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Implementing Inquiry-based Learning Into A High School Science Classroom To Improve Student Engagement And Learning Outcomes

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IMPLEMENTING INQUIRY-BASED LEARNING INTO A HIGH SCHOOL SCIENCE CLASSROOM TO IMPROVE STUDENT ENGAGEMENT AND LEARNING OUTCOMES

by

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Abstract

Inquiry-based learning is the practice of teaching and learning through asking questions and discovering answers through scientific processes. Rooted in progressive education, inquiry-based learning focuses on giving students the opportunity to actively engage in their learning, and improve learning outcomes. Inquiry-based learning has been met with skepticism due to the required resources and training to prepare educators to effectively implement inquiry lessons.The Next Generation Science Standards were written to implement inquiry-based learning methods in science curriculums across the United States. Due to the Minnesota Department of Education's decision to draft the 2019 science standards using the Next Generation Science Standards, Minnesota science educators are required to implement inquiry practices to fulfill the new standards by the 2023/24 school year. This capstone reviews the literature on inquiry-based learning, the Next Generation Science Standards, and student engagement to develop a curriculum to help answer the research question, *how can inquiry-based teaching models promote learning in a high school biology class?*

Keywords: Inquiry-based learning, Next Generation Science Standards, Secondary biology

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CHAPTER ONE

Introduction

Capstone Question

In today's world, educators compete with cell phones, computers, and the endless entertainment provided by the internet. Creating engaging lesson designs that promote student interest and student learning can be a difficult task. Using inquiry-based learning models, teachers have the opportunities to frame content in a way that allows students to practice scientific processes while learning material and using critical thinking skills. Throughout my journey to becoming an educator, I have been left with the question, *how can inquiry-based teaching models promote learning in a high school biology class?*

From my experiences as a high school student, my science classes were never particularly interesting. They were not too challenging, I listened to lectures daily, and completed one lab per unit before taking the test. This predictable format did not leave much room for inquiry, asking questions, or digging deeper into the vast field of science. I did not discover my own interest in science until I took a biology class as a post-secondary enrollment option (PSEO) student at a local community college my senior year of high school, where I actually was able to *do* science. I fertilized sea urchin eggs, bred fruit flies, isolated DNA, and learned how to micropipette small quantities of samples. I was able to use microscopes to look for more than a newspaper's letter e, and I learned about science at a depth that allowed me to formulate questions about the material I was learning. This course led me to take an introduction to genetics course and a biopsychology course, which guided me to pursue an undergraduate degree in biopsychology, a pre-med degree.

Before making the decision to become a teacher, I worked in a large inner-city hospital, where I received skills-based training in a hands-on, on-the-job approach. While I was in an entry-level position that did not require my bachelor's degree, I was excited to have the opportunity to learn useful skills that gave me experience in every area of the hospital. Arguably, I learned more about healthcare and actual medicine in my year and a half working at the hospital than I did in my entire undergraduate career. This experience reinforced my belief that hands-on learning can often be more effective and meaningful than a more traditional learning approach that focuses on reading and lecturing. While at the hospital, I also saw how important it was that people receive an education. I worked with many young patients who did not finish high school and who were not well informed about basic concepts of biology, health, or science. During this time, I asked myself about how teaching and learning could be more conducive to fit the needs of students who did not thrive in classrooms that primarily taught content through more traditional approaches.

I never thought I would become a teacher. My own experience as a high school student left me with the belief that, "those who can, do, and those who can't, teach." My mindset was not changed until I began to think of ways that education could be improved, and be made to fit the needs and interests of more students, like some of my young patients. Throughout my master's degree program in teaching, the concept of inquiry learning was presented as the forefront of science education. The benefits of teaching students using a model that allowed them to engage in science past the level of memorization and reading textbooks were abundantly apparent. I realized that I had experienced a version of this approach while in my PSEO science courses, and found it encouraging that this was the direction of science education at the high school level. Previous experiences I had teaching younger students Spanish taught me that engagement can be a struggle in the classroom setting. Approaching learning from a hands-on approach where students discover content through asking questions, performing experiments, and conducting research felt like an answer to the issue of lacking engagement.

MN Science Standards

The Minnesota Department of Education (MDE) is enacting new science standards that need to be implemented by the 2023/24 school year (MDE, 2019). These standards follow the Next Generation Science Standards (NGSS) model, focusing on inquiry and phenomena as the primary approaches to teaching science (Next Generation, n.d.). The MDE has opted to move in the direction of inquiry-based learning in an effort to improve student learning in STEM, and promote cross-cutting concepts by providing interdisciplinary learning experiences. The high school where I work implemented the new MN science standards in the 2021/22 school year, replacing the previous curriculum which follows a more traditional approach, based in lecturing, textbook readings, and end-of-unit labs. While my capstone will help me put the new MN science standards into effect in my district, I also hope to increase student engagement in my classroom, and promote learning in a more hands-on, inquiry-based approach.

Definitions

Throughout the remainder of this capstone, the following terms will be used. When the following terms are mentioned, they refer to the definitions found below.

Inquiry-Based Learning: teaching and learning through asking questions and discovering answers through scientific processes, such as experimentation, observation, and critical thinking

Phenomena Based Learning: teaching and learning through real-world phenomena and experiences

Crosscutting Concepts: concepts that connect multiple fields of science, or STEM; an interdisciplinary approach to science instruction

NGSS: Next Generation Science Standards: k-12 science content standards that set expectations for what students should know and be able to do in science courses

STEM: Science, Technology, Engineering, Mathematics; multidisciplinary educational approach to the science and technology fields

Benefactors of Capstone

Developing and implementing an inquiry-based curriculum for a high school biology course expanded students' opportunities to interact with science on a first hand basis. Students gained insight into how science is done, practice in critical thinking, and opportunities to pursue their own areas of interest in biology. Creating a curriculum for my biology class directly impacted and benefited my students. As an educator, I also benefited from researching and creating inquiry-based curriculum. Taking the time to look at the research behind this methodology gave me a deeper understanding of how to effectively incorporate this pedagogy into my classroom. My colleagues also benefited from research supported, inquiry-based curriculum being brought into the school as NGSS is implemented.

Summary of Chapter

My personal experience as a student, my journey to becoming an educator, and my current role as a teacher developing curriculum prompted my interest in inquiry learning models and teaching through discovery. As I delved into reviewing the literature on how inquiry-based teaching models promote learning in a high school biology class, I gained insights into the creation and implementation of effective discovery-centered approaches to teaching biology at the high school level.

In the next chapter, I further investigate the research behind inquiry-based teaching models, and the evolution of these practices. I research the rationale behind the new MN science standards, the inquiry learning approach to teaching science, and the ways that NGSS has been implemented by other schools. In the literature review, I discuss how research can be used in the formation of inquiry-based curriculum in my biology classroom. The project description outlines the IBL curriculum that I developed to cover an animal behavior unit in a tenth grade standard biology course, along with the rationale behind my choices. The final chapter reviews the capstone project and process, including a reflection of my learning and plans for using the curriculum in the future.

CHAPTER TWO

Introduction

Science can be defined as "the pursuit and application of knowledge and understanding of the natural world following a systematic methodology based on evidence" (Our Definition, 2020). Inquiry-based learning aims to give students the opportunity to practice scientific methodology to pursue knowledge and understanding. In this chapter, I delve into the current literature supporting *how inquiry-based teaching models can promote learning in a high school biology class*.

Inquiry-Based Learning

Inquiry-based learning (IBL) was founded by John Dewey, an educator who felt that learning by doing was more effective than solely learning by hearing. In his book, *Experience and Education* (1938), he introduced the idea of teaching skills in partnership with content, as to prepare students for the real world, rather than prepare human encyclopedias. Today's interpretation of inquiry-based learning in science education focuses on introducing problems or phenomena for students to solve and interpret using scientific practices. Creating experiments, communicating results, working collaboratively, and thinking critically are all components of effective inquiry-based learning. While not a new idea, inquiry-based learning has faced skepticism largely due to the challenges in implementing this method of instruction, but educators in Minnesota are now making a shift to inquiry-based learning as new state science standards are introduced (Justice, Rice, Roy, Hudspith, & Jenkins, 2009; Sadler, & Brown, 2018).

History

Inquiry-based learning (IBL) has been derived from various educational movements and pedagogical approaches, including John Dewey's progressive education (Dewey, 1938). The IBL approach involves students asking questions and investigating these queries through experimentation and data collection, followed by analyzing and communicating these findings with others. This teaching method is inherently student-centered in its focus on student interests and hands-on learning, causing a paradigm shift in the teacher's role in the classroom.

Inquiry-based learning can be further explained using a few different models. The inquiry cycle by Pedaste et al. (2015) includes five phases. The phases include: orientation, conceptualization, investigation, conclusion, and discussion. Orientation includes stimulating interest in the topic. This may include connecting a topic to a student's daily life, or presenting a common misconception or phenomena of science that peaks a student's interest. Conceptualization involves composing research questions and hypotheses as students try to problem solve and make sense of the topic being presented. Investigation involves students actually planning and carrying out an investigation, such as an experiment. Through this process, they test their hypothesis and find an answer to their research question. Once their results are obtained, they draw a conclusion from the data they collected, making up the conclusion phase. As science is based on sharing findings, the Discussion phase involves students communicating their findings and reflecting on the process (Lehtinen, Lehesvuori, & Viiri, 2017; Pedaste et al., 2015).

Today's emphasis on IBL methods aims to give students authentic learning opportunities, which allow for students to learn both concepts and content knowledge through experience (Levy, Thomas, Drago, & Rex, 2013). In science classes, this learning would occur through scientific processes, such as experiments, observational data collection, and other guided learning activities. Inquiry-based learning would ideally equip students with the skills to enter their fields prepared to think critically, problem solve, work collaboratively, and learn through experience. In the field of science, these skills translate well to the jobs available, such as research, medicine, engineering, and resource management.

