# EMPHASIZING THE PROCESS OF SCIENCE IN BIOLOGY

BY

TRACY MARIE D'AUGUSTINO

A THESIS

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

MASTERS OF SCIENCE

Interdepartmental Biological Sciences

2012

**ABSTRACT**

EMPHASIZING THE PROCESS OF SCIENCE IN BIOLOGY

BY

TRACY MARIE D'AUGUSTINO

The purpose of this project was to emphasize the process of science which is used in all aspects of life. Students in an Introductory Biology class practiced making observations, identifying patterns and asking questions based on observed patterns. The questions led to the development of multiple hypotheses with students predicting possible results. Students had opportunities to discuss their predictions with peers and the instructor. They discussed additional steps, alternative observations and questions, further exploring the process of science. To objectively evaluate the increased knowledge, students were given a pre-test and post-test that covered the points presented. Data analysis indicated that participation in unit activities successfully increased the students' understanding of the process of science.

ACKNOWLEDGEMENTS

Merle Heidemann

Ken Nadler

Margaret Iding

Chuck Elzinga

George Faulkenhagen

Fred Dyer

My Family

My Students

TABLE OF CONTENTS


| | |
|---|---|
| LIST OF TABLES | vi |
| LIST OF FIGURES | vii |
| INTRODUCTION | 1 |
| THEORETICAL FRAMEWORK | 1 |
| RESEARCH AND DESIGN | 8 |
| DEMOGRAPHICS | 14 |
| IMPLEMENTATION | 16 |
| ANALYSIS OF ACTIVITIES | 19 |
| RESULTS INCLUDING DATA AND MODIFIED CASE STUDIES | 27 |
| DISCUSSION | 36 |
| CONCLUSION | 42 |
| APPENDICES | 43 |
| APPENDIX 1 – FORMS | 44 |
| A. CONSENT FORM | 45 |
| B. STUDENT LABORATORY SAFETY CONTRACT | 48 |
| C. ACC SYLABUS | 49 |
| APPENDIX 2 – TEACHER NOTES AND INSTRUCTIONS | 50 |
| A. PROCESS OF SCIENCE POWERPOINT | 51 |
| B. VIDEO RESOURCES | 60 |
| C. CHAPTER 1 – A VIEW OF LIFE – NOTES | 61 |
| D. CHAPTER 2 – THE CHEMICAL BASIS OF LIFE – NOTES | 64 |
| E. CHAPTER 17 – THE FIRST FORMS OF LIFE – NOTES | 66 |
| APPENDIX 3 – STUDENT ASSIGNMENTS AND ACTIVITIES | 68 |
| A. PROCESS OF SCIENCE GUIDE | 69 |
| B. SEED VARIATION LAB | 70 |
| C. CHAPTER 1 – A VIEW OF LIFE OUTLINE | 71 |
| D. CHAPTER 2 – THE CHEMICAL BASIS OF LIFE OUTLINE | 74 |
| E. CHARACTERISTICS OF LIFE LAB | 77 |
| F. BASIC CHEMISTRY LAB | 79 |

G. I WONDER IF…? 80
H. DESIGN A LAB WITH PLANTS 81
I. CHAPTER 17 – THE FIRST FORMS OF LIFE OUTLINE 82
J. DESIGN A LAB WITH BACTERIA 85

APPENDIX 4 - ASSESSMENT TOOLS 86
A. UNIT PRE/POSTTEST 87
B. UNIT PRE/POSTTEST SCORING RUBRIC 88
C. LAB REPORTING RURBRIC 89
D. PROCESS OF SCIENCE SCORING RUBRIC 90

REFERENCES 91

LIST OF TABLES

Table 1 Components of the *Incorporating an emphasis on the process of science* unit; assignment name, type, time spent for each assignment and intended outcomes. 17

Table 2 Student Pretest and Posttest Scores and the Corresponding Percent Change. Average Pretest = 40.9% Average Posttest = 84.2% Average Change = 43.3% 28

Table 3 Student Pre and Posttest scores and the percent change by question (n=11). 30

Table 5 Process of Science Guide – Rubric available to students and used to score *Process of Science guides*

Table 4 Laboratory Reporting Rubric – Rubric available to students and used to score lab reports

