdeeper learning skills, which can be applied across all content areas:

- Think critically and solve complex problems.
- Work collaboratively.
- Communicate effectively.
- Learn how to learn.
- Reason abstractly.
- Construct viable arguments and critique the reasoning of others.
- Apply discrete knowledge and skills to real-world situations.
- Construct, use, or analyze models.

Rubric VII Scoring Guide:

3: An object is rated *superior* for its opportunities for deeper learning only if **all** of thefollowing are true:

- At least three of the deeper learning skills from the list identified in this rubric arerequired in the object.
- The object offers a range of cognitive demand that is appropriate and supportive ofthe material.
- Appropriate scaffolding and direction are provided.

2: An object is rated *strong* for its opportunities for deeper learning if it includes one or twodeeper learning skills identified in this rubric. *For example, the object might involve a complex problem that requires abstract reasoning skills to reach a solution.*

1: An object is rated *limited* for its opportunities for deeper learning if it includes one deeper learning skill identified in the rubric but is missing clear guidance on how to tapinto the various aspects of deeper learning. *For example, an object might include a provision for learners to collaborate, but the process and product are unclear.*

0: An object is rated *very weak* for its opportunities for deeper learning if it appears to be designed to provide some of the deeper learning opportunities identified in this rubric, but it is not useful as it is presented. *For example, the object might be based on poorly formulated problems and/or unclear directions, making it unlikely that this*

lesson or activity will lead to skills like critical thinking, abstract reasoning, constructing arguments,or modeling.

N/A: This rubric is *not applicable* (N/A) to an object that does not appear to be designed toprovide the opportunity for deeper learning, even though one might imagine how it could be used to do so.

Rubric VIII: Assurance of Accessibility Standards

This rubric is used to assure materials are accessible to all students, including students identified as blind, visually impaired or print disabled, and those students who may qualify under the Chafee Amendment to the U.S. 1931 Act to Provide Books to the Adult Blind as Amended. It was developed to assess compliance with U.S. standards and requirements, butcould be adapted to accommodate differences in other sets of requirements internationally.

Accessibility is critically important for all learners and should be considered in the design of allonline materials. Identification of certain characteristics will assist in determining if materials will be fully accessible for all students. Assurance that materials are compliant with the standards, recommendations, and guidelines specified assists educators in the selection and use of accessible versions of materials that can be used with all students, including those withdifferent kinds of challenges and assistive devices.

The Assurance of Accessibility Standards Rubric does not ask reviewers to make a judgment on the degree of object quality. Instead, it requests that a determination (yes/no) of characteristicsbe made that, together with assurance of specific Standards, may determine the degree to which the materials are accessible. Only those who feel qualified to make judgments about an object's accessibility should use this rubric.

Rubric VIII Scoring Guide (see table next page):

Yes: The object displays the characteristic or complies with the standards, recommendations or guidelines.

No: The object does NOT display the characteristic or comply with the standards, recommendations or guidelines.

Comment: Comments on Rubric 8 Object determination may include notes that describethe reason materials do not comply with the standard, recommendations or guidelines or further description that may clarify the characteristics of the object.

	YES/NO /NA	**Comment or Explanation**	**Organization that Maintains the Standard**
Available in Tagged PDF Format			Adobe
Available in ePUB Format			International Digital Publishing Form
Accessible Course within an Open Learning Management System (LMS)			Moodle

Accessible Course within another Learning Management System (LMS)			LMS Provider
Available in an accessible media format and includes alternate text or subtitles			Provider or Publisher
Includes alternative text (image)			Provider or Publisher
Includes captions and subtitles (video)			Provider or Publisher
Includes flash accessibility functions (SWF)			Adobe
Includes functionality that provide accessibility			Provider or Publisher
Complies with WC3 WCAG2 Recommendations for web pages			WC3 Recommendations
Compliant with Section 508 of the Rehabilitation Act			US Government
Is accessible as determined by Utah StateWebAIM Web Accessibility Evaluation (WAVE) Tool			Utah State WebAIM
Available in National Accessible Instructional Materials Standard (NIMAS) Format – Accessible XML			NIMAS Center at CAST
Complies with Audio/Video Cassette Production Standards			ITA Standards
Complies with DVD/DVD-ROM Production Standards			DVD Forum Specifications
Complies with Blue-ray Disk Production Standards			UDF 2.5 – Blue-ray Disk Association
Complies with NCAM Guidelines for Movies, Web and Multimedia			NCAM Guidelines

Additional references for accessibility:

Accessible Instructional Materials at the Center for Applied Special Technology

- http://aim.cast.org/learn/e-esources/accessibility_resources

National Center for Accessible Media

- http://ncam.wgbh.org/about/accessibility-links

Accessible Publishing: Best Practice Guidelines for Publishers.

-PDF: http://www.editeur.org/109/Enabling-Technologies-Framework/

-HTML: http://www.editeur.org/files/Collaborations/Accessibility/WIPO.html

Appendix B
AP Biology Big Ideas

BIG IDEA 1: EVOLUTION (EVO)

The process of evolution drives the diversity and unity of life. Evolution is a change in the genetic makeup of a population over time, with natural selection as its major driving mechanism. Darwin's theory, which is supported by evidence from many scientific disciplines, states that inheritable variations occur in individuals in a population. Due to competition for limited resources, individuals with more favorable genetic variations are more likely to survive and produce more offspring, thus passing traits to future generations. A diverse gene pool is vital for the survival of species because environmental conditions change. The process of evolution explains the diversity and unity of life, but an explanation about the origin of life is less clear. In addition to the process of natural selection, naturally occurring catastrophic and human-induced eventsas well as random environmental changes can result in alteration in the gene pools of populations. Scientific evidence supports that speciation and extinction have occurred throughout Earth's history and that life continues to evolve within a changing environment, thus explaining the diversity of life.

- EVO-1 Evolution is characterized by a change in the genetic makeup of a populationover time and is supported by multiple lines of evidence.
  - EVO-1.A Describe similarities and/or differences in compartmentalization between prokaryotic and eukaryotic cells
    - EVO-1.A.1 Membrane-bound organelles evolved from once free-livingprokaryotic cells via endosymbiosis.
    - EVO-1.A.2 Prokaryotes generally lack internal membrane-bound organelles but have internal regions with specialized structures andfunctions.
    - EVO-1.A.3 Eukaryotic cells maintain internal membranes that partitionthe cell into specialized regions.
  - EVO-1.B Describe the relationship between the functions of endosymbiotic organelles and their free-living ancestral counterparts.
    - EVO-1.B.1 Membrane-bound organelles evolved from previously free-living prokaryotic cells via endosymbiosis.
  - EVO-1.C Describe the causes of natural selection.
    - EVO-1.C.1 Natural selection is a major mechanism of evolution.
    - EVO-1.C.2 According to Darwin's theory of natural selection, competitionfor limited resources results in differential survival. Individuals with more favorable phenotypes are more likely to survive and produce more offspring, thus passing traits to subsequent generations.
  - EVO-1.D Explain how natural selection affects populations.
    - EVO-1.D.1 Evolutionary fitness is measured by reproductive success.
    - EVO-1.D.2 Biotic and abiotic environments can be more or less stable/fluctuating, and this affects the rate and direction of evolution;different genetic variations can be selected in each generation.
  - EVO-1.E Describe the importance of phenotypic variation in a population.
    - EVO-1.E.1 Natural selection acts on phenotypic variations in populations.