Inquiry-based learning applied to the sciences gives students the opportunities to *do* science. Students are presented with a problem or question and have the opportunity to think about the issue at hand, apply the knowledge they already have, and build upon that knowledge through investigation. A scientist is unable to innovate if they can only practice methods used in the past (Next Generation, n.d.). Following this logic, students need to have opportunities to do more than the instructions on an assignment to truly learn how science works.

Role of Teachers

Within the IBL approach, teachers play the role of a facilitator or guide, rather than a lecturer or instructor (Kuang, Eysink, & de Jong, 2019). The type of role a teacher possesses in IBL is a shift from more traditional secondary science teaching approaches, where a teacher is a content master who works to pass down their knowledge to their students by giving explanations or setting up labs where students follow a predetermined set of instructions (Lehtinen, Lehesvuori, & Viiri, 2017). This more authoritative approach does not give students the opportunity to engage in science practices nor does it teach students about the nature of science.

A teacher acting as a guide facilitates class discussions in order to assess students' prior knowledge (Lehtinen, Lehesvuori, & Viiri, 2017). These guided discussions give students an opportunity to identify their preconceived notions about a scientific topic, think through their misconceptions, and identify ways that the concept can be further investigated. A teacher guiding a discussion will help students link new material with students' existing knowledge, which promotes student engagement (Lehtinen, Lehesvuori, & Viiri, 2017).

Implementing IBL methods requires significant preparation and professional development for teachers (Voet & De Wever, 2019). While IBL has been discussed as an ideal teaching method for science classes, it is often still met with hesitation and confusion (Lehtinen, Lehesvuori, & Viiri, 2017). The massive shift in instructional style from authoritative to guide or facilitator leaves a significant need for professional development and training for teachers to teach in inquiry-based way (Kawasaki & Sandoval, 2020). While it takes time to re-establish a teaching framework, even a two week professional development can aid teachers make this transition (Kazempour, & Amirshokoohi, 2014).

While inquiry-based learning focuses on students actively learning through hands-on activities and experimentation, scaffolding is a key component to making students successful in their learning (Van Uum, Verhoeff, & Peeters, 2017). Finding the balance between providing too much support, and controlling learning, and effectively guiding inquiry has been a challenge for many teachers. Scaffolding involves providing support to students to help them accomplish a task or learn content, and slowly removing that support as students gain the skills to do something independently (Kuang, Eysink, & de Jong, 2019).

Assessing students' prior knowledge of a topic can help a teacher determine the appropriate amount of scaffolding to provide for a given inquiry task. Scaffolding in inquiry-based learning might include giving students research questions early in the year as they design experiments and gather data. As they continue to go through the experimental design process throughout the school year, students can modify the research questions given to them, and eventually write their own. Learning effective scaffolding techniques in inquiry-based learning can be accomplished through teacher professional development (Van Uum, Verhoeff, & Peeters, 2017).

Skepticism

Although there has been a push from the state level to move towards IBL models, some schools, educators, and administrators feel as though it is an unrealistic expectation (Justice, Rice, Roy, Hudspith, & Jenkins, 2009). Concerns regarding resources, training, student ability, and time remain present regardless of the push toward the NGSS. Confusion regarding the definition of IBL has also caused hesitation among some educators (Levy, Thomas, Drago, & Rex, 2013). Different subjects approach IBL differently depending on the skills that are most important in that field. In science education, IBL includes collecting data through an investigation in order to explain a natural phenomena. Other fields such as history may work to address biases rather than collect data, while another subject area may approach IBL in a completely different way. The differences in the way IBL is interpreted across disciplines has created some confusion about the best way to implement this pedagogical approach. The National

Research Council outlined ways that IBL can be incorporated into science classrooms specifically, and provides resources to teachers in all domains of science education (2019).

Additional concerns revolve around the cognitive skills required for students to learn from inquiry-based practices (Lehtinen, Lehesvuori, & Viiri, 2017). If students do not yet possess the cognitive skills necessary to learn from an inquiry exercise, they will not be able to master the objective of the lesson. This concern shows the importance of scaffolding as teachers plan lessons using inquiry-based pedagogy. The apprehension shown by teachers holding this opinion also indicates the need for professional development in the area of IBL. The concerns regarding the cognitive load required of students in IBL lessons potentially shows that some teachers do not yet feel equipped to guide students through IBL activities.

Giving students the opportunity to investigate phenomena and perform experiments takes a greater amount of time than passing down information through lectures and reading. Implementing cross-cutting concepts through these activities also alters the chapter by chapter sequencing that many curriculums are built upon. The breadth of content required by state standards across the country has some science teachers concerned about the practicality of implementing IBL practices. Addressing numerous standards in an individual lesson by introducing cross-cutting concepts could help teachers cover all standards throughout the school year, but likely in a different format than has been previously utilized.

Implementation

Implementing IBL practices takes a substantial amount of training and preparation. Planning is a crucial component of effectively teaching IBL lessons. A teacher cannot simply rely on their own knowledge of content to teach a class. Teachers must have an understanding of the learning process, and be able to guide students through this process. Science educators must also have a sense of how scientists conduct research and solve problems in order to model and guide students through the scientific process.

The State of Minnesota is in the process of adopting new science standards for grades K-12 that align with an IBL pedagogical approach and follow the Next Generation Science Standards. Implementation occurs on a schedule set by each individual school district, with a deadline for this transition set at a state level. The final draft for the new science standards was created in 2019, and was originally set to be implemented by the 2021/22 school year, however, the Covid-19 pandemic may delay this requirement (Science, n.d.). School resources and training have largely been devoted to education in a distance and hybrid model in response to the pandemic. While this delayed the standards from being put into effect in many schools, the broadening of education to virtual platforms may broaden the ways that IBL methods can be utilized in the classroom. The implementation of more IBL focused standards in Minnesota schools will provide an opportunity to compare against learning outcomes obtained through previous standards, and gain further insight into the effectiveness of inquiry practices on student learning. It is anticipated that once IBL practices are put into effect, that they will improve student engagement and learning outcomes, helping to answer the question, *how can inquiry-based teaching models promote learning in a high school biology class?*

Next Generation Science Standards

The Next Generation Science Standards (NGSS) combine core ideas, practices, and cross-cutting concepts to teach science in an innovative and engaging way (Next Generation, n.d.). The Minnesota Department of Education (MDE) instituted new science standards utilizing NGSS, which need to be implemented in all Minnesota public schools by 2023/24. The goal of NGSS is to teach science in a way that focuses more on concepts than content, eliminating the "memorize and regurgitate" method of learning that has historically been a prevalent component of science courses (McComas & Nouri, 2017). NGSS are incorporated into the classroom through student-centered inquiry-based learning methods in order to fulfill the practices component of the standards, while simultaneously covering content through the core ideas that are woven through an activity or lesson (Ford, 2015). The goal of the NGSS is for students to gain knowledge of major scientific topics, while gaining an understanding of how science works, and the interdisciplinary nature of science (Next Generation, n.d.). Students will be prepared to discuss science-related issues, be critical thinkers regarding science information they come across after high school, and to continue learning about science in their everyday lives or in further education (Taylor, 2013).

Minnesota State Science Standards

During the 2018/19 school year, the MDE reviewed the state's K-12 science standards, and approved a final draft in 2019 (Science, n.d.). Currently, MDE is recommending a full implementation of these standards in the 2023/24 school year. MDE has made a transition timeline available to schools, recommending a sequence of training and teaching practice that will eventually lead to full implementation of the new standards in 2023/24. The COVID-19 pandemic has likely altered the timeline for many schools, as the focus of professional development and training has shifted to distance learning and engaging students in hybrid and online learning settings. While the focus of many science departments in Minnesota has shifted to teaching students in online and hybrid formats, the implementation of the new science standards has been delayed in many school districts (MDE, 2019).

As highlighted in the Potential Transition Timeline provided by MDE, implementation of the new science standards is not solely the responsibility of teachers (2019). Administrators, school leaders, and the State of Minnesota all possess roles in the successful transition to this new science teaching framework (Justice, Rice, Roy, Hudspith, & Jenkins, 2009). Administration and school leaders can assist in providing training opportunities for science teachers, and allocating a budget for the resources required to develop new curriculum to satisfy the new standards' requirements (Kawasaki & Sandoval, 2020). Professional development provided by leadership in the area of inquiry-based instruction could support science teachers' transition to the new standards.

Disciplinary Core Ideas

The content of high school science courses makes up the disciplinary core ideas (DCI) of the NGSS (Next Generation, n.d.). Disciplinary core ideas include topics that are relevant across the disciplines of physical science, life science, earth and space science, and engineering. As students move on from one course to the next, they build on these ideas in each domain of science (Taylor, 2013). The complexity and depth covered increase as students progress through grades, allowing them to gain increasing understanding over time. The topics are designed to connect to students' lives and appeal to their natural interests and curiosity. The DCI of the NGSS include the concepts found in Table 1.

Table 1

Disciplinary Core Ideas for each science discipline as defined by the Next Generation Science Standards

Physical Sciences (PS)	**Life Sciences (LS)**
PS1: Matter and its interactions PS2: Motion and stability: Forces and interactions PS3: Energy PS4: Waves and their applications in technologies for information transfer	LS1: From molecules to organisms: Structures and processes LS2: Ecosystems: Interactions, energy, and dynamics LS3: Heredity: Inheritance and variation of traits LS4: Biological evolution: Unity and diversity
Earth and Space Sciences (ESS)	**Engineering, Technology, and Applications of Science (ETS)**
ESS1: Earth's place in the universe ESS2: Earth's systems ESS3: Earth and human activity	ETS1: Engineering design ETS2: Links among engineering, technology, science, and society

Note: Disciplinary core ideas are broken down by scientific discipline, including physical sciences (PS), life sciences (LS), earth and space sciences (ESS), and engineering, technology, and applications of sciences (ETS).