LIST OF FIGURES


| | | |
|---|---|---|
| Figure 1 | Comparison of Alcona and Iosco Counties with the Michigan State Data on Poverty and Education. | 14 |
| Figure 2 | Question 1 – Write at least three questions based on observations from the video clip. | 31 |
| Figure 3 | Question 2 – Choose one of your questions then write hypotheses addressing that question. | 32 |
| Figure 4 | Question 3 – Choose one hypothesis and write the predictions. | 32 |
| Figure 5 | Question 4 – Graph hypothetical data for your prediction if it is supported. | 33 |
| Figure 6 | Question 5 – Explain your reasoning for your graph in question 4. | 33 |
| Figure 7 | Question 6 – Graph hypothetical data for your prediction if it is refuted. | 34 |
| Figure 8 | Question 7 – Explain your reasoning for your graph in question 6. | 34 |
| Figure 9 | Question 8 – Graph hypothetical data for your prediction if the data is inconclusive. | 35 |
| Figure 10 | Question 9 – Explain your reasoning for your graph in question 8. | 35 |
| Figure 11 | Slide 1 - Process of Science PowerPoint Overview Slide | 51 |
| Figure 12 | Slide 2 – Process of Science Observations Slide | 52 |
| Figure 13 | Slide 3 – Process of Science Questions Slide | 53 |
| Figure 14 | Slide 4 - Process of Science Patterns Slide | 54 |
| Figure 15 | Slide 5 – Process of Science Hypotheses Slide | 55 |
| Figure 16 | Slide 6 – Process of Science Prediction Slide | 56 |

| | | |
|---|---|---|
| Figure 17 | Slide 7 – Process of Science Observations Slide | 57 |
| Figure 18 | Slide 8 – Process of Science Results Slide | 58 |
| Figure 19 | Slide 9 – Process of Science Critical Thinking Skills Slide | 59 |

# INTRODUCTION

## THEORETICAL FRAMEWORK

The goal of science education is to teach critical thinking and inspire students to become independent thinkers. Judah Schwartz, Harvard Professor, states that "raising a generation of people who know how to think should be central to the mission of all schools." He emphasizes that learners should not be expected to function like sheep, but instead should be challenged to create and to develop the skills of taste and judgment in every content area (Kinnaman, 1990). Using inquiry in the classroom, builds critical thinking skills and is beneficial to students, empowering them to think analytically and to logically perceive the world around them (Bogiages & Lotter, 2011).

Inquiry is the science, art and spirit of imagination. It is a scientific process of active exploration by which we use critical, logical and creative-thinking skills to raise and engage in questions. Inquiry as defined by the National Science Education Standards is a "multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results." (NCR, 1996) As we are driven by our curiosity and wonder of observed phenomena, inquiry investigations engage students in the continuous exploration of the natural world using the process of science.

Science teachers across the country face many challenges while they struggle with a variety of tools to engage students in science, tools that will build on the natural curiosity while developing scientific habits. Teaching scientific habits and methods of analyzing information enable people in every walk of life to critically assess problems that involve evidence, quantitative considerations, logical arguments, and uncertainty. Given the challenges that currently face society, it's important that everyone is able to critically consider scientific information, determining its relevance and validity, and utilizing it to make informed decisions on issues that affect our lives (Rutledge, 2005). Without the ability to think critically and independently, citizens are easy prey to dogmatists, flimflam artists, and purveyors of simple solutions for complex problems (AAAS, 1989).

By taking time to explore the nature of science, students are invited into the exciting world of science. Some teachers and professors may feel that discussing the nature of science would give them less time to cover biological content. However, today's introductory biology students are tomorrow's teachers and parents, decision makers, politicians, and world leaders. It is essential that members of society understand how science is distinct from religion, cultural and philosophical thinking. Students need to hone their ability to distinguish science-based information from information not grounded in scientific research, so they can make informed decisions about matters that affect their own lives and those of all living things (Musante, 2005). Science literacy is necessary for the success and survival of the planet.

Why is science literacy important? "Americans are confronted increasingly with questions in their lives that require scientific information and scientific ways of thinking for informed decision making. And the collective judgment of our people will determine how we manage shared resources—such as air, water, and national forests." (NRC, 1996) The scientifically literate individual is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations. They understand the key concepts and principles of science and are familiar with the natural world, recognizing both its diversity and unity. Scientifically literate people use scientific knowledge and scientific ways of thinking for individual and social purposes (AAAS, 1989). They develop question asking skills, essential even if they do not become scientists or engineers. The ability to ask well defined questions is an important part of science literacy, helping to make people critical consumers of knowledge (NRC, 2012).