- EVO-1.E.2 Environments change and apply selective pressures topopulations.
- EVO-1.E.3 Some phenotypic variations significantly increase or decreasefitness of the organism in particular environments.
- EVO-1.F Explain how humans can affect diversity within a population.
- EVO-1.F.1 Through artificial selection, humans affect variation in otherspecies.
- EVO-1.G Explain the relationship between changes in the environment and evolutionary changes in the population.
- EVO-1.G.1 Convergent evolution occurs when similar selective pressures result in similar phenotypic adaptations in different populationsor species.
- EVO-1.H Explain how random occurrences affect the genetic makeup of a population.
- EVO-1.H.1 Evolution is also driven by random occurrences—
- a. Mutation is a random process that contributes to evolution.
- b. Genetic drift is a nonselective process occurring in smallpopulations—
- i. Bottlenecks.
- ii. Founder effect.
- c. Migration/gene flow can drive evolution.
- EVO-1.I Describe the role of random processes in the evolution of specific populations.
- EVO-1.I.1 Reduction of genetic variation within a given population canincrease the differences between populations of the same species.
- EVO-1.J Describe the change in the genetic makeup of a population over time.
- EVO-1.J.1 Mutation results in genetic variation, which providesphenotypes on which natural selection acts.
- EVO-1.K Describe the conditions under which allele and genotype frequencieswill change in populations.
- EVO-1.K.1 Hardy-Weinberg is a model for describing and predicting allele frequencies in a nonevolving population. Conditions for a populationor an allele to be in Hardy-Weinberg equilibrium are—(1) a large population size, (2) absence of migration, (3) no net mutations, (4) random mating, and (5) absence of selection. These conditions are seldom met, but they provide a valuable null hypothesis.
- EVO-1.K.2 Allele frequencies in a population can be calculated fromgenotype frequencies.
  RELEVANT EQUATION
  Hardy-Weinberg Equation—$p^2 + 2pq + q^2 = 1$
  $p + q = 1$where:
  p = frequency of allele 1 in the populationq = frequency of allele 2 in the population

- EVO-1.L Explain the impacts on the population if any of the conditions of Hardy-Weinberg are not met.
- EVO-1.L.1 Changes in allele frequencies provide evidence for theoccurrence of evolution in a population.
- EVO-1.L.2 Small populations are more susceptible to randomenvironmental impact than large populations.
- EVO-1.M Describe the types of data that provide evidence for evolution.
- EVO-1.M.1 Evolution is supported by scientific evidence from manydisciplines

(geographical, geological, physical, biochemical, and mathematical data).

- EVO-1.N Explain how morphological, biochemical, and geological data provide evidence that organisms have changed over time.
  - EVO-1.N.1 Molecular, morphological, and genetic evidence from extantand extinct organisms adds to our understanding of evolution—
    - a. Fossils can be dated by a variety of methods. These include:
      - i. The age of the rocks where a fossil is found
      - ii. The rate of decay of isotopes including carbon-14
      - iii. Geographical data
    - b. Morphological homologies, including vestigial structures,represent features shared by common ancestry.
  - EVO-1.N.2 A comparison of DNA nucleotide sequences and/or proteinamino acid sequences provides evidence for evolution and common ancestry.
- EVO-1.O Explain the interaction between the environment and random or preexisting variations in populations.
  - EVO-1.O.1 An adaptation is a genetic variation that is favored by selection and is manifested as a trait that provides an advantage to anorganism in a particular environment.
  - EVO-1.O.2 Mutations are random and are not directed by specificenvironmental pressures.
- EVO-2 Organisms are linked by lines of descent from common ancestry.
- EVO-2.A Explain how shared, conserved, fundamental processes and featuressupport the concept of common ancestry for all organisms.
  - EVO-2.A.1 DNA and RNA are carriers of genetic information.
  - EVO-2.A.2 Ribosomes are found in all forms of life.
  - EVO-2.A.3 Major features of the genetic code are shared by all modernliving systems.
  - EVO-2.A.4 Core metabolic pathways are conserved across all currentlyrecognized domains.
- EVO-2.B Describe the fundamental molecular and cellular features sharedacross all domains of life, which provide evidence of common ancestry.
  - EVO-2.B.1 Many fundamental molecular and cellular features andprocesses are conserved across organisms.
  - EVO-2.B.2 Structural and functional evidence supports the relatednessof organisms in all domains.
- EVO-2.C Describe structural and functional evidence on cellular and molecularlevels that provides evidence for the common ancestry of all eukaryotes.
  - EVO-2.C.1 Structural evidence indicates common ancestry of alleukaryotes—
    - a. Membrane-bound organelles
    - b. Linear chromosomes
    - c. Genes that contain introns
- EVO-3 Life continues to evolve within a changing environment.
- EVO-3.A Explain how evolution is an ongoing process in all living organisms.
  - EVO-3.A.1 Populations of organisms continue to evolve.
  - EVO-3.A.2 All species have evolved and continue to evolve—
    - a. Genomic changes over time.
    - b. Continuous change in the fossil record.
    - c. Evolution of resistance to antibiotics, pesticides, herbicides, orchemotherapy drugs.

- d. Pathogens evolve and cause emergent diseases.
  - EVO-3.B Describe the types of evidence that can be used to inferan evolutionary relationship.
    - EVO-3.B.1 Phylogenetic trees and cladograms show evolutionaryrelationships among lineages—
- a. Phylogenetic trees and cladograms both show relationshipsbetween lineages, but phylogenetic trees show the amount of change over time calibrated by fossils or a molecular clock.
- b. Traits that are either gained or lost during evolution can be usedto construct phylogenetic trees and cladograms—
  - i. Shared characters are present in more than one lineage.
  - ii. Shared, derived characters indicate common ancestryand are informative for the construction of phylogenetic trees and cladograms.
  - iii. The out-group represents the lineage that is least closely related to the remainder of the organisms in thephylogenetic tree or cladogram.
- c. Molecular data typically provide more accurate and reliableevidence than morphological traits in the construction of phylogenetic trees or cladograms.
  - EVO-3.C Explain how a phylogenetic tree and/or cladogram can be used to infer evolutionary relatedness.
    - EVO-3.C.1 Phylogenetic trees and cladograms can be used to illustratespeciation that has occurred. The nodes on a tree represent the most recent common ancestor of any two groups or lineages.
    - EVO-3.C.2 Phylogenetic trees and cladograms can be constructed frommorphological similarities of living or fossil species and from DNA and protein sequence similarities.
    - EVO-3.C.3 Phylogenetic trees and cladograms represent hypothesesand are constantly being revised, based on evidence.
  - EVO-3.D Describe the conditions under which new species may arise.
    - EVO-3.D.1 Speciation may occur when two populations becomereproductively isolated from each other.
    - EVO-3.D.2 The biological species concept provides a commonly useddefinition of species for sexually reproducing organisms. It states that species can be defined as a group capable of interbreeding and exchanging genetic information to produce viable, fertile offspring.
  - EVO-3.E Describe the rate of evolution and speciation under different ecological conditions.
    - EVO-3.E.1 Punctuated equilibrium is when evolution occurs rapidly aftera long period of stasis. Gradualism is when evolution occurs slowly over hundreds of thousands or millions of years.
    - EVO-3.E.2 Divergent evolution occurs when adaptation to new habitatsresults in phenotypic diversification. Speciation rates can be especially rapid during times of adaptive radiation as new habitats become available.
  - EVO-3.F Explain the processes and mechanisms that drive speciation.
    - EVO-3.F.1 Speciation results in diversity of life forms.
    - EVO-3.F.2 Speciation may be sympatric or allopatric.
    - EVO-3.F.3 Various prezygotic and postzygotic mechanisms can maintainreproductive isolation and prevent gene flow between populations.
  - EVO-3.G Describe factors that lead to the extinction of a population.

- EVO-3.G.1 Extinctions have occurred throughout Earth's history.
- EVO-3.G.2 Extinction rates can be rapid during times of ecologicalstress.
  - EVO-3.H Explain how the risk of extinction is affected by changes in the environment.
- EVO-3.H.1 Human activity can drive changes in ecosystems that causeextinctions.
  - EVO-3.I Explain species diversity in an ecosystem as a function of speciationand extinction rates.
- EVO-3.I.1 The amount of diversity in an ecosystem can be determinedby the rate of speciation and the rate of extinction.
  - EVO-3.J Explain how extinction can make new environments available for adaptive radiation.
- EVO-3.J.1 Extinction provides newly available niches that can then beexploited by different species.