Scientific and Engineering Practices

The inquiry-based nature of the NGSS composes the scientific and engineering practices of the standards (Next Generation, n.d.). Students' involvement in activities that allow them to participate in the scientific process and in engineering should give them a deeper understanding of not only the content but also of scientific nature and the way science works. Another primary goal of the NGSS is teaching students the nature of science (Summers & Abd-El-Khalick, 2019). By giving students the opportunity to practice science and investigate content, they gain an understanding of how science works. The practices included in the NGSS include:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

The third pillar of NGSS, crosscutting concepts, consists of making connections between scientific domains, including Physical Science, Life Science, Earth and Space Science, and Engineering Design (Next Generation, n.d.). The crosscutting concepts in the NGSS include:

1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change

Cross-cutting concepts allow for students to synthesize information and build upon their preexisting knowledge. By providing students opportunities to connect content to other disciplines, they increase their critical thinking skills, and gain an understanding of how the sciences interact and allow us to further the field of science at large. All science disciplines, every subject in school, and most college and career paths require students to identify patterns, understand cause and effect, be able to use a system model, along with many of the remaining crosscutting concepts outlined above. Incorporating these concepts throughout a science curriculum gives students the opportunity to improve upon these skills.

3D Assessment

Assessing the three dimensions of the NGSS requires more than solely multiple choice exams and essays (Kaldaras, Akaeze, & Krajcik, 2020; Taylor, 2013). The National Research Council has composed a recommended list of tasks that serve to assess all three dimensions of the standards (Next Generation, n.d.). A task-oriented approach to assessment allows students to show their mastery of core disciplinary ideas through the practices and crosscutting concepts of science. Assessments may be formative or summative, and involve presenting a problem or question to students, who then solve the problem by putting into practice their working knowledge of the three-dimensional standard. Authentic assessment of the three dimensions may be challenging to implement initially, as this is a major framework shift for educators (Voet & De Wever, 2019). Assessment is a crucial component to evaluating learning outcomes and determining the success of a lesson or teaching model (Kaldaras, Akaeze, & Krajcik, 2020). The use of assessments in a newly created IBL curriculum will provide an opportunity to measure students' learning outcomes and determine effectiveness of the lessons. In addition, these assessments will give further insight into how IBL can be used to improve student learning outcomes and student engagement with science. The NGSS has framed how to implement IBL in a way that helps answer the question, *how can inquiry-based teaching models promote learning in a high school biology class?*

Student Engagement

Student engagement has a clear link to student learning and retention (Martin et al., 2020; van Uum, Verhoeff, & Peeters, 2017). Engagement in science classes can lead to students continuing their science education in college and increased learning outcomes in the classroom (Sinatra, Heddy, & Lombardi, 2015). Inquiry-based learning aims to provide students with learning opportunities that are more engaging than historical approaches to education. Within science, students have many hands-on learning experiences through IBL. These naturally engaging activities improve student learning and comprehension in science topics and practices. High student engagement in science will allow for students to build science-related skills, and potentially continue their education and build career paths in science fields. Student engagement in science was found to more frequently be measured at a low level than a fully engaged level, making it an important focus of science curriculum development (Schmidt, Rosenberg, & Bermer, 2018).

Types of Engagement

Engagement within education is a topic that has garnered increased interest in the last two decades. According to Schmidt, Rosenberg, and Bermer, student engagement can be categorized as behavioral, cognitive, or affective (2018). Behavioral engagement, which is the action of being engaged in a particular task, such as a lab. Behavioral engagement has been determined to be a critical factor in student achievement. Cognitive engagement refers to the degree to which students find their academic activities as valuable. Lastly, affective engagement (also known as emotional engagement) refers to how a student feels about learning activities, school, or teachers (Sinatra, Heddy, & Lombardi, 2015). Students must possess some level of cognitive and affective engagement in order to display behavioral engagement (Schmidt, Rosenberg, & Bermer, 2018). While activities such as assessments will garner behavioral engagement, this is due to the importance of a grade, which establishes a level of affective and cognitive engagement first. However, this engagement has not been seen as a positive form.

Establishing relevance between science content and students' lives can increase the levels of cognitive and affective engagement, to create a higher level of behavioral engagement (Sinatra, Heddy, & Lombardi, 2015). Inquiry-based learning provides students opportunities to be engaged behaviorally, cognitively, and emotionally by using hands-on learning activities that require critical thinking and connect to students' life experiences.

Learning Activities

The aim of the NGSS is to implement a curriculum filled with highly engaging learning activities (Ford, 2015). These learning activities should give students opportunities to be engaged in the three types of engagement; behavioral, cognitive, and affective (Hampden-Thompson & Bennett, 2013). By designing activities that allow students to be hands-on with the material, like John Dewey's (1938) work modeled in the early 1900s, students have the opportunity to practice the concepts they learn, and to learn them through inquiry. The challenge posed by investigative learning allows students to cognitively engage, and connecting the material to students' lives develops an affective level of engagement. Examples of these learning activities may include investigating a phenomena found in the natural world or designing and implementing an experiment to answer a student-generated, or teacher-prompted question.

Student Choice

A commonly used practice to increase student engagement is to give students choices regarding the topics they would like to learn, and how they would like to present their learning (Schmidt, Rosenberg, & Bermer, 2018). The goal of student choice is to increase students' intrinsic motivation by appealing to their academic and personal interests (Van Schijndel, Jansen, & Raijmakers, 2018). If students feel as though they are an active participant in the creation of an activity or project, they show increased levels of engagement, even if they did not choose the task or the topic of the activity (Schmidt, Rosenberg, & Bermer, 2018). Student choice can create a higher level of behavioral engagement, where students are actively involved in the learning process and take charge of their own learning (Sinatra, Heddy, & Lombardi, 2015). While behavioral engagement may be high when students buy into an activity in the classroom, other factors must be involved to foster cognitive and affective engagement.

Conclusion

Inquiry-based learning has been shown to improve learning outcomes in science courses (Levy, Thomas, Drago, & Rex, 2013). Inquiry practices fulfill the requirements of the NGSS, and can improve student engagement on the behavioral, cognitive, and affective levels. The literature supports a science teaching model that allows students to be active participants in the learning process and receive practice being scientists by exploring scientific phenomena through inquiry. While professional development is necessary to support teachers in adopting this model, once a comprehensive understanding of IBL has been accomplished, student learning can benefit from activities rooted in this pedagogical practice. The next chapter outlines the curriculum project that was created to implement the new Minnesota science standards in a tenth grade biology class and answer the question, *how can inquiry-based teaching models promote learning in a high school biology class?*

CHAPTER THREE

Project Description

Introduction

The shift in Minnesota state science standards necessitates a new curriculum that fulfills the IBL model of the NGSS. In this chapter, I outline a curriculum for an animal behavior unit that fulfills the requirements of a specific high school and the new 2019 science standards in Minnesota. The goal of the curriculum is to implement the new standards while assessing how inquiry-based practices can promote learning. Throughout this paper, I address the question, *How can inquiry-based teaching models promote learning in a high school biology class?*

Project Framework

Inquiry-based learning is the framework for the new NGSS passed by the Minnesota Department of Education in 2019. Inquiry-based learning focuses on students investigating phenomena as a means of learning both content and science skills simultaneously (Van Uum, Verhoeff, & Peeters, 2017). It aims to remove the memorize and regurgitate method of science courses in the past and replace it with methods that allow for students to actively participate in science in order to learn about science content.

Studies have shown that IBL improves learning outcomes for students by increasing engagement across all areas, including behavioral, cognitive, and affective, while giving students greater opportunities to think critically and interact with the material at a higher cognitive level (Kreuzer & Dreesmann, 2017; Levy, Thomas, Drago, & Rex, 2013; Sinatra, Heddy, & Lombardi, 2015). IBL allows for students to become scientists in their high school science classes, better preparing them for further education in a science field or other research driven area. The NGSS encourages the use of IBL practices to meet the standards in an engaging manner.

Curriculum Design

Understanding by Design (UbD) is a curriculum format created by ASCD designed to help teachers design lessons that allow students to meet state standards and improve student achievement (Wiggins, & McTighe, 2005). Understanding by Design starts with classroom outcomes, often shaped by state standards, which can be rewritten as individual lesson objectives by a teacher. The objectives represent the learning goals, or desired results, of a lesson or unit. While individual states, school districts, and schools have an established set of standards that students must meet to pass classes and move forward, teachers also play a role in determining what it looks like for students to achieve proficiency in the standards. Once objectives are established, a teacher is able to determine the optimal assessment strategy to use to measure student achievement of the objectives. The assessment provides evidence that students have reached the desired results of the lesson, and learning has occurred. The final stage of UbD is the learning plan, which is the actual lesson plan which allows for students to reach the desired learning outcomes (Wiggins, & McTighe, 2005).

Audience

This curriculum is designed for a 9-12 grade high school in rural Minnesota with a student body of approximately 950 students. The school has a staff of 55 teachers. The racial demographics of the school are approximately 91% White, 6% Latinx, 1% Black, 1% Asian, and 1% two or more races. The curriculum will be placed in a 10th grade

Biology Kingdoms course for ten, one hour class periods occurring over the course of two weeks. Approximately 15% of students in the class have an IEP or 504 plan. A group of approximately 20 students with the highest learning needs are placed in a special education section of the course with adjusted curriculum and standards. The course is the second half of a two-part biology course series and fulfills half of the biology credit required to graduate high school in Minnesota.

Project Description

This ten day unit will be implemented in one hour sessions in the 2021/22 school year during the second trimester to teach animal behavior following a two week ecology unit (Appendices A-F). This unit focuses on how animals interact with other animals and the environment, fulfilling state standards 9L.2.2.1.1, 9L.3.1.1.1, 9L.3.2.1.4, 9L.3.2.1.5, 9L.4.1.1.1, and 9L.4.1.1.3 (MDE, 2019). During this unit, students will be provided opportunities to conduct experiments, collect data, draw conclusions, communicate results, read scientific literature, use models, and work collaboratively.

Students will begin the unit following an ecology unit, so they will have a basic understanding of how organisms interact with other organisms and the environment. Animal behavior goes deeper into the relationships between animals. Students will start the unit with a closed-bottle ecosystem lab, where students will create an ecosystem habitat for a single guppy in a 2 liter container. Students will do research and create their own habitat based on their predictions for what makes a successful habitat. This activity acts as a bridge between the two units, and builds upon students' new ecology knowledge while adding in a new layer of animal behavior concepts.