Teachers face many challenges while striving to increase scientific literacy in students. Some of the biggest challenges faced by teachers surround the portrayal of the scientific method within textbooks. Scientists are the first to state that there is no single "scientific method" universally employed by everyone. Each individual uses a wide array of methods to develop hypotheses, models and formal and informal theories (Michaels, Shouse, & Schweingruber, 2008). A closer look shows that scientists approach and solve problems with imagination, creativity, prior knowledge and perseverance, using the same methods as all effective problem-solvers (McComas, 1998). Scientists often begin an investigation by tinkering, brainstorming, making new observations, chatting with colleagues about an idea, or doing some reading (Understanding Science, 2011). Science is no different from other human endeavors where puzzles are investigated. Teachers need to be encouraged to ignore the idealistic 'Scientific Method' that is touted by textbooks as the way to DO science (McComas, 1998) and begin to teach science as the flexible process it is.

Research that began in 1961 and continues, indicated that students and average citizens do not think science is engaging or exciting. The early analysis of students' understanding of science "concluded that students lacked sufficient knowledge of (a) the role of creativity in science; … (f) the fact that science is not solely concerned with the collection and classification of facts; (g) what constitutes a scientific explanation; and (h) the interrelationship among and the interdependence of the different branches of science." (Abell & Lederman, 2007).

Many common science teaching orientations and methods serve to work against the creative element in science. The majority of experiments in textbooks are “cookbook” activities where the teacher discusses what is going to happen in the laboratory, the manual provides step-by-step directions and the student is expected to arrive at a particular answer. As when solving many problems, there are techniques and tools that must be mastered and while these exercises can provide valuable opportunities to hone techniques and enable students to become adept with tools, their exclusive use is antithesis of the way in which science actually operates. The problem is that too often cookbook labs are the only experiences students have with science. These exercises portray science as dry, clinical and uninteresting to many students (McMomas, 1998). In her 1990 book, *They’re Not Dumb, They’re Different,* Tobias argues that many capable and clever students reject science as a career because they are not given opportunities to see it as an exciting and creative pursuit. The moral in Tobias’ thesis is that science may be impoverished when students who feel a need for creative outlet eliminate it as a potential career because of the way it is taught (Tobias, 1990).

The traditional way science is taught in a classroom centers on the textbook and lectures. Traditional lecture styles are instructor centered where the teacher provides one form of instruction to students with a variety of learning styles and abilities (Marshall & Horton, 2011). This method of instruction is passive and appeals to some students who prefer to do the least needed for the highest grade (McLoughlin, 2009). The instructor-centered lecture contains very little student participation as students are given few opportunities to make decisions, draw conclusions, or engage in discussions. Students who regurgitate information receive their A, move on, and do not expect to participate in their own learning experience. They often resist changing from the instructor centered process of learning to content centered inquiry-based learning (Ibid). Inquiry-based learning differs from instructor centered as students are given opportunities to express their understanding and learn from each other.

Inquiry, one of the eight core National Science Standards (NRC, 1996) and included in the Next Generation Science Standards Framework released in 2012, is a valuable means of engaging and educating science students. Inquiry learning environments include active settings for students that provide essential scaffolding based on each student's current ability. Meaningful inquiry investigations bring students to a point of deep understanding regarding key concepts in the discipline (Marshall & Horton, 2011). Student discussions about a shared experience is a way for them to synthesize what they know. Discussions also emphasize how the process of science circles around to what questions remain or arose and potential answers (Shwartz et all., 2009). "Scientific inquiry is holistic, fluid, reflexive, context-dependent and idiosyncratic, not a matter of following a set of rules that requires particular behaviors at particular times." (Hodson 1998).

Teaching strategies that support inquiry in the classroom are the 5 Es and discussion. The 5 Es are not a clearly defined process, rather they are a sequence through which science lessons should progress. The 5 Es includes the following five phases: Engagement, Exploration, Explanation, Elaboration or Extension, and Evaluation. (Bosse , Lee, Swinson, & Faulconer, 2010). When students are **engaged** they connect with a scientific question, event or phenomenon that confirm what they already know or disagrees with assumptions they have made motivating them to learn more. Engagement in the classroom can be a well-designed, robust question that generates a need to know in students. When **exploring,** students experience ideas through hands-on activities. They may formulate and test hypotheses, solve problems and/or collect information. Building on their exploration, students analyze and interpret data, synthesize their ideas and clarify concepts. Students build new ideas and **explanations** upon current knowledge. Students then **extend** their new understanding and apply it to new situations. Students should begin to connect their results or conclusions with existing scientific knowledge. During **evaluation**, students engage in conversations with their peers and teacher. They share explanations, ask questions and discuss their reasoning to solidify their arguments and resolve contradictions (Ibid). Discussions are an integral part of inquiry with the 5 Es. A student's ability to successfully communicate with peers and the teacher can be enhanced through discussions carefully planned by the teacher.