BIG IDEA 2: ENERGETICS (ENE)

Biological systems use energy and molecular building blocks to grow, reproduce, and maintain dynamic homeostasis. Cells and organisms must exchange matter with the environment. Organisms respond to changes in their environment at the molecular, cellular, physiological, and behavioral levels. Living systems require energy and matter to maintain order, grow, and reproduce. Organisms employ various strategies to capture,use, and store energy and other vital resources. Energy deficiencies are not only detrimental to individual organisms but they can cause disruptions at the population and ecosystem levels. Homeostatic mechanisms that are conserved or divergent across related organisms reflect either continuity due to common ancestry orevolutionary change in response to distinct selective pressures.

- ENE-1 The highly complex organization of living systems requires constant input ofenergy and the exchange of macromolecules.
  - ENE-1.A Describe the composition of macromolecules required by living organisms.
- ENE-1.A.1 Organisms must exchange matter with the environment togrow, reproduce, and maintain organization.
- ENE-1.A.2 Atoms and molecules from the environment are necessary tobuild new molecules—
- a. Carbon is used to build biological molecules such as carbohydrates, proteins, lipids, and nucleic acids. Carbon is usedin storage compounds and cell formation in all organisms.
- b. Nitrogen is used to build proteins and nucleic acids. Phosphorus is used to build nucleic acids and certainlipids.
  - ENE-1.B Explain the effect of surface area-to-volume ratios on the exchange of materials between cells or organisms and the environment.
- ENE-1.B.1 Surface area-to-volume ratios affect the ability of a biologicalsystem to obtain necessary resources, eliminate waste products, acquireor dissipate thermal energy, and otherwise exchange chemicals and energy with the environment.

RELEVANT EQUATIONS

Volume of a Sphere: $V= 4/3\pi r^3$
Volume of a Cube: $V = s^2$
Volume of a Rectangular Solid: V = lwh
Volume of a Cylinder: $V =\pi r^2h$ Surface Area of a Sphere:
$SA = 4\pi r^2h$ Surface Area of a Cube: $SA= 6s^2$ Surface Area of a Rectangular Solid:
SA = 2lh + 2lw + 2wh
Surface Area of a Cylinder: $SA = 2\pi rh + 2\pi r^2$
r = radius
l = length
h = height
w = width
s = length of one side of a cube

- ENE-1.B.2 The surface area of the plasma membrane must be large enough to adequately exchange materials—
- a. These limitations can restrict cell size and shape. Smaller cellstypically have a higher surface area-to-volume ratio and more efficient exchange of materials with the environment.
- b. As cells increase in volume, the relative surface area decreasesand the demand for internal resources increases.
- c. More complex cellular structures (e.g., membrane folds) arenecessary to adequately exchange materials with the environment.
- d. As organisms increase in size, their surface area-to-volume ratio decreases, affecting properties like rate of heat exchangewith the environment.
- ENE-1.C Explain how specialized structures and strategies are used forthe efficient exchange of molecules to the environment.
- ENE-1.C.1 Organisms have evolved highly efficient strategies toobtain nutrients and eliminate wastes. Cells and organisms use specialized exchange surfaces to obtain and release molecules from or into the surrounding environment.
- ENE-1.D Describe the properties of enzymes.
- ENE-1.D.1 The structure of enzymes includes the active site thatspecifically interacts with substrate molecules
- ENE-1.D.2 For an enzyme-mediated chemical reaction to occur,the shape and charge of the substrate must be compatible with the active site of the enzyme.
- ENE-1.E Explain how enzymes affect the rate of biological reactions.
- ENE-1.E.1 The structure and function of enzymes contribute tothe regulation of biological processes—
  - A. Enzymes are biological catalysts that facilitate chemicalreactions in cells by lowering the activation energy.
- ENE-1.F Explain how changes to the structure of an enzyme may affectits function.
- ENE-1.F.1 Change to the molecular structure of a component inan enzymatic system may result in a change of the function or efficiency of the system—
  - a. Denaturation of an enzyme occurs when the protein structure is disrupted, eliminating the ability to catalyzereactions.
  - b. Environmental temperatures and pH outside the optimalrange for a given enzyme will cause changes to its structure, altering the efficiency with which it catalyzes reactions.

- ENE-1.F.2 In some cases, enzyme denaturation is reversible,allowing the enzyme to regain activity.
- ENE-1.G Explain how the cellular environment affects enzyme activity.
- ENE-1.G.1 Environmental pH can alter the efficiency of enzymeactivity, including through disruption of hydrogen bonds that provide enzyme structure.
- ENE-1.G.2 The relative concentrations of substrates and products determine how efficiently an enzymatic reactionproceeds.
- ENE-1.G.3 Higher environmental temperatures increase the speed of movement of molecules in a solution, increasing thefrequency of collisions between enzymes and substrates andtherefore increasing the rate of reaction.
- ENE-1G.4 Competitive inhibitor molecules can bind reversibly orirreversibly to the active site of the enzyme. Noncompetitive inhibitors can bind allosteric sites, changing the activity of the enzyme.
- ENE-1.H Describe the role of energy in living organisms.
- ENE-1.H.1 All living systems require constant input of energy.
- ENE-1.H.2 Life requires a highly ordered system and does notviolate the second law of thermodynamics—
  - a. Energy input must exceed energy loss to maintain orderand to power cellular processes.
  - b. Cellular processes that release energy may be coupledwith cellular processes that require energy.
  - C. Loss of order or energy flow results in death.
- ENE-1.H.3 Energy-related pathways in biological systems are sequential to allow for a more controlled and efficient transfer ofenergy. A product of a reaction in a metabolic pathway is generally the reactant for the subsequent step in the pathway.
- ENE-1.I Describe the photosynthetic processes that allow organisms tocapture and store energy.
- ENE-1.I.1 Organisms capture and store energy for use inbiological processes—
  - a. Photosynthesis captures energy from the sun andproduces sugars.
    - i. Photosynthesis first evolved in prokaryoticorganisms.
    - ii. Scientific evidence supports the claim that prokaryotic (cyanobacterial) photosynthesis wasresponsible for the production of an oxygenatedatmosphere.
    - iii. Prokaryotic photosynthetic pathways were thefoundation of eukaryotic photosynthesis.
- ENE-1.I.2 The light-dependent reactions of photosynthesis in eukaryotes involve a series of coordinated reaction pathways that capture energy present in light to yield ATP and NADPH,which power the production of organic molecules.
- ENE-1.J Explain how cells capture energy from light and transfer it tobiological molecules for storage and use.
- ENE-1.J.1 During photosynthesis, chlorophylls absorb energyfrom light, boosting electrons to a higher energy level in photosystems I and II.
- ENE-1.J.2 Photosystems I and II are embedded in the internal membranes of chloroplasts and are connected by the transfer ofhigher energy electrons through an electron transport chain (ETC).
- ENE-1.J.3 When electrons are transferred between molecules in a sequence of reactions as they pass through the ETC, an electrochemical gradient of protons

(hydrogen ions) is establishedacross the internal membrane.