Following the closed-bottle ecosystem lab, students will develop a cricket behavior choice chamber lab. Modified from the AP biology curriculum, students will give crickets choices between different foods, environments, or social situations to test behavioral preferences of crickets. Students will design their lab and communicate their results with the class.

The final student-designed lab is a mate selection lab using guppies (Appendix E). This lab requires the most preparation on the part of the teacher, but students will be able to design components of the lab. Students will build environments where some guppies stand out, and others blend into the environment to research mate preference and mate selection by female guppies.

Student-Designed Labs

One of the primary IBL components of this unit involves student-designed experiments. Students will design three labs over the course of the unit. One includes the use of crickets, and the other two involve fish, such as guppies or minnows. Students will be guided through the process of building a research question and hypothesis, then given a list of available materials, and told to build an experiment in a small group. They will be guided through the data collection process, compile their results, and draw conclusions to either support or refute their hypotheses. Students will then format these results into a shareable format, such as a digital poster, to share with classmates.

Scientific Literature

In order to give students examples of what communicating research looks like in the field of science, students will be introduced to authentic scientific literature. In the area of animal behavior, there is greater availability of scientific literature that uses vocabulary familiar to students, that is at an appropriate reading level. This exposure gives students an idea of what their own lab write-ups might look like, and shows them the real-world application of the work they are doing in the classroom.

Models

Since animal behavior is a speciality most often researched in the field, there are many instances where models are the most realistic and appropriate approach to introducing content. Students will use computer simulations that model animal behavior phenomena. In a traditional learning model, these phenomena may have been read about in a textbook or article, but these models provide opportunities for IBL and fulfill the goals of the NGSS. Models can be used to collect and analyze data, or as a way to discover a phenomena leading to further investigation.

Assessment

The effectiveness of the unit will be assessed using exams, projects, and papers throughout the unit. Student work and test scores will be compared with previous years' assessments to gain a better understanding of how inquiry-based practices and the NGSS has affected student learning. A student survey will also be given at the end of the unit to gauge student reception of the activities, and the shift in instructional strategies from being traditional to inquiry-based (Appendix F).

Timeline

In order to implement the curriculum in the 2021/22 school year, planning took place in the summer of 2021. Planning for each lesson required a range of time from one hour to eight hours depending on the level of interactive components, and the materials required. Material acquisition took place in the summer of 2021, but some live animal and plant materials will be purchased when required during the school year to prevent the need to maintain materials in the classroom throughout the year.

During the summer of 2021, fish tanks were set up with guppies, and cricket cultures were started in order to have well-established colonies for experiments during the school year. The fewer transitions necessary for experiments, the better animals are likely to perform in students' labs. Throughout the school year, students will play a role in caring for the animals in the classroom as a community-building activity.

Additional units will be converted to IBL models to implement the NGSS over the course of two years, so that the new Minnesota science standards are fully implemented by the 2022/23 school year. This aligns with the newly delayed timeline passed by the Minnesota Department of Education in response to the Covid-19 pandemic which caused a need for more time to allocate resources and build new curriculum in many school districts.

Summary

This chapter served as an outline of a curriculum designed in response to the questions, *how can inquiry-based teaching models promote learning in a high school biology class?* This inquiry-based curriculum was designed to promote learning in an animal behavior unit within the general biology curriculum of a 9-12 high school in rural Minnesota. The curriculum focuses on implementing the new Minnesota science standards through inquiry-learning activities and phenomena based approaches. The rationale for this approach is supported in the literature and represents the direction of science education in America today. In the following chapter, I review my capstone project and offer insight into what I have learned through the process of designing and implementing an IBL curriculum using the UbD framework.

CHAPTER 4

Reflection

Throughout the capstone process, I sought to answer the question, *how can inquiry-based teaching models promote learning in a high school biology class?* After repeatedly hearing the term inquiry-based learning (IBL) throughout my master's program, I was interested in seeing how IBL can be applied to the high school science classroom, as I saw it as a potential means to improve student engagement and learning outcomes. After reflecting on my own educational journey, extensively reviewing the literature, and thinking through a curriculum framework, I created a unit curriculum covering animal behavior concepts for a tenth grade biology class that met the new 2019 NGSS in Minnesota. The capstone process spanned over two semesters, and is a culmination of two years of work toward a master's of arts in teaching. While developing this curriculum, I learned a great deal about implementing inquiry-based learning, reasons why it has been met with skepticism, and ways to better incorporate inquiry opportunities into my classroom.

As a new teacher, the idea of hands-on learning is extremely appealing, but also daunting, as there aren't always resources readily available to help support the amount of planning and materials needed to be successful. While I was able to find stand-alone inquiry-based activities, I was surprised by the lack of complete chapter, unit, or course curriculums available considering IBL is derived from Dewey's philosophies founded in the early 1900s (Dewey, 1938).

Key Understandings

Researching and building an IBL curriculum has given me a greater understanding of how to develop curriculum, and how to maintain a student-centered, hands-on classroom that allows for students to take part in the scientific process. I see many opportunities for learning to be enhanced through inquiry-based activities and anticipate positive learning outcomes due to higher levels of engagement in my classroom, due to the lessons having higher student buy-in. As a newer teacher, I have further refined my understanding of my role in the classroom. I see myself as a facilitator and guide through the inquiry process. The inquiry process gives me the opportunity to support students in their discoveries, rather than pass down knowledge in a lecture or *recipe lab* format.

Throughout the capstone process, I had the opportunity to further reflect and study IBL and how I can best implement these practices in my teaching. I remember learning about IBL while taking classes in my graduate program, and often having questions on how to actually build lessons that guide student inquiry and allow them to take part in scientific discovery. Looking into the literature available on IBL gave me the deeper insight I needed to build quality inquiry learning lessons that will allow for students to take an active role in their learning and develop transferable skills that will stay with them throughout their academic and professional careers.

Using the UbD curriculum design framework suited IBL practices well, as it ensured that the activities I prepared were aligned with state and school standards, and worked towards specific objectives, rather than being an activity for the sake of doing a lab. The UbD framework also provided a consistent format that promotes the idea that content acquisition is a means, not an end (Wiggins, & McTighe, 2005). The way in which students obtain content knowledge is ultimately more important than students being able to regurgitate memorized facts on an exam. Inquiry-based learning emphasizes learning through discovery, and focuses heavily on the means, rather than solely the end result. Through the inquiry process, students gain invaluable skills that can be transferred to many other areas of academics and career fields, such as critical thinking, data analysis, making evidence-based conclusions, and collaboration.

Review of the Literature

Inquiry-Based Learning

The concept of learning through inquiry is not novel, however the widespread implementation of IBL through state standards is a new next step for Minnesota's science curriculum. Ideas relating to IBL can be found in John Dewey's works in the first half of the 20th century. With a focus on pragmatism and learning transferable skills, he is attributed with laying the foundation for today's inquiry-based learning. While Dewey's ideas were controversial at the time, the concepts behind learning through discovery continue to be met with hesitation and confusion (1938). The struggle to implement IBL curriculum and teaching models on a widespread basis shows that there remains much to be learned and understood about this approach to learning (Levy, Thomas, Drago, & Rex, 2013).

Inquiry-based teaching approaches put a teacher in the role of a facilitator to learning, rather than a presenter of information. Teachers also serve to clarify information for students as they go through the process of discovery. This paradigm shift regarding a teacher's position in the classroom requires a great deal of training, and increased access to IBL curriculum that can be easily modified and implemented to fit the needs of diverse classrooms across Minnesota. This training will require continued professional development, reflection, and trial and error to see how IBL can enhance students' learning opportunities and improve student engagement in the science classroom (Voet & De Wever, 2019). Inquiry-based learning can require more time to be spent on labs and activities so that students have the ability to process the question or problem being introduced, and test their hypotheses . Although there is a greater time commitment, the renewed focus on practices and cross-cutting concepts in the Next Generation Science Standards warrants the additional time spent on these activities (Next Generation, n.d.).

Next Generation Science Standards

In 2019, MDE drafted a new set of science standards that were to be implemented within a three year time frame (Science., n.d.). Although delayed due to the pressing concerns related to providing distance learning opportunities to students during the Covid-19 pandemic, the standards are still required to be implemented by 2024. These standards, known as the Next Generation Science Standards, focus heavily on core disciplinary ideas, scientific and engineering practices, cross-cutting concepts (Next Generation, n.d.). The core disciplinary ideas for life science courses include LS1: From molecules to organisms: Structures and processes, LS2: Ecosystems: Interactions, energy, and dynamics, LS3: Heredity: Inheritance and variation of traits, and LS4: Biological evolution: Unity and diversity. Everything taught within a biology class will connect to one of these four main ideas. Scientific and engineering practices embody how science is done. By incorporating practices into the way science is taught at the high school level, students are able to gain skills that can be applied to various fields. Cross-cutting concepts include major ideas that relate to all science disciplines. These include identifying patterns, establishing cause and effect relationships, and using models (Next Generation, n.d.).

Student Engagement

High levels of student engagement have been correlated with improved student learning outcomes (Sinatra, Heddy, & Lombardi, 2015; van Uum, Verhoeff, & Peeters, 2017). Inquiry-based learning provides many opportunities for students to engage with content by actively building solutions to problems. Students can be engaged in different capacities when participating in class work, including behavioral, cognitive, and affective (Schmidt, Rosenberg, and Bermer, 2018). Engaging students at the behavioral level, involves engaging them in a particular task. In order to engage students at the behavioral level, they must first be engaged at the cognitive and affective levels. When students find learning activities to be of value, they are cognitively engaged. When students feel positively towards their learning activities, they are affectively engaged (Sinatra, Heddy, & Lombardi, 2015; van Uum, Verhoeff, & Peeters, 2017). Inquiry learning practices aim to engage students at a behavioral level by first engaging students at the cognitive and affective levels. When students are given the chance to solve problems and learn through inquiry, they are more likely to see value in what they are doing. They may also feel excited about participating, or feel interested in the activity. These thoughts and feelings towards their learning can lead to behavioral engagement, where students are actively engaged in the task at hand, which is always a teacher's goal (Sinatra, Heddy, & Lombardi, 2015).