Students often know how to talk and listen to teachers, as the authority figure, but they generally don't know how to talk and listen to each other or the teacher in a discussion that works toward answers among equals. Teachers need to plan discussions with care so they do not become a question and answer session rather than the desired conversation and discussion. The objective is to engage, and involve as many students as possible so that students become agents in their own education (Barton, Heilker, Rutkowski, Retrieved 2012).

Successful discussion requires careful planning and teachers may need to establish classroom expectations or choose to use cues to signal a discussion. Students need to be 'primed' prior to a discussion, having answered written questions ensuring they have begun to process the materials. Most importantly, the teacher needs to be prepared by developing a script of questions to begin and potentially guide the discussion. The teacher should also be open to a deviation if a productive conversation develops (Ibid).

Carefully thought out purposeful questions can lead to lively discussions. Questions effective for discussion in science classrooms can be classified as analysis, interpretation, evaluation and sincere questions. The analysis or interpretation questions are when students are asked how or why. “How might the data be used to support the hypothesis?” “Why do you think the researcher chose that particular species for this experiment?” Evaluation questions ask students to compare something or consider how well something fulfills its function. “How well do you think the data support the hypothesis?” “What other conclusions might be supported by these data?” Sincere questions ask students to help find an answer that the teacher does not know. Sincere questions bring students and teacher together as collaborators in the construction of knowledge (Ibid).

The process of designing a unit is as important as the delivery of that unit with in the classroom. The Backward Design Process focuses on content and has three stages for unit development. Stage one is the identification of the desired results, or learning targets, and provide them as clearly stated objectives to the students (Wiggins & McTighe, 2001; Cox-Petersen & Olson, 2002). The learning targets should ideally include both content and/or necessary skills students will need to master at the end of the unit. Stage two is development of the assessment or the determination of acceptable evidence that will demonstrate students have achieved the desired unit outcomes. Both formative and summative assessments should be used. Stage three is planning the learning experience that students will have and the instruction that will need to take place (Wiggins & McTighe, 2001).

While developing activities through backward design the teacher needs to select materials intentionally and with consideration to the type of assessments offered. This purposeful planning results in every student activity directly relating to the unit learning goals. When standards, assessment and inquiry-oriented activities drive curriculum design, teaching science literacy and process of science, learning can be transformed, becoming meaningful for all students (Childre, Sands, & Pope, 2009).

## RESEARCH AND DESIGN

The objective of this thesis project was to plan and administer a research based unit in the writer's classroom to impact student understanding of biology through emphasizing the process of science. The writer's class at Alpena Community College on Huron Shores Campus consisted of dual enrolled high school students, traditional students recently graduated from high school and nontraditional students returning to college after numerous years out of school. The hypothesis is that students will significantly increase their understanding of the process of science through active participation in activities designed to emphasize the process of science.

This writer's interest in pursuing research and development to support a stronger understanding of the process of science within the classroom began while attending a lecture titled *Learning How to Do Science* with Dr. Dyer on March 12, 2011 as part of the Frontiers Lecture Series, Michigan State University. Dr. Dyer's lecture focused on the Scientific Method and how few students and elementary teachers understand or use it. This resonated with the frustration felt by the writer when expecting students to correctly use the "Scientific Method".