- ENE-1.J.4 The formation of the proton gradient is linked to thesynthesis of ATP from ADP and inorganic phosphate via ATP synthase.
- ENE-1.J.5 The energy captured in the light reactions and transferred to ATP and NADPH powers the production of carbohydrates from carbon dioxide in the Calvin cycle, whichoccurs in the stroma of the chloroplast.
- ENE-1.K Describe the processes that allow organisms to use energystored in biological macromolecules.
- ENE-1.K.1 Fermentation and cellular respiration use energy frombiological macromolecules to produce ATP. Respiration and fermentation are characteristic of all forms of life.
- ENE-1.K.2 Cellular respiration in eukaryotes involves a series of coordinated enzyme-catalyzed reactions that capture energy frombiological macromolecules.
- ENE-1.K.3 The electron transport chain transfers energy fromelectrons in a series of coupled reactions that establish an electrochemical gradient across membranes—
  - a. Electron transport chain reactions occur in chloroplasts,mitochondria, and prokaryotic plasma membranes.
  - b. In cellular respiration, electrons delivered by NADH and FADH2 are passed to a series of electron acceptors as they move toward the terminal electron acceptor, oxygen. In photosynthesis, the terminal electron acceptor is NADP+. Aerobic prokaryotes use oxygen as a terminal electron acceptor, while anaerobic prokaryotes use other molecules.
- ENE-1.L Explain how cells obtain energy from biological macromoleculesin order to power cellular functions.
- ENE-1.L.1 Glycolysis is a biochemical pathway that releasesenergy in glucose to form ATP from ADP and inorganic phosphate, NADH from NAD+, and pyruvate.
- ENE-1.L.2 Pyruvate is transported from the cytosol to themitochondrion, where further oxidation occurs.
- ENE-1.L.3 In the Krebs cycle, carbon dioxide is released fromorganic intermediates, ATP is synthesized from ADP and inorganic phosphate, and electrons are transferred to thecoenzymes NADH and FADH2.
- ENE-1.L.4 Electrons extracted in glycolysis and Krebs cycle reactions are transferred by NADH and FADH2 to the electron transport chain in the inner mitochondrial membrane.
- ENE-1.L.5 When electrons are transferred between molecules ina sequence of reactions as they pass through the ETC, an electrochemical gradient of protons (hydrogen ions) across the inner mitochondrial membrane is established.
- ENE-1.L.6 Fermentation allows glycolysis to proceed in the absence of oxygen and produces organic molecules, includingalcohol and lactic acid, as waste products.
- ENE-1.L.7 The conversion of ATP to ADP releases energy, whichis used to power many metabolic processes.
- ENE-1.M Describe the strategies organisms use to acquire and useenergy.
- ENE-1.M.1 Organisms use energy to maintain organization, grow,and reproduce—
  - a. Organisms use different strategies to regulate bodytemperature and metabolism.
    - i. Endotherms use thermal energy generated bymetabolism to maintain homeostatic body temperatures.

- ii. Ectotherms lack efficient internal mechanisms formaintaining body temperature, though they may regulate their temperature behaviorally by moving into the sun or shade or by aggregating ith other individuals.
  - b. Different organisms use various reproductive strategiesin response to energy availability
  - c. There is a relationship between metabolic rate per unitbody mass and the size of multicellular organisms— generally, the smaller the organism, the higher the metabolic rate.
  - d. A net gain in energy results in energy storage or thegrowth of an organism.
  - e. A net loss of energy results in loss of mass and,ultimately, the death of an organism.
- ENE-1.N Explain how changes in energy availability affect populationsand ecosystems.
- ENE-1.N.1 Changes in energy availability can result in changes inpopulation size.
- ENE.1.N.2 Changes in energy availability can result in disruptionsto an ecosystem—
  - a. A change in energy resources such as sunlight canaffect the number and size of the trophic levels.
  - b. A change in the producer level can affect the numberand size of other trophic levels.
- ENE-1.O Explain how the activities of autotrophs and heterotrophsenable the flow of energy within an ecosystem.
- ENE-1.O.1 Autotrophs capture energy from physical or chemicalsources in the environment—
  - a. Photosynthetic organisms capture energy present insunlight.
  - b. Chemosynthetic organisms capture energy from small inorganic molecules present in their environment, and thisprocess can occur in the absence of oxygen.
- ENE-1. O.2 Heterotrophs capture energy present in carboncompounds produced by other organisms.
  - a. Heterotrophs may metabolize carbohydrates, lipids, andproteins as sources of energy by hydrolysis.
  - ENE-2 Cells have membranes that allow them to establish and maintain internal environments that are different from their external environments.
- ENE-2.A Describe the roles of each of the components of the cellmembrane in maintaining the internal environment of the cell.
- ENE-2.A.1 Phospholipids have both hydrophilic and hydrophobicregions. The hydrophilic phosphate regions of the phospholipids are oriented toward the aqueous external or internal environments, while the hydrophobic fatty acid regions face each other within the interior of the membrane.
- ENE-2.A.2 Embedded proteins can be hydrophilic, with charged and polar side groups, or hydrophobic, with nonpolar side groups.
- ENE-2.B Describe the Fluid Mosaic Model of cell membranes.
- ENE-2.B.1 Cell membranes consist of a structural framework of phospholipid molecules that is embedded with proteins, steroids (such as cholesterol in eukaryotes), glycoproteins, and glycolipidsthat can flow around the surface of the cell within the membrane.
- ENE-2.C Explain how the structure of biological membranes influencesselective permeability.

- ENE-2.C.1 The structure of cell membranes results in selectivepermeability.
- ENE-2.C.2 Cell membranes separate the internal environment ofthe cell from the external environment.
- ENE-2.C.3 Selective permeability is a direct consequence ofmembrane structure, as described by the fluid mosaic model.
- ENE-2.C.4 Small nonpolar molecules, including N2, O2, and CO2, freely pass across the membrane. Hydrophilic substances,such as large polar molecules and ions, move across the membrane through embedded channel and transport proteins.
- ENE-2.C.5 Polar uncharged molecules, including H2O, passthrough the membrane in small amounts.
- ENE-2.D Describe the role of the cell wall in maintaining cell structureand function.
- ENE-2.D.1 Cell walls provide a structural boundary, as well as apermeability barrier for some substances to the internal environments.
- ENE-2.D.2 Cell walls of plants, prokaryotes, and fungi arecomposed of complex carbohydrates.
- ENE-2.E Describe the mechanisms that organisms use to maintainsolute and water balance.
- ENE-2.E.1 Passive transport is the net movement of moleculesfrom high concentration to low concentration without the direct input of metabolic energy.
- ENE-2.E.2 Passive transport plays a primary role in the import ofmaterials and the export of wastes.
- ENE-2.E.3 Active transport requires the direct input of energy tomove molecules from regions of low concentration to regions of high concentration
- ENE-2.F Describe the mechanisms that organisms use to transport largemolecules across the plasma membrane.
- ENE-2.F.1 The selective permeability of membranes allows forthe formation of concentration gradients of solutes across the membrane.
- ENE-2.F.2 The processes of endocytosis and exocytosis requireenergy to move large molecules into and out of cells—
  - a. In exocytosis, internal vesicles fuse with the plasma membrane and secrete large macromolecules out of thecell.
  - b. In endocytosis, the cell takes in macromolecules and particulate matter by forming new vesicles derived from theplasma membrane.
- ENE-2.G Explain how the structure of a molecule affects its ability topass through the plasma membrane.
- ENE-2.G.1 Membrane proteins are required for facilitateddiffusion of charged and large polar molecules through a membrane—
  - a. Large quantities of water pass through aquaporins.
  - b. Charged ions, including Na+ and K+, require channelproteins to move through the membrane.
  - c. Membranes may become polarized by movement of ionsacross the membrane.
- ENE-2.G.2 Membrane proteins are necessary for active transport.
- ENE-2.G.3 Metabolic energy (such as from ATP) is required foractive transport of molecules and/or ions across the membrane and to establish and maintain concentration gradients.
- ENE-2.G.4 The Na+/K+ ATPase contributes to the maintenanceof the membrane potential.