Fulfillment of NGSS

The focus of my capstone was to create a curriculum that will allow my school to implement the 2019 NGSS. Each of the lessons that I built for this 10 day unit aligns with both state benchmarks and the NGSS. The curriculum begins the transition from the 2009 Minnesota science standards to the 2019 standards in the biology course at my high school. Next Generation Science Standards incorporate core ideas, practices, and cross-cutting concepts to teach science in an innovative and engaging way, focusing on learning through inquiry. Science and engineering practices focus on the process of exploring the natural world and creating solutions and gaining understanding of various processes. This component of the NGSS encompasses IBL practices by stressing the importance of students going through the scientific process on a first-hand basis. Cross-cutting concepts help students connect what they have learned to other scientific disciplines. Focusing on concepts that relate to all fields of science helps students gain a rounded understanding of science and the natural world, and allows them to develop transferable skills. Lastly, the core ideas of the NGSS include the main content that should be taught and learned in each science discipline. In biology, core ideas relate to major topics including evolution, genetics, ecology, and cell biology.

Limitations and Modifications

The curriculum that I designed was created for a Minnesota public high school outside of the Twin Cities metropolitan area. With this in mind, there are definitely limitations to the curriculum that should be considered before implementing it in other school environments. The unit that I have created was built for a largely native English speaking demographic. Most English language learners have a 1:1 language paraprofessional with them in the classroom at all times. Implementing this curriculum in a school with a more diverse student population would require further supports and modifications to help students meet the reading and writing requirements of the lessons. Utilizing oral assessments and strategically planned groups can be a starting point for some learners.

Resource availability may also be a limiting factor when implementing this curriculum. Adjustments can easily be made regarding materials used in the student labs. For example, isopods can be used instead of crickets, or goldfish can be used instead of guppies. However, the size of containers will need to be increased if goldfish are used. Group sizes can also be increased if fewer live specimens are preferred. Additional adjustments can be made to best accommodate the class environment.

Project Successes

My project provides students with the opportunity to explore animal behavior concepts in a hands-on way that engages students and promotes critical thinking. These animal behavior topics serve as a bridge between ecology and evolution concepts. The curriculum outlined in Appendices A-E successfully provides students with IBL opportunities and gives me a better understanding of how to implement IBL in the science classroom. Developing this project has also enhanced my ability as an educator to utilize inquiry practices in my classroom. Throughout the development of this curriculum, I have gained a deeper understanding of how to promote inquiry, and provide students with authentic learning experiences that allow for them to think critically and participate in the scientific process.

Future Use and Research

In the future, I plan to expand my project to include two full trimesters of tenth grade biology curriculum and two trimesters of eleventh grade chemistry, as I will be teaching both in the future. I am interested to see how IBL can be implemented in the chemistry classroom, where safety and procedure are of greater concern and limiting factors when it comes to students building their own labs. I hope that as more schools in Minnesota convert to the 2019 science standards, that more IBL curriculum becomes widely available to teachers.

I plan to adjust these activities to fit the language and academic needs of my students. Rather than writing complete lab reports, some students will be able to orally explain their experimental design and outcomes. Some students have their paper broken up into a question and answer format, to help the writing process feel more manageable. Strategically grouping students can also help students with different strengths and areas for improvement be successful in the labs outlined in this curriculum.

Implementation

This unit was implemented into my classroom in the 2021/22 school year, and will be adapted for future use based on student learning outcomes measured through the assessments outlined in Appendices B-E. Animal behavior is not a standard unit outlined in the Minnesota state standards, but it acts as a bridge between ecology and evolution. Due to the fact that it is not a standard unit, it will serve as an opportunity to focus on research and lab skills, as this will be the second or third time many of the benchmarks have been met within the classroom. A test will not be issued as a formal summative assessment, but rather the focus will be on scientific writing, and sharing ideas through presentations and collaborative class discussions.

As a new teacher, I will not be able to measure student outcomes directly against previous years' assessment results, but I will assess the quality of students' conclusions drawn, the methods they design, and their ability to discuss content between peers and in written form against the rubrics found in Appendices B-E.

Following the animal behavior unit, an evolution unit will be covered. The guppy sexual selection lab will serve as a bridge into the discussion revolving around genes are passed down and characteristics change within populations over time throughout generations. Students will be better prepared to explore evolutionary concepts after having seen the sexual selection process and considering what types of environmental factors influence mate selection.

Conclusion

Throughout the capstone process I had the opportunity to look deeper into inquiry-based learning methods and their potential to improve student learning and engagement. I believe that implementing inquiry-based lessons and labs will encourage student engagement in my tenth grade biology classes, and promote inquiry into further scientific ideas. Focusing on hands-on learning gives students more opportunities to develop transferable skills that can be applied to other academic areas, or future career endeavors. As I researched the question, *how can inquiry-based teaching models promote learning in a high school biology class*, I found various ways to apply IBL practices to the science classroom, and built upon my abilities to design lessons incorporating inquiry. After a year and a half of distance and hybrid teaching due to Covid-19, I believe students will be extremely receptive to hands-on learning opportunities, also contributing to improved engagement and learning outcomes.

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Appendix A

Animal Behavior Unit Timeline

Day 1
- Guppy lab intro/ethogram/discussion/preparation
- Jamboard
- Prep Packet

Day 2
- Prep Packet
- Design guppy lab
- Conduct guppy lab

Day 3
- Collect guppy data
- Begin writing intro section of paper
- Begin writing methods section of paper

Day 4
- Collect guppy data
- Research methods activity

Day 5
- Collect guppy data
- Cricket lab intro

Day 6
- Collect guppy data
- Cricket lab

Day 7
- Collect guppy data
- Create & Present CER in small groups

Day 8
- Collect guppy data
- Mate selection lab

Day 9
- Collect guppy data
- Mate selection lab

Day 10
- Collect guppy data
- Finish guppy lab report

Appendix B

<table>
<tr><td colspan="2">Title: Animal Behavior: Lesson 1 (3 Days)
Topic: Habitat Selection & Guppy Lab
Subject/Course: Biology Kingdoms Grade: 10</td></tr>
<tr><td colspan="2">Stage 1 - Desired Results</td></tr>
<tr><td colspan="2">State Aligned Standards:
9L.2.2.1.1 Use a computational model to support or revise an evidence-based explanation for factors that have ecological and economic impacts on different sized ecosystems, including factors caused by the practices of various human groups.** (P: 5, CC: 3, CI: LS2) Examples of ecological impacts might include changes in the carrying capacity, species numbers and/or types of organisms present in an environment. Examples of human practices that can have positive or negative impacts, such as stream restoration versus deforestation as an ecological example. Examples of computational models may include online simulations of population dynamics, population ecology, or population growth.

9L.3.1.1.1 Develop and use a model to illustrate the levels of organization of interacting systems and how that translates into specific functions in multicellular organisms. (P: 2, CC: 6, CI: LS1) Emphasis is on specific functions at the organ system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. Examples of models may include real (e.g. fish, birds, insects, etc.) or imaginary organisms with attention to the various structures and systems that assist the organism in performing necessary life functions.</td></tr>
<tr><td>Understandings:
Students will understand how biotic and abiotic factors interact in an ecosystem to support life.
Students will understand how an animal’s habitat supports its behaviors needed for survival.</td><td>Essential Questions:
What is the difference between a habitat and an ecosystem?
What behaviors does a habitat support?
What components of a habitat support life?
How can a fish survive in a closed-bottle ecosystem?</td></tr>
<tr><td>Students will know…
The definitions of the words: ecosystem, habitat, abiotic, biotic
what makes a habitat
how habitats support animal behavior necessary to survival and reproduction</td><td>Students will be able to…
identify the key features of a habitat
identify the behaviors of a guppy and how their habitat supports those behaviors
design a closed-bottle habitat that will support the life of a fish</td></tr>
<tr><td colspan="2">Stage 2 - Assessment Evidence</td></tr>
<tr><td>Performance Tasks:
Students will design and build their own guppy habitats to sustain life for 3 weeks.
Students will collect data looking at their water quality and the behavior of the fish to measure the success of their habitat. They will write an explanation for each characteristic of their habitat (oxygen content, plant use, type of water, food source, etc.) and submit it before being able to build their habitat.</td><td>Other Evidence:
Students will write a short, 2-3 page report using scientific literature format. Students will reflect on their learning and the outcome of their labs in the discussion portion of their paper.</td></tr>
<tr><td colspan="2">Stage 3 - Learning Plan</td></tr>
</table>

Learning Activities

Day 1

- Lab Preparation Jamboard
- Fish ethogram video with timer
- Guppy *(Poecilia reticulata*) Habitat Lab Preparation

Day 2

- Guppy (*Poecilia reticulata*) Habitat Lab Preparation
    - Design lab
    - Build habitat

Day 3

- Collect guppy lab data
- Guppy Lab Report

Materials Available

- Let me know if there is something else you'd be interested in having in your habitat. Either you can bring it in, or I'll see what I can do.