Virtually every science textbook begins with a chapter on the *Scientific Method*, this almost mystical process that tells us how to do science. The problem is many of these textbooks fail to convey the complexity involved. "As soon as an idea is developed, it is subjected to evaluation (by observation, experiment, comparison with other theories, etc.). Sometimes that evaluation leads to new ideas, to further and different experiments, or even to a complete re-casting of the original idea" (Hodson, 1998). Textbooks often neglect to incorporate the natural curiosity inherent in humans. Science is about exploration and discovery with the key elements of the scientific method being (Dyer, 2011):

- Making observations about particular natural patterns

- Questions about the causes/explanations for these patterns
- Hypotheses about the possible causes of the phenomenon or potential answer to a question
- Predictions that each hypothesis makes if it is supported
- An additional observation or experiment that you could do that would allow you to test this prediction

Teachers engage students in the process of science by setting the stage and capturing their initial interest. Engaging students from the onset can be one of the most import things a teacher does. Humans are inherently curious; we are drawn to patterns and to make observations about the patterns we see and their circumstances. In his presentation Dr. Dyer showed a short video to engage the participants' curiosity and encouraged them to make observations, writing three questions about what they saw. Time to discuss the questions generated is an important next step. Some of the questions generated were about the causal processes generating the pattern, often the focus of most textbooks. Are the Archer Fish teaching the young to hunt? Why jump when they can shoot? Some are questions that would flesh out the pattern, help us see it in more detail, like focusing the microscope. What is the range they can shoot? Jump? What do they shoot? Sometimes it helps first to find out more details about the things we are trying to understand. This often involves asking quantitative questions and may require additional research.

After making observations and generating questions students can begin formulating hypotheses. Textbooks may lead students to believe there is only ONE hypothesis for an observation. The reality is there are numerous possible hypotheses for any single question.

Hypotheses are proposed explanations or answers for a fairly narrow set of phenomena. These reasoned explanations are NOT guesses – of the wild or educated variety. Hypotheses are reasoned and informed explanations (Understanding Science, 2011). It is possible to have a variety of hypotheses be supported under different circumstances. It's important that students are recognized for thinking about what they observed and encouraged to be creative. Generating a variety of hypotheses can also help students understand what might need to be controlled for a specific experiment or hypotheses. "It is also imperative to demonstrate that alternative hypotheses can generate identical predictions, there is no crucial experiment to decide between, and that obtaining negative results and anomalous data is a natural feature of science." (Karsai & Kampis, 2010). Data and observations can reflect on a stated hypothesis in many different ways – supporting it, contradicting it, suggesting is should be revised, suggesting the revision of an assumption, or suggesting a new research question (Understanding Science, 2011).

The traditional next step after developing a hypothesis is to design an experiment or observational study to test it. Dr. Dyer introduced another step by asking the participants to predict the nature of the data that supported the stated hypothesis. When a scientist talks about the predicted rates he or she really means something like "the rate that we'd expect to see if our hypothesis were correct." (Ibid). Dr. Dyer also asked students to construct and discuss a graph to represent these expected data in two other circumstances: a graph refuting and a graph inconclusive with regards to the stated hypothesis. These graphical representations generated further questions that were discussed. It is important during scientific testing that students make a connection between the data and hypothesis. "You can think of scientific testing as occurring in two logical steps: (1) if the idea is correct, what would we expect to see, and (2) does that expectation match what we actually observe?" (Ibid). The process of science is a circular process that generates multiple questions and hypotheses. Data and observations from testing one hypothesis generate many more questions and hypotheses.

After attending *Learning How to Do Science*, this writer spent five weeks at Michigan State University researching, testing experiments and developing activities and collaborating with peers and advisors. The research was twofold; one was to modify activities and discussions that would provide the foundation for the process of science as described in Dr. Dyer's lecture. The other was to incorporate the process of science into the content of the Introductory Biology course providing students with multiple experiences using the process of science.

The backward design process discussed earlier was used to develop the unit. First the writer needed to identify the learning targets for the unit. This was done based on the Instructional Objectives and Core Competencies from the Alpena Community College Bio 114 Syllabus (Appendix 1C). Two main Core Competencies were identified for the bases of the assessment; 1) How to solve problems; and 2) How to communicate effectively. The objectives for the unit are that students will have the following abilities: (1) make qualitative and quantitative observations, (2) develop questions based on observations they made, (3) write a hypothesis as a statement that answers a question or offers an explanation for an observed phenomena, (4) make a prediction based on their hypothesis (5) represent and explain data that support the hypothesis, refute the hypothesis, are inconclusive regarding the hypothesis.

Step two of the backward design process was to develop assessments and determine the evidence that would support mastery of the desired outcomes. For this unit, formative and summative assessments were developed. The formative assessments are purposefully designed to monitor student's thinking about doing science throughout instruction and were used to guide future instruction rather than grade students (Cox-Petersen & Olson, 2002; Tanner & Allen, 2002). Students often do not know what they don't know (D'avanzo 2003). Formative assessments can be used to inform both the instructor