- ENE-2.H Explain how concentration gradients affect the movement ofmolecules across membranes.
- ENE-2.H.1 External environments can be hypotonic, hypertonicor isotonic to internal environments of cells—
  - a. Water moves by osmosis from areas of high water potential/low osmolarity/low solute concentration to areasof low water potential/high osmolarity/high solute concentration.
    RELEVANT EQUATION
    Water Potential:
    $\Psi = \Psi_p + \Psi_s$
    Ψ_p = pressure potential
    Ψ_s = solute potential
- ENE-2.I Explain how osmoregulatory mechanisms contribute to thehealth and survival of organisms.
- ENE-2.I.1 Growth and homeostasis are maintained by theconstant movement of molecules across membranes.
- ENE-2.I.2 Osmoregulation maintains water balance and allowsorganisms to control their internal solute composition/water potential.
  SOLUTE POTENTIAL OF A SOLUTION
  $\Psi_s = -iCRT$
  where:
  i = ionization constantC = molar
  concentrationR = pressure constant
  (R=0.0831* (L*bars/mol*K) T=temperature in Kelvin
  (°C + 273)

- ENE-2.J Describe the processes that allow ions and other molecules tomove across membranes.
- ENE-2.J.1 A variety of processes allow for the movement of ionsand other molecules across membranes, including passive and active transport, endocytosis and exocytosis.
- ENE-2.K Describe the membranebound structures of the eukaryotic cell.
- ENE-2.K.1 Membranes and membrane-bound organelles ineukaryotic cells compartmentalize intracellular metabolic processes and specific enzymatic reactions.
- ENE-2.L Explain how internal membranes and membranebound organelles contribute to compartmentalization of eukaryotic cell functions.
- ENE-2.L.1 Internal membranes facilitate cellular processes byminimizing competing interactions and by increasing surface areas where reactions can occur.
  - ENE-3 Timing and coordination of biological mechanisms involved in growth, reproduction, and homeostasis depend on organisms responding to environmental cues.
- ENE-3.A Describe positive and/or negative feedback mechanisms.
- ENE-3.A.1 Organisms use feedback mechanisms to maintain their internal environments and respond to internal and externalenvironmental changes.
- ENE-3.B Explain how negative feedback helps to maintain homeostasis.
- ENE-3.B.1 Negative feedback mechanisms maintain homeostasisfor a particular

condition by regulating physiological processes. If a system is perturbed, negative feedback mechanisms return the system back to its target set point. These processes operate at the molecular and cellular levels.

- ENE-3.C Explain how positive feedback affects homeostasis.
- ENE-3.C.1 Positive feedback mechanisms amplify responses andprocesses in biological organisms. The variable initiating the response is moved farther away from the initial set point. Amplification occurs when the stimulus is further activated, which, in turn, initiates an additional response that produces system change.
- ENE-3.D Explain how the behavioral and/or physiological response of anorganism is related to changes in internal or external environment.
- ENE-3.D.1 Organisms respond to changes in their environmentthrough behavioral and physiological mechanisms.
- ENE-3.D.2 Organisms exchange information with one another inresponse to internal changes and external cues, which can change behavior.
- ENE-4 Communities and ecosystems change on the basis of interactions among populations and disruptions to the environment.
- ENE-4.A.1 The structure of a community is measured and described interms of species composition and species diversity.
  RELEVANT EQUATION
  Simpson's Diversity Index—
  Diversity Index = $1- \Sigma (n/N)^2$
  n = the total number of organisms ofa particular species
  N = total number of organisms ofall species
- ENE-4.B Explain how interactions within and among populations influence community structure.
- ENE-4.B.1 Communities change over time depending on interactionsbetween populations.
- ENE-4.B.2 Interactions among populations determine how they accessenergy and matter within a community.
- ENE-4.B.3 Relationships among interacting populations can be characterized by positive and negative effects and can be modeled. Examples include predator/prey interactions, trophic cascades, and nichepartitioning.
- ENE-4.B.4 Competition, predation, and symbioses, including parasitism,mutualism, and commensalism, can drive population dynamics.
- ENE-4.C Explain how community structure is related to energy availability in the environment.
- ENE-4.C.1 Cooperation or coordination between organisms, populations,and species can result in enhanced movement of, or access to, matter and energy.

BIG IDEA 3: INFORMATION STORAGE AND TRANSMISSION (IST)

Living systems store, retrieve, transmit, and respond to information essential to life processes. Genetic information provides for continuity of life, and, in most cases, this information is passed from parent to offspring via DNA. Nonheritable information transmission influences behavior within and between cells, organisms, and populations.These behaviors are directed by underlying genetic information, and responses to information are vital to natural selection and evolution. Genetic information is a repository of instructions necessary for the survival, growth, and reproduction of the organism. Genetic variation can be advantageous for the long-term survival and evolution of a species.

- IST-1 Heritable information provides for continuity of life.
  - IST-1.A Describe the structural similarities and differences between DNA andRNA.
    - IST-1.A.1 DNA and RNA molecules have structural similarities anddifferences related to their function—
- a. Both DNA and RNA have three components—sugar, a phosphate group, and a nitrogenous base—that form nucleotideunits that are connected by covalent bonds to form a linear molecule with 5’ and 3’ ends, with the nitrogenous bases perpendicular to the sugar-phosphate backbone.
- b. The basic structural differences between DNA and RNA includethe following:
  - i. DNA contains deoxyribose and RNA contains ribose.
  - ii. RNA contains uracil and DNA contains thymine.
  - iii. DNA is usually double stranded; RNA is usually singlestranded.
  - iv. The two DNA strands in double-stranded DNA areantiparallel in directionality.
  - IST-1.B Describe the events that occur in the cell cycle.
    - IST-1.B.1 In eukaryotes, cells divide and transmit genetic information viatwo highly regulated processes.
    - IST-1.B.2 The cell cycle is a highly regulated series of events for thegrowth and reproduction of cells—
- a. The cell cycle consists of sequential stages of interphase (G1,S, G2), mitosis, and cytokinesis.
- b. A cell can enter a stage (G0) where it no longer divides, but it can reenter the cell cycle in response to appropriate cues. Nondividing cells may exit the cell cycle or be held at a particularstage in the cell cycle.
  - IST-1.C Explain how mitosis results in the transmission of chromosomes fromone generation to the next.
    - IST-1.C.1 Mitosis is a process that ensures the transfer of a completegenome from a parent cell to two genetically identical daughter cells—
- a. Mitosis plays a role in growth, tissue repair, and asexualreproduction.
- b. Mitosis alternates with interphase in the cell cycle.
- c. Mitosis occurs in a sequential series of steps (prophase,metaphase, anaphase, telophase).
  - IST-1.D Describe the role of checkpoints in regulating the cell cycle.
    - IST-1.D.1 A number of internal controls or checkpoints regulateprogression

through the cycle.

- IST-1.D.2 Interactions between cyclins and cyclin-dependent kinasescontrol the cell cycle.
  - IST-1.E Describe the effects of disruptions to the cell cycle on the cell or organism.
- IST-1.E.1 Disruptions to the cell cycle may result in cancer and/orprogrammed cell death (apoptosis).
  - IST-1.F Explain how meiosis results in the transmission of chromosomes fromone generation to the next.
- IST-1.F.1 Meiosis is a process that ensures the formation of haploidgamete cells in sexually reproducing diploid organisms—
- a. Meiosis results in daughter cells with half the number ofchromosomes of the parent cell.
- b. Meiosis involves two rounds of a sequential series of steps(meiosis I and meiosis II).
  - IST-1.G Describe similarities and/or differences between the phases and outcomes of mitosis and meiosis.
- IST-1.G.1 Mitosis and meiosis are similar in the way chromosomes segregate but differ in the number of cells produced and the geneticcontent of the daughter cells.
  - IST-1.H Explain how the process of meiosis generates genetic diversity.
- IST-1.H.1 Separation of the homologous chromosomes in meiosis I ensures that each gamete receives a haploid (1n) set of chromosomesthat comprises both maternal and paternal chromosomes.
- IST-1.H.2 During meiosis I, homologous chromatids exchange geneticmaterial via a process called “crossing over” (recombination), which increases genetic diversity among the resultant gametes.
- IST-1.H.3 Sexual reproduction in eukaryotes involving gamete formation—including crossing over, the random assortment of chromosomes during meiosis, and subsequent fertilization of gametes—serves to increase variation.
  - IST-1.I Explain the inheritance of genes and traits as described by Mendel’slaws.
- IST-1.I.1 Mendel’s laws of segregation and independent assortment canbe applied to genes that are on different chromosomes.
- IST-1.I.2 Fertilization involves the fusion of two haploid gametes, restoring the diploid number of chromosomes and increasing genetic variation in populations by creating new combinations of alleles in thezygote—
- a. Rules of probability can be applied to analyze passage ofsingle-gene traits from parent to offspring.
- b. The pattern of inheritance (monohybrid, dihybrid, sex-linked, and genetically linked genes) can often be predicted from data, including pedigree, that give the parent genotype/phenotype andthe offspring genotypes/phenotypes.