Guppy

Container
2L Bottle

Water
Pond Water
Lake Water
River Water
Tap Water

Plants
Elodea
Hornwort
Anacharis

Algae Pads

Other animals
Snails

Sediment
Fertilizer
Pebbles
Rocks
Sand
Dirt

Guppy (*Poecilia reticulata*) Habitat Lab Preparation

1. Observe the fish video for 3 minutes. Make a list of the behaviors that you see below.
   https://youtu.be/LaUe-Hf0uSM

2. Define each behavior above
3. Come up with an abbreviation for each.
   a. Ex. Eating (E), Resting (R)
4. Fill out your Ethogram with the behaviors that you identified.
5. Watch the next 5 minutes of the fish video and fill out the ethogram for ONE of the fish.
   https://youtu.be/LaUe-Hf0uSM

Name of Observer: Study Species: Goldfish Study Animal: Details of environment:						
	Types of Behaviors					
Time						
0:00						
0:15						
0:30						
0:45						
1:00						
1:15						
1:30						

1:45						
2:00						
2:15						
2:30						
2:45						
3:00						
3:15						
3:30						
3:45						
4:00						
4:15						
4:30						
4:45						
5:00						
Total						

Project Objective: To put together a suitable habitat (ecosystem) that will allow one guppy to survive to the end of the school year and beyond. You will be making observations of your ecosystem for the next three weeks and recording data to be used in your write up for this lab. The ecosystem in this experiment will be closed, meaning that once you set up your ecosystem, the bottle cap will remain on for the remainder of the experiment. In other words you will not take off the cap to add any food, water, etc.

6. What do you need to research before building your habitat?

7. What does your habitat need to have to support your guppy's physical and behavioral needs? You will need to do some research for this section. Make a list below and include links to your sources.

Get in your Groups

8. Write your research question.
    a. Hint - this will include specifics about the habitat you decide to build

9. Write a hypothesis. (What do you think the answer to your question will be?)

10. Design your habitat.

Available Materials - Let me know if there is something else you'd be interested in having in your habitat. Either you can bring it in, or I'll see what I can do.

Container	**Water**	**Plants/Algae**	**Sediment**
2L Bottle	Pond Water	Elodea	Fertilizer
	Lake Water	Hornwort	Pebbles
Other animals	River Water	Anacharis	Rocks
Snails	Tap Water	Algae Pads	Sand
			Dirt

a. What materials will you use?
b. For each material, explain why you chose that item and how it will meet your fish's physical and behavioral needs.
    i. *Hint - The more you write here, the less you will need to write for your lab report. You'll just be able to copy and paste this section into your paper.*

c. What are your controlled variables? (The variables that will not change)

d. What are your uncontrollable variables? (The variables that could affect your experiment, but you cannot control)

11. What type of data will you collect? (How will you measure the success of your habitat for your fish?)
    a. Make your data table below.

12. Draw and label your setup below. (Feel free to draw on a piece of paper. Include a photo of your drawing here, or submit a picture to the Google Classroom assignment).

Guppy Lab Report

You will be writing a formal lab report following the standard formatting of scientific literature. Your report will be written in a similar format to the article we read called, “Weather-Dependent Foraging Behavior of Some Birds Wintering in a Deciduous Woodland.”

Your paper will include:

- Introduction: Introduce the goal of the experiment, including your research question and hypothesis.
- Methods: Explain what you did, including the materials you used, why you used them, and how you measured the success of your habitat.
- Results: Include your data table and describe the changes you observed in your habitat as well as how long your fish lived.
- Discussion: Describe what the results mean. Was your habitat successful? What was the possible cause of your fish’s death? If your fish is still living, talk about how long you think it could live in its habitat and why it has been successful.
- Summary: A brief paragraph summarizing everything you’ve covered in your report.
- Literature Cited: Cite the sources you used for your research in the paper in the intro and methods section (to support why you chose each source).

Formatting Guidelines:

- 11 or 12 size font
- Double spaced
- 2-3 pages
- Headings for each section of your paper (Intro, methods, etc.)
- In-text citations and proper citations in your literature cited section

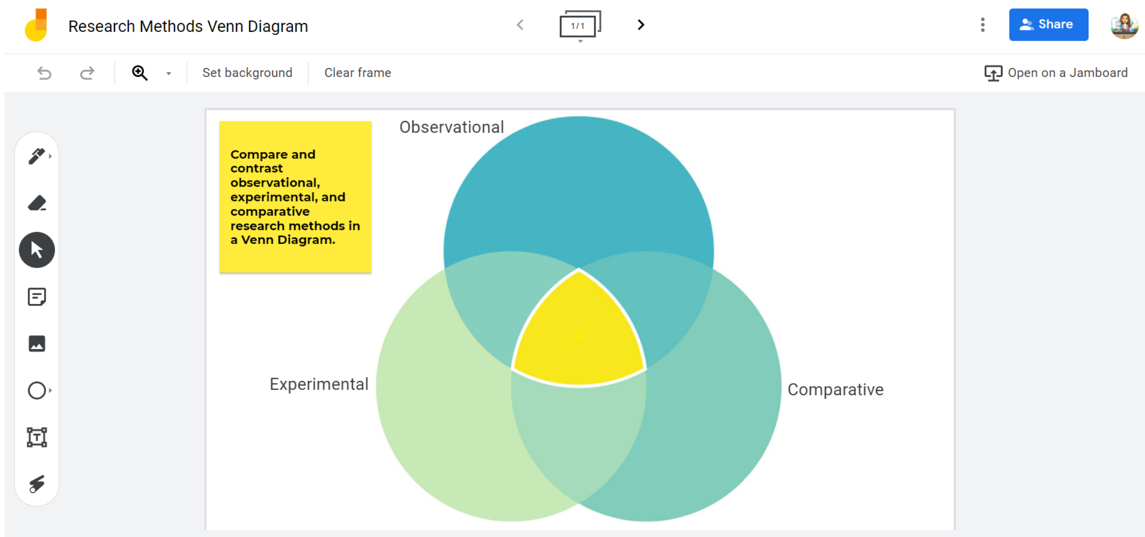
Guppy Lab Rubric:

	1	2	3	4
Intro	Does not explain goal of project, include research question, or hypothesis.	Poorly explains goal of project, includes research question, and hypothesis.	Adequately explains goal of project, includes research question, and hypothesis.	Excellently explains goal of project, includes research question, and hypothesis.
Methods	Does not explain why each material was chosen, cites sources, or how habitat success was measured.	Poorly explains why each material was chosen, cites sources, and how habitat success was measured.	Adequately explains why each material was chosen, cites sources, and how habitat success was measured.	Excellently explains why each material was chosen, cites sources, and how habitat success was measured.
Results	Poorly organized data table, does not describe results of experiment.	Organized data table, poorly describes results of experiment.	Organized data table, adequately describes results of experiment.	Well organized data table, excellently describes results of experiment.
Discussion	Poorly describes meaning of results.	Somewhat describes meaning of results.	Adequately describes meaning of results.	Excellently describes meaning of results.
Conclusion	Does not summarize paper.	Poorly summarizes paper.	Adequately summarizes paper.	Excellently summarizes paper.

Appendix C

<table>
<tr><td colspan="2">Title: Animal Behavior: Lesson 2 (1 Day)
Topic: Research Methods and Application of Animal Behavior
Subject/Course: Biology Kingdoms Grade: 10</td></tr>
<tr><td colspan="2">Stage 1 - Desired Results</td></tr>
<tr><td colspan="2">State Aligned Standards:
4.1.1 Students will be able to engage in argument from evidence for the explanations the students construct, defend and revise their interpretations when presented with new evidence, critically evaluate the scientific arguments of others, and present counter arguments.</td></tr>
<tr><td>Understandings:
Why different research methods are used in different situations.
The ethical concerns of research using animals.</td><td>Essential Questions:
How is animal behavior researched?
What are the pros and cons of observational, experimental, and comparative research methods?
When is it appropriate to use a specific research method?</td></tr>
<tr><td>Students will know…
The definitions of the words: ethology, comparative methods, observational methods, experimental methods
The differences between observational, experimental, and comparative research methods.</td><td>Students will be able to…
Compare and contrast research methods in the field of animal behavior
Determine what research method is best fit to test a specific hypothesis</td></tr>
<tr><td colspan="2">Stage 2 - Assessment Evidence</td></tr>
<tr><td>Performance Tasks:
Class discussion and Jamboard participation
Jamboard discussion tool</td><td>Other Evidence:
Venn Diagram Jamboard</td></tr>
<tr><td colspan="2">Stage 3 - Learning Plan</td></tr>
<tr><td colspan="2">Learning Activities
Day 4
Collect guppy ecosystem data - 5 minutes
Think-pair-share discussion about opening question: What are some ways we can study and/or research animal behavior? (Have students share ideas on Jamboard in whole-class discussion) - 15 minutes
Follow-up question: How could we categorize these different methods? Students sort answers in Jamboard Venn diagram
Follow-up question: Why would you choose to use each method?
Watch research video clips and discuss research methods presentation - 25 minutes
What are some pros and cons to these methods?
Students refine Jamboard Venn diagram with table partners - 5 minutes
Animal research ethics discussion - 10 minutes
What are some things that need to be considered when using animals in research?</td></tr>
</table>

Animal Behavior Research Methods Jamboard



Research Method Presentation

Appendix D

<table>
<tr><td colspan="2">Title: Animal Behavior: Lesson 3 (2 Days)
Topic: Cricket Lab
Subject/Course: Biology Kingdoms Grade: 10</td></tr>
<tr><td colspan="2">Stage 1 - Desired Results</td></tr>
<tr><td colspan="2">State Aligned Standards:
9L.4.1.1.3 Evaluate the evidence supporting claims that changes in environmental conditions may result in (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species (P: 7, CC: 2, CI: LS4) Emphasis is on determining cause and effect relationships for (1) how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and (2) the rate of change of the environment affect distribution or disappearance of traits in species.

9L.3.1.1.1 Develop and use a model to illustrate the levels of organization of interacting systems and how that translates into specific functions in multicellular organisms. (P: 2, CC: 6, CI: LS1) Emphasis is on specific functions at the organ system level such as nutrient uptake, water delivery, and organism movement in response to neural stimuli. Examples of models may include real (e.g. fish, birds, insects, etc.) or imaginary organisms with attention to the various structures and systems that assist the organism in performing necessary life functions.</td></tr>
<tr><td>Understandings:
Students will understand how to create and test a hypothesis based on a research question.
Students will understand the difference between learned and innate behaviors.</td><td>Essential Questions:
What are some observable cricket behaviors?
What behaviors are learned and innate?
How can I develop an experiment to learn more about a cricket’s behavior?</td></tr>
<tr><td>Students will know…
The definitions of the words: instinct, innate behavior, learned behavior
The difference between an innate and a learned behavior.
That some behaviors are a combination of instinct and learned behaviors.</td><td>Students will be able to…
Write and test a hypothesis
Support a claim using evidence and reasoning
Communicate ideas to peers
Compare and contrast innate and learned behaviors</td></tr>
<tr><td colspan="2">Stage 2 - Assessment Evidence</td></tr>
<tr><td>Performance Tasks:
Claim, Evidence, Reasoning virtual poster presentation
Assessed against rubric below</td><td>Other Evidence:
Students will draw a conclusion based on evidence
Students will support a claim in a small group virtual poster presentation</td></tr>
<tr><td colspan="2">Stage 3 - Learning Plan</td></tr>
<tr><td colspan="2">Learning Activities
Day 5
Collect guppy lab data
Cricket lab preparation
Students are broken into groups of 3-5 students determined by teacher
Students watch crickets interact and complete an ethogram
Discuss components of a research question as a class</td></tr>
</table>

        - Small groups choose behavior they want to research and design a research question.
        - Teacher checks groups' questions as they finish them.

Day 6
- Collect guppy lab data
- Cricket Lab
    - Students design an experiment to test their hypotheses based on their research question and create data table - 15 minutes
    - Students build and conduct their experiments. Students repeat multiple trials to obtain significant results. - 25 minutes
    - Students organize results and draw final experimental design and write the introduction and methods section of their paper - 10 minutes

Day 7
- Collect guppy lab data
- CER
    - Students write a claim answering their research question using their results
    - Students write reasoning and design a virtual poster to communicate their findings with their classmates - 30 minutes
- Present virtual CER posters - 30 minutes
    - Classmates ask questions following each presentation and groups evaluate ways they could improve or build upon their experiment.

Day 10
- Collect guppy lab data - 5 minutes
- Compile guppy lab data and add to results section of lab report - 5 minutes
- Discuss the rubric and discussion section of a lab report - 10 minutes
- Students write discussion section of lab report and complete revise any sections that need to be updated - 30 minutes
- Student unit review survey - 10 minutes

Cricket Lab Preparation

1. Observe your crickets for 5 minutes. Make a list of the behaviors that you see below.

2. Define each behavior above
3. Come up with an abbreviation for each.
   a. Ex. Eating (E), Resting (R)
4. Fill out your Ethogram with the behaviors that you identified.
5. Observe your crickets and fill out the ethogram for 15 minutes.

Name of Observer:
Study Species: Study Animal:
Details of environment:

	Types of Behaviors									
Time										
0:00										
0:15										
0:30										
0:45										
1:00										
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14:00										
14:15										
14:30										
14:45										
15:00										
Total										

6. What behavior would you like to research? Create a research question for your experiment.

7. What do you need to research before creating your experiment?

8. Research more about crickets, and write your notes below.

Cricket Lab Experiment

1. Write your research questions.
    a. Example: Do crickets prefer to eat fruits or vegetables?

2. Why did you choose this research question?

3. Write a hypothesis. (What do you think the answer to your question will be?)

4. Design your experiment.
    a. How are you going to test your hypothesis? What research method are you using (comparative, experimental, observational)?

    b. What materials will you use?

c. What is your independent variable? (The variable you are changing)

d. What is your dependent variable? (The variable you are measuring)

e. What are your controlled variables? (The variables will not change)

f. What are your uncontrollable variables? (The variables that could affect your experiment, but you cannot control)

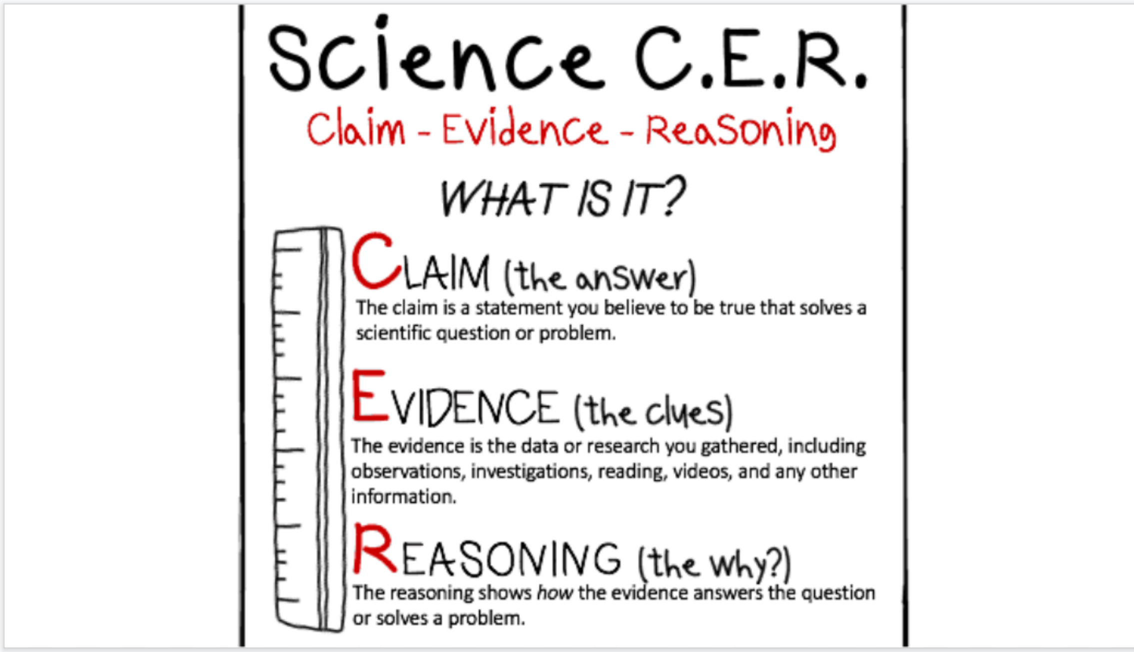
g. How many trials will you conduct? Will you use the same cricket? Different crickets?

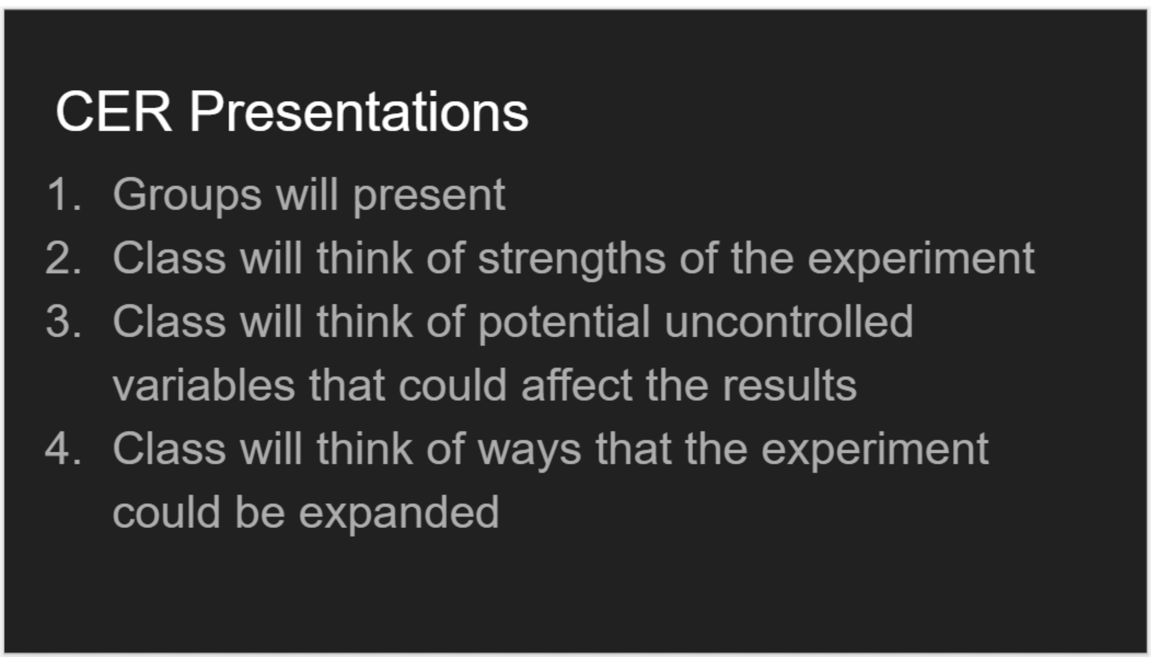
5. How will you collect your data? (date table, measuring time, tallying instances, etc.)

6. Set up your experiment. Draw your setup below.
    a. Be careful when moving crickets!

7. Conduct your experiment and collect data.

CER Presentation Instructions and Template Example






[Research Question Goes Here]
Claim:
Evidence:
[Include Data Here]
Reasoning:
Include a model of your experiment setup.
Example

Cricket Lab CER Rubric

	4	3	2	1
Claim – a conclusion that answers the original question	· Scientifically accurate · Completely answers the question · Common inaccurate claim(s) are clearly addressed.	· Scientifically accurate · Nearly completely answers the question · Inaccurate claim(s) are only generally addressed, no specifics	· Partially scientifically accurate · Partially answers the question · Inaccurate claim(s) are not addressed	· Is not scientifically accurate overall · Does not adequately answer the question
Evidence – scientific data that supports the claim	· The data are scientifically appropriate to support the claim. · The data are thorough and convincing – enough details and evidence provided. · Proper units are used in data · Shows with evidence why alternate claims do not work	· The data are scientifically appropriate to support the claim · The data are basically sufficient and convincing, but tend to be more general and not as specific and in depth · Does not address why alternate claims do not work · Evidence may be repetitive	· The data relate to the claim, but are not entirely scientifically appropriate · The data are not sufficient, though generally support the claim	· There is some evidence provided, but it is not logically linked to the claim or scientifically appropriate

Reasoning – a justification that links the claim and evidence	· Reasoning clearly links evidence to claim · Shows why the data count as evidence by using appropriate scientific principles · There are sufficient scientific principles to make links clear between claim and evidence	· Reasoning adequately links claim to evidence · Includes related scientific principles, but only passably clarifies why this data count as evidence · Reasoning tends to be more general and shows only partial depth of content understanding	· Reasoning does not adequately link claim to evidence, or clarify why data count as evidence · Includes related and non-related scientific principles, and shows little depth of content understanding	· Reasoning is clearly insufficient and relates only tangentially to question and claim at hand · Scientific understanding is very limited
Language and Vocabulary	· Response clearly and effectively expresses ideas using precise, scientifically appropriate descriptions and vocabulary	· Response adequately expresses ideas and scientifically appropriate descriptions and vocabulary, but they are more general than specific	· Response inconsistently and sometimes inappropriately expresses ideas or scientific descriptions and vocabulary	· Scientific language and vocabulary are not precise or appropriate
Focus and Organization	· Focus only on question at hand · Logical progression of ideas · Clearly stated and focused claim that is	· Focus mainly on question at hand, some loosely connected material present · Logical progression of ideas	· Focus not consistent on question at hand · Progression of ideas not entirely logical · Have a claim, but it's not	· Focus not at all consistent · Progression of ideas not logical · Have an unclear claim that is not maintained

	strongly maintained	· Clearly stated and focused claim that is adequately maintained	entirely clear or maintained	

Rubric adapted by Kevin J. B. Anderson from K. McNeill and J. Krajcik, NSTA, and SBAC Argumentative Writing Rubric for grades 6-11

Appendix E

<table>
<tr><td colspan="2">Title: Animal Behavior: Lesson 4 (4 Days)
Topic: Mate Selection Lab
Subject/Course: Biology Kingdoms Grade: 10</td></tr>
<tr><td colspan="2">Stage 1 - Desired Results</td></tr>
<tr><td colspan="2">State Aligned Standards:
9L.4.1.1.1 Evaluate evidence for the role of group behavior on an individual’s and species’ chances to survive and reproduce. (P: 7, CC: 2, CI: LS2) Emphasis of the practice is on identifying evidence supporting the outcomes of group behavior, and developing logical and reasonable arguments based on evidence. Emphasis of the core idea is on distinguishing between group and individual behavior. Examples of group behavior may include herding, migratory behaviors, or various symbioses.

9L.3.2.1.5 Construct an explanation based on evidence for how natural selection leads to the adaptation of populations. (P: 6, CC: 2, CI: LS4) Emphasis is on using data to provide evidence for how specific biotic and abiotic differences in ecosystems contribute to a change in gene frequency over time, leading to adaptation of populations. Examples of selective forces may include long-term climate change, or variations in seasonal temperatures, pH, light cycles, geographic barriers, or in response to the evolution of other organisms.

9L.2.2.1.1 Use a computational model to support or revise an evidence-based explanation for factors that have ecological and economic impacts on different sized ecosystems, including factors caused by the practices of various human groups.** (P: 5, CC: 3, CI: LS2) Examples of ecological impacts might include changes in the carrying capacity, species numbers and/or types of organisms present in an environment. Examples of human practices that can have positive or negative impacts, such as stream restoration versus deforestation as an ecological example. Examples of computational models may include online simulations of population dynamics, population ecology, or population growth.</td></tr>
<tr><td>Understandings:
● Students will understand how environmental factors can affect natural selection and sexual selection.
● Students will understand how to design and test a hypothesis.</td><td>Essential Questions:
● How can mate preference in different environmental conditions be tested?
● How do environmental factors influence natural and sexual selection?
● How does mate selection influence evolution?</td></tr>
<tr><td>Students will know…
● The definitions of the words: natural selection, fitness, sexual selection, courtship display
● How environmental factors, both naturally occurring and human induced, can influence natural selection.</td><td>Students will be able to…
● Design and carry out an experiment
● Create and test a hypothesis
● Collect evidence and draw a conclusion
● Support a claim using data-based evidence
● Identify how mate selection influences evolution
● Model how different environmental factors affect natural selection</td></tr>
<tr><td colspan="2">Stage 2 - Assessment Evidence</td></tr>
<tr><td>Performance Tasks:
● Students will write a conclusion statement answering their research question.</td><td>Other Evidence:
● Students will draw a conclusion based on evidence</td></tr>
</table>

	• Students will record and organize data in their lab packet.
Stage 3 - Learning Plan	

Learning Activities
Day 8
• Mate preference discussion
    ○ Watch videos of courtship rituals - https://youtu.be/nNrieMwfpWQ
    ○ Why would females be the “choosy” sex
• Mate preference lab setup
    ○ Research question design
    ○ Write hypothesis
    ○ Determine what defines mate preference in guppies
Day 9
• Complete mate preference lab
    ○ Write concluding statement using data collected
• Mate preference discussion
    ○ What did you conclude? What evidence supports your claim? How could this affect evolution?
Day 10
• See Appendix B	

Guppy Mate Selection Lab Preparation

1. Observe a male fish for 5 minutes. Describe the physical appearance of the fish and make a list of the behaviors that you see below. Repeat with a female fish.

Male	Female

2. Define each behavior above.
3. Come up with an abbreviation for each.
    a. Ex. Eating (E), Resting (R)

4. Fill out your Ethogram with the behaviors that you identified.
5. Watch the male fish and fill out the ethogram for the fish. Repeat with a female.

Name of Observer: Study Species: Study Animal: Details of environment:						
	Types of Behaviors Male			**Types of Behaviors Female**		
Time						
0:00						
0:15						
0:30						
0:45						
1:00						
1:15						

1:30						
1:45						
2:00						
2:15						
2:30						
2:45						
3:00						
3:15						
3:30						
3:45						
4:00						
4:15						
4:30						
4:45						
5:00						
Total						

Project Objective: *Do environmental factors affect mate selection?* Guppies (*Poecilia reticulata*) have been used extensively to gain an understanding of sexual selection and the evolution of mating systems. Several competing and complementary theories can be used to explain the evolution of female choice.

The purpose of your experiment is to determine the effect of the environment on mate choice by female guppies.

Is the orange coloration an honest signal of healthy genes in male guppies?

An alternate theory suggests that the male's orange coloration may be a “sensory trap”. According to this theory the males orange color exploits the female's preference for orange that initially evolved for detecting the nutrient rich cabrehash fruits. Signals that contrast the environment are more readily detected. Therefore, once established, preference for a color may evolve further due to contrast with the environment.

By determining whether a female's preference varies with the degree of contrast between signal and environment, we can test these hypotheses. We will measure a female's preference for showy over drab males on orange (low contrast) and blue (high contrast) backgrounds. We will also measure the coloration of the males in the experiment to determine which body color, blue or orange, affects preference in different environments. Before you begin lab, consider what experimental results will support the "Good genes" theory over the "Sensory Trap enhanced by Contrast" theory.

6. What do you need to research before designing an experiment to test mate preference under different environmental conditions?

Get in your Groups

7. Write your research question. (Hint - this will include your prediction of which male guppies a female guppy will choose in different environments.)

<u>METHODS</u>

Materials for each photostation (3/lab):
1 camera
1 tripod
paper towels
ruler
pencils

Materials for each pair of students:
Animals: 4 female guppies (housed 4 weeks in all female tanks)
8 male guppies (housed 4 weeks in all male tanks) (4 showy and 4 drab)
(ideally all animals would be inexperienced virgin animals)

Setup:
2 five gallon aquaria
4 clear plexiglass dividers
4 black plastic dividers
4 finger bowls (for holding males)
1 orange, 1 blue, 1 white and 1 black tank shroud (10 inches X tank circumference)
1 small dip net
ruler
Sharpie
timer

Experimental Trial: Each lab group will test 2 females in 4 background color conditions (orange, blue, white, black). The female will be placed in the center compartment while 1 showy male will be placed on one end compartment and one dull male will be placed in the other end compartment. The fish should be allowed to acclimate to the testing apparatus for 10 minutes. Begin the trial by lifting the two removable black dividers. A timer should be set to beep every 10 seconds for 5 minutes. A score will be recorded on each beep.

Setup: Divide a 5 gallon aquarium into 3 sections. Each end section, 6 cm, will be used for one male while the center section will contain the female. The center section is divided into three equal sections. The water depth will be only 6 centimeters and the background color shroud will extend 4 centimeters above the water. Use tape on the table under the tank to identify the center sections because the experiment will be viewed from above.

8. Write a hypothesis. (What do you think the answer to your question will be?)

9. Design your lab setup.

   b. What backgrounds will you use? Why did you choose those backgrounds?

   c. What are your controlled variables? (The variables that will not change)

   d. What are your uncontrollable variables? (The variables that could affect your experiment, but you cannot control)

10. How will you determine which male the female preferred? You may need to research how to determine which mate has been chosen (ex. How long the female spends with the male, orientation, etc.)

11. How will you organize your data? Make your data table below.

12. Draw and label your setup below. (Feel free to draw on a piece of paper. Include a photo of your drawing here, or submit a picture to the Google Classroom assignment).

13. If you were to do this experiment again, what is something you would do differently? Why would you make this change?

14. CONCLUSIONS: Write a simple concluding statement that evaluates your results in light of the alternate hypotheses that were proposed to explain the evolution of female preference for orange color in male guppies.

Acknowledgements: This lab exercise builds upon an idea discussed with Mike Kinneson (University of Maine) at the 2008 Ecological and Evolutionary Ethology of Fishes Conference in Boston MA. The text is adapted from a preliminary report written by Emily Stevens (University of Maine).

Appendix F

Animal Behavior Unit Reflection

1. How has our animal behavior unit been similar or different to other units in biology class?

2. On a scale of 1-5 (1 being very little, 3 being neutral, 5 being very much), how did you enjoy the lessons? Why?

3. On a scale of 1-5 (1 being very difficult, 3 being appropriate difficulty, 5 being very easy), how would you rate the difficulty of the lessons? Why?

4. If you did any of the labs again, what would you do differently?

5. What were the 3 main things you learned in our animal behavior unit?