  RELEVANT EQUATION

  Laws of Probability—

  If A and B are mutually exclusive, then:$P(A \text{ or } B) = P(A) + P(B)$

  If A and B are independent, then:

  $P(A \text{ and } B) = P(A) \times P(B)$

- IST-1.J Explain deviations from Mendel's model of the inheritance of traits.
  - IST-1.J.1 Patterns of inheritance of many traits do not follow ratios predicted by Mendel's laws and can be identified by quantitative analysis,where observed phenotypic ratios statistically differ from the predicted ratios—
  - a. Genes that are adjacent and close to one another on the samechromosome may appear to be genetically linked; the probability that genetically linked genes will segregate as a unit can be usedto calculate the map distance between them.
  - IST-1.J.2 Some traits are determined by genes on sex chromosomes and are known as sexlinked traits. The pattern of inheritance of sex-linkedtraits can often be predicted from data, including pedigree, indicating the parent genotype/phenotype and the offspring genotypes/phenotypes.
  - IST-1.J.3 Many traits are the product of multiple genes and/or physiological processes acting in combination; these traits therefore donot segregate in Mendelian patterns.
  - IST-1.J.4 Some traits result from non-nuclear inheritance—
  - a. Chloroplasts and mitochondria are randomly assorted to gametes and daughter cells; thus, traits determined by chloroplastand mitochondrial DNA do not follow simple Mendelian rules.
  - b. In animals, mitochondria are transmitted by the egg and not bysperm; as such, traits determined by the mitochondrial DNA are maternally inherited.
  - c. In plants, mitochondria and chloroplasts are transmitted in the ovule and not in the pollen; as such, mitochondria-determined andchloroplast-determined traits are maternally inherited.
- IST-1.K Describe the structures involved in passing hereditary information fromone generation to the next.
  - IST-1.K.1 DNA, and in some cases RNA, is the primary source ofheritable information.
  - IST-1.K.2 Genetic information is transmitted from one generation to thenext through DNA or RNA—
  - a. Genetic information is stored in and passed to subsequent generations through DNA molecules and, in some cases, RNAmolecules.
  - b. Prokaryotic organisms typically have circular chromosomes,while eukaryotic organisms typically have multiple linear chromosomes.
  - IST-1.K.3 Prokaryotes and eukaryotes can contain plasmids, which aresmall extra-chromosomal, double-stranded, circular DNA

- IST-1.L Describe the characteristics of DNA that allow it to be used as the hereditary material.
  - IST-1.L.1 DNA, and sometimes RNA, exhibits specific nucleotide base pairing that is conserved through evolution: adenine pairs with thymine oruracil (A-T or A-U) and cytosine pairs with guanine (C-G)—
  - a. Purines (G and A) have a double ring structure.
  - b. Pyrimidines (C, T, and U) have a single ring structure.
- IST-1.M Describe the mechanisms by which genetic information is copied for transmission between generations.
  - IST-1.M.1 DNA replication ensures continuity of hereditary information—
  - a. DNA is synthesized in the 5' to 3' direction.

- b. Replication is a semiconservative process—that is, one strand of DNA serves as the template for a new strand of complementaryDNA.
- c. Helicase unwinds the DNA strands.
- d. Topoisomerase relaxes supercoiling in front of the replicationfork.
- e. DNA polymerase requires RNA primers to initiate DNAsynthesis.
- f. DNA polymerase synthesizes new strands of DNA continuouslyon the leading strand and discontinuously on the lagging strand.
- g. Ligase joins the fragments on the lagging strand.

- IST-1.N Describe the mechanisms by which genetic information flows from DNA

- IST-1.N.1 The sequence of the RNA bases, together with the structure ofthe RNA molecule, determines RNA function—

- a. mRNA molecules carry information from DNA to the ribosome.
- b. Distinct tRNA molecules bind specific amino acids and haveanti-codon sequences that base pair with the mRNA. tRNA is recruited to the ribosome during translation to generate the primary peptide sequence based on the mRNA sequence.
- c. rRNA molecules are functional building blocks of ribosomes.

- IST-1.N.2 Genetic information flows from a sequence of nucleotides inDNA to a sequence of bases in an mRNA molecule to a sequence of amino acids in a protein.
- IST-1.N.3 RNA polymerases use a single template strand of DNA to direct the inclusion of bases in the newly formed RNA molecule. Thisprocess is known as transcription.
- IST-1.N.4 The DNA strand acting as the template strand is also referred to as the noncoding strand, minus strand, or antisense strand. Selection of which DNA strand serves as the template strand depends on the genebeing transcribed.
- IST-1.N.5 The enzyme RNA polymerase synthesizes mRNA molecules in the 5’ to 3’ direction by reading the template DNA strand in the 3’ to 5’direction.
- IST-1.N.6 In eukaryotic cells the mRNA transcript undergoes a series of enzyme-regulated modifications—

- a. Addition of a poly-A tail.
- b. Addition of a GTP cap.
- c. Excision of introns and splicing and retention of exons.
- d. Excision of introns and splicing and retention of exons can generate different versions of the resulting mRNA molecule; this isknown as alternative splicing.

- IST-1.O Describe how the phenotype of an organism is determined by its genotype.

- IST-1.O.1 Translation of the mRNA to generate a polypeptide occurs onribosomes that are present in the cytoplasm of both prokaryotic and eukaryotic cells and on the rough endoplasmic reticulum of eukaryotic cells.
- IST-1.O.2 In prokaryotic organisms, translation of the mRNA moleculeoccurs while it is being transcribed.
- IST-1.O.3 Translation involves energy and many sequential steps,including initiation, elongation, and termination.
- IST-1.O.4 The salient features of translation include—

- a. Translation is initiated when the rRNA in the ribosome interactswith the mRNA at the start Codon.
- b. The sequence of nucleotides on the mRNA is read in tripletscalled codons.
- c. Each codon encodes a specific amino acid, which can be deduced by using a

genetic code chart. Many amino acids areencoded by more than one codon.
- d. Nearly all living organisms use the same genetic code, which isevidence for the common ancestry of all living organisms.
- e. tRNA brings the correct amino acid to the correct placespecified by the codon on the mRNA.
- f. The amino acid is transferred to the growing polypeptide chain.
- g. The process continues along the mRNA until a stop codon isreached.
- h. The process terminates by release of the newly synthesizedpolypeptide/protein.
- IST-1.O.5 Genetic information in retroviruses is a special case and has an alternate flow of information: from RNA to DNA, made possible by reverse transcriptase, an enzyme that copies the viral RNA genome intoDNA. This DNA integrates into the host genome and becomes transcribed and translated for the assembly of new viral progeny.
- IST-1.P Explain the use of genetic engineering techniques in analyzing or manipulating DNA.
- IST-1.P.1 Genetic engineering techniques can be used to
- analyze and manipulate DNA and RNA—
- a. Electrophoresis separates molecules according to size andcharge.
- b.During polymerase chain reaction (PCR), DNA fragments areamplified
- c. Bacterial transformation introduces DNA into bacterial cells.
- d. DNA sequencing determines the order of nucleotides in a DNAmolecule.
- IST-2 Differences in the expression of genes account for some of the phenotypicdifferences between organisms.
- IST-2.A Describe the types of interactions that regulate gene expression.
- IST-2.A.1 Regulatory sequences are stretches of DNA that interact withregulatory proteins to control transcription.
- IST-2.A.2 Epigenetic changes can affect gene expression throughreversible modifications of DNA or histones.
- IST-2.A.3 The phenotype of a cell or organism is determined by the combination of genes that are expressed and the levels at which they areexpressed—
- a. Observable cell differentiation results from the expression ofgenes for tissue-specific proteins.
- b. Induction of transcription factors during development results insequential gene expression.
- IST-2.B Explain how the location of regulatory sequences relates to their function.
- IST-2.B.1 Both prokaryotes and eukaryotes have groups of genes thatare coordinately regulated—
- a. In prokaryotes, groups of genes called operons are transcribedin a single mRNA molecule. The lac operon is an example of an inducible system.
- b. In eukaryotes, groups of genes may be influenced by the sametranscription factors to coordinately regulate expression.
- IST-2.C Explain how the binding of transcription factors to promoter regions affects gene expression and/or the phenotype of the organism.
- IST-2.C.1 Promoters are DNA sequences upstream of the transcription start site where RNA polymerase and transcription factors bind to initiatetranscription.
- IST-2.C.2 Negative regulatory molecules inhibit gene expression bybinding to

DNA and blocking transcription.
- IST-2.D Explain the connection between the regulation of gene expression and phenotypic differences in cells and organisms.
- IST-2.D.1 Gene regulation results in differential gene expression andinfluences cell products and function.
- IST-2.D.2 Certain small RNA molecules have roles in regulating geneexpression.
- IST-2.E Describe the various types of mutation.
- IST-2.E.1 Changes in genotype can result in changes in phenotype—
- a. The function and amount of gene products determine thephenotype of organisms.
- i. The normal function of the genes and gene products collectively comprises the normal function of organisms.
- ii. Disruptions in genes and gene products cause newphenotypes.
- IST-2.E.2 Alterations in a DNA sequence can lead to changes in the typeor amount of the protein produced and the consequent phenotype. DNA mutations can be positive, negative, or neutral based on the effect or the lack of effect they have on the resulting nucleic acid or protein and the phenotypes that are conferred by the protein.
- IST-3 Cells communicate by generating, transmitting, receiving, and responding tochemical signals.
- IST-3.A Describe the ways that cells can communicate with one another.
- IST-3.A.1 Cells communicate with one another through direct contactwith other cells or from a distance via chemical signaling—
- a. Cells communicate by cell-to-cell contact.

- IST-3.B Explain how cells communicate with one another over short andlong distances.
- IST-3.B.1 Cells communicate over short distances by using localregulators that target cells in the vicinity of the signal-emitting cell—
- a. Signals released by one cell type can travel longdistances to target cells of another cell type.
- IST-3.C Describe the components of a signal transduction pathway.
- IST-3.C.1 Signal transduction pathways link signal reception withcellular responses.
- IST-3.C.2 Many signal transduction pathways includeprotein modification and phosphorylation cascades.
- IST-3.D Describe the role of components of a signal transductionpathway in producing a cellular response.
- IST-3.D.1 Signaling begins with the recognition of a chemicalmessenger—a ligand—by a receptor protein in a target cell—
- a. The ligand-binding domain of a receptor recognizes aspecific chemical messenger, which can be a peptide, asmall chemical, or protein, in a specific one-to-one relationship.
- b. G protein-coupled receptors are an example of areceptor protein in eukaryotes.
- IST-3.D.2 Signaling cascades relay signals from receptors to cell targets, often amplifying the incoming signals, resulting in the appropriate responses by the cell, which could include cell growth,secretion of molecules, or gene expression—
- a. After the ligand binds, the intracellular domain of a receptor protein changes shape,

initiating transduction ofthe signal.
- b. Second messengers (such as cyclic AMP) are molecules that relay and amplify the intracellular signal.
- c. Binding of ligand-to-ligand-gated channels can causethe channel to open or close.
- IST-3.E Describe the role of the environment in eliciting a cellularresponse.
- IST-3.E.1 Signal transduction pathways influence how the cellresponds to its environment.
- IST-3.F Describe the different types of cellular responses elicited by asignal transduction pathway.
- IST-3.F.1 Signal transduction may result in changes in gene expression and cell function, which may alter phenotype or resultin programmed cell death (apoptosis).
- IST-3.G Explain how a change in the structure of any signaling moleculeaffects the activity of the signaling pathway.
- IST-3.G.1 Changes in signal transduction pathways can altercellular response—
- a. Mutations in any domain of the receptor protein or in anycomponent of the signaling pathway may affect the downstream components by altering the subsequent transduction of the signal.
- IST-3.G.2 Chemicals that interfere with any component of thesignaling pathway may activate or inhibit the pathway.
- IST-4 The processing of genetic information is imperfect and is a source of genetic variation.
- IST-4.A Explain how changes in genotype may result in changes inphenotype.
- IST-4.A.1 Errors in DNA replication or DNA repair mechanisms, and external factors, including radiation and reactive chemicals,can cause random mutations in the DNA—
- a. Whether a mutation is detrimental, beneficial, or neutraldepends on the environmental context.
- b. Mutations are the primary source of genetic variation.
- IST-4.A.2 Errors in mitosis or meiosis can result in changes in phenotype—
- a. Changes in chromosome number often result in newphenotypes, including sterility caused by triploidy, and increased vigor of other polyploids.
- b. Changes in chromosome number often result in humandisorders with developmental limitations, including Down syndrome/Trisomy 21 and Turner syndrome.
- IST-4.B Explain how alterations in DNA sequences contribute to variationthat can be subject to natural selection.
- IST-4.B.1 Changes in genotype may affect phenotypes that aresubject to natural selection. Genetic changes that enhance survival and reproduction can be selected for by environmental conditions—
- a. The horizontal acquisitions of genetic information primarily in prokaryotes via transformation (uptake of naked DNA), transduction (viral transmission of genetic information), conjugation (cell-to-cell transfer of DNA), andtransposition (movement of DNA segments within and between DNA molecules) increase variation.
- b. Related viruses can combine/recombine geneticinformation if they infect the same host cell.
- c. Reproduction processes that increase genetic variationare evolutionarily conserved and are shared by various organisms.
- IST-5 Transmission of information results in changes within and between biological systems.

- IST-5.A Explain how the behavioral responses of organisms affect theiroverall fitness and may contribute to the success of the population.
- IST-5.A.1 Individuals can act on information and communicate itto others.
- IST-5.A.2 Communication occurs through various mechanisms—
  - a. Organisms have a variety of signaling behaviors that produce changes in the behavior of other organisms andcan result in differential reproductive success.
  - b. Animals use visual, audible, tactile, electrical, andchemical signals to indicate dominance, find food, establish territory, and ensure reproductive success.
- IST-5.A.3 Responses to information and communication ofinformation are vital to natural selection and evolution—
  - a. Natural selection favors innate and learned behaviorsthat increase survival and reproductive fitness.
  - b. Cooperative behavior tends to increase the fitness of theindividual and the survival of the population.

BIG IDEA 4: SYSTEMS INTERACTIONS (SYI)

Biological systems interact, and these systems and their interactions exhibit complex properties. All biological systems comprise parts that interact with one another. These interactions result in characteristics and emergent properties not found in the individualparts alone. All biological systems from the molecular level to the ecosystem level exhibit properties of biocomplexity and diversity. These two properties provide robustness to biological systems, enabling greater resiliency and flexibility to tolerateand respond to changes in the environment.

- SYI-1 Living systems are organized in a hierarchy of structural levels that interact.
  - SYI-1.A- Explain how the properties of water that result from its polarity and hydrogen bonding affect its biological function.
- SYI-1.A.1 The subcomponents of biological molecules and theirsequence determine the properties of that molecule.
- SYI-1.A.2 Living systems depend on properties of water that result fromits polarity and hydrogen bonding.
- SYI-1.A.3 The hydrogen bonds between water molecules result incohesion, adhesion, and surface tension.
  - SYI-1.B Describe the properties of the monomers and the type of bonds thatconnect the monomers in biological macromolecules.
- SYI-1.B.1 Hydrolysis and dehydration synthesis are used to cleave andform covalent bonds between monomers.
  - SYI-1.C Explain how a change in the subunits of a polymer may lead to changesin structure or function of the macromolecule.
- SYI-1.C.1 Directionality of the subcomponents influences structure andfunction of the polymer—
- a. Nucleic acids have a linear sequence of nucleotides that have ends, defined by the 3’ hydroxyl and 5’ phosphates of the sugar inthe nucleotide. During DNA and RNA synthesis, nucleotides are added to the 3’ end of the growing strand, resulting in the formation of a covalent bond between nucleotides.
- b. DNA is structured as an antiparallel double helix, with each strand running in

opposite 5’ to 3’ orientation. Adenine nucleotides
- pair with thymine nucleotides via two hydrogen bonds. Cytosinenucleotides pair with guanine nucleotides by three hydrogen bonds.
- c. Proteins comprise linear chains of amino acids, connected bythe formation of covalent bonds at the carboxyl terminus of the growing peptide chain.
- d. Proteins have primary structure determined by the sequence order of their constituent amino acids, secondary structure that arises through local folding of the amino acid chain into elementssuch as alpha-helices and beta-sheets, tertiary structure that is
  - the overall three-dimensional shape of the protein and often minimizes free energy, and quaternary structure thatarises from
  - interactions between multiple polypeptide units. The fourelements of protein structure determine the function of aprotein.
- e. Carbohydrates comprise linear chains of sugar monomers connected by covalent bonds. Carbohydrate polymers may be linear or branched.
  - SYI-1.D Describe the structure and/or function of subcellular components and organelles.
    - SYI-1.D.1 Ribosomes comprise ribosomal RNA (rRNA) and protein. Ribosomes synthesize protein according to mRNA sequence.
    - SYI-1.D.2 Ribosomes are found in all forms of life, reflecting the commonancestry of all known life.
    - SYI-1.D.3 Endoplasmic reticulum (ER) occurs in two forms—smooth andrough. Rough ER is associated with membrane-bound ribosomes—
- a. Rough ER compartmentalizes the cell.
- b. Smooth ER functions include detoxification and lipid synthesis.
    - SYI-1.D.4 The Golgi complex is a membrane-bound structure thatconsists of a series of flattened membrane sacs—
- a. Functions of the Golgi include the correct folding and chemicalmodification of newly synthesized proteins and packaging for protein trafficking.
- b. Mitochondria have a double membrane. The outer membrane issmooth, but the inner membrane is highly convoluted, forming folds.
- c. Lysosomes are membrane-enclosed sacs that containhydrolytic enzymes.
- d. A vacuole is a membrane-bound sac that plays many anddiffering roles. In plants, a specialized large vacuole serves multiple functions.
- e. Chloroplasts are specialized organelles that are found in photosynthetic algae and plants. Chloroplasts have a double outermembrane.
  - SYI-1.E Explain how subcellular components and organelles contribute to the function of the cell.
    - SYI-1.E.1 Organelles and subcellular structures, and the interactionsamong them, support cellular function—
- a. Endoplasmic reticulum provides mechanical support, carries outprotein synthesis on membrane-bound ribosomes, and plays a role in intracellular transport.
- b. Mitochondrial double membrane provides compartments fordifferent metabolic reactions.
- c. Lysosomes contain hydrolytic enzymes, which are important inintracellular digestion, the recycling of a cell’s organic materials, and programmed cell death

(apoptosis).

- d. Vacuoles have many roles, including storage and release of macromolecules and cellular waste products. In plants, it aids inretention of water for turgor pressure.

- SYI-1.F Describe the structural features of a cell that allow organisms to capture,store, and use energy.
  - SYI-1.F.1 The folding of the inner membrane increases the surface area,which allows for more ATP to be synthesized.
  - SYI-1.F.2 Within the chloroplast are thylakoids and the stroma.
  - SYI-1.F.3 The thylakoids are organized in stacks, called grana.
  - SYI-1.F.4 Membranes contain chlorophyll pigments and electrontransport proteins that comprise the photosystems.
  - SYI-1.F.5 The light-dependent reactions of photosynthesis occur in thegrana.
  - SYI-1.F.6 The stroma is the fluid within the inner chloroplast membraneand outside of the thylakoid.
  - SYI-1.F.7 The carbon fixation (Calvin-Benson cycle) reactions of photosynthesis occur in the stroma.
  - SYI-1.F.8 The Krebs cycle (citric acid cycle) reactions occur in the matrixof the mitochondria.
  - SYI-1.F.9 Electron transport and ATP synthesis occur on the inner
- SYI-1.G Describe factors that influence growth dynamics of populations.
  - SYI-1.G.1 Populations comprise individual organisms that interact withone another and with the environment in complex ways.
  - SYI-1.G.2 Many adaptations in organisms are related to obtaining andusing energy and matter in a particular environment—

- a. Population growth dynamics depend on a number of factors.
- RELEVANT EQUATION
  Population Growth—
  $dN/dt = B - D$
  where:
  dt = change in timeB = birth rate
  D = death rate
  N = population size
- i. Reproduction without constraints results in theexponential growth of a population.
- RELEVANT EQUATION
  Exponential Growth—$dN/dt = r_{max} N$
  where:
  dt = change in time
  N = population size
  r_{max} = maximum per capita growth rateof population
- SYI-1.H Explain how the density of a population affects and is determined by resource availability in the environment.
  - SYI-1.H.1 A population can produce a density of individuals that exceedsthe system’s

resource availability.

- SYI-1.H.2 As limits to growth due to density-dependent and density-independent factors are imposed, a logistic growth model generally ensues.
- Relevant equation
  dN/dt =rmax N (K-N/K)where:
  dt = change in timeN = population size
  rmax = maximum per capita growth rateof population
  K=carrying capacity
- SYI-2 Competition and cooperation are important aspects of biological systems.
  - SYI-2.A Explain how invasive species affect ecosystem dynamics
    - SYI-2.A.1 The intentional or unintentional introduction of an invasive species can allow the species to exploit a new niche free of predators orcompetitors or to outcompete other organisms for resources.
    - SYI-2.A.2 The availability of resources can result in uncontrolled population growth and ecological changes.
  - SYI-2.B Describe human activities that lead to changes in ecosystem structureand/or dynamics.
    - SYI-2.B.1 The distribution of local and global ecosystems changes overtime.
    - SYI-2.B.2 Human impact accelerates change at local and global levels—
      - a. The introduction of new diseases can devastate native species.
      - b. Habitat change can occur because of human activity.
  - SYI-2.C Explain how geological and meteorological activity leads to changes in ecosystem structure and/or dynamics.
    - SYI-2.C.1 Geological and meteorological events affect habitat changeand ecosystem distribution. Biogeographical studies illustrate these changes.
- SYI-3 Naturally occurring diversity among and between components within biologicalsystems affects interactions with the environment.
  - SYI-3.A Explain the connection between variation in the number and types of molecules within cells to the ability of the organism to survive and/or reproduce in different environments.
    - SYI-3.A.1 Variation at the molecular level provides organisms withthe ability to respond to a variety of environmental stimuli.
    - SYI-3.A.2 Variation in the number and types of molecules within cellsprovides organisms a greater ability to survive and/or reproduce in different environments.
  - SYI-3.B Explain how the same genotype can result in multiple phenotypes under different environmental conditions.
    - SYI-3.B.1 Environmental factors influence gene expression and can lead to phenotypic plasticity. Phenotypic plasticity occurs when individuals withthe same genotype exhibit different phenotypes in different environments.

Appendix C

Interview Questions

1. Tell me about your submissions to the biology textbook project.

a. What was the first submission you made? Second?

b. How did you find the resources you used?

c. How did you decide what to use?

2. What was different about your OER submission project when compared to other projects you have completed in school?

a. Do you know what OER stands for or means?

b. harder/easier/the same?

c. More pressure/less pressure/the same?

3. Describe the peer-review process used to evaluate your and other student's submissions.

a. What did you think about having fellow students evaluate your work?

b. What did you think about having to evaluate other student's work?

4. What are your feelings about next year's students seeing your work in the textbook?

a. Would it be different if your name wasn't attached?

b. How does it compare to other projects/tell me about similar projects?

Vita

Scott Evans grew up in a rural area of North Carolina. His family moved to Tennessee, where he attended 4 years of high school. He then moved on to the University of Tennessee at Martin and earned a B.S. in Biology. He then moved to Raleigh and attended NCSU in the Department of Microbiology. After earning their M.S. degrees, he and Kristie married and moved to Boone NC. They have two sons, Thaddeus and Elias. Scott started teaching in the North Carolina Community College System and taught for 17 years before transitioning to teaching high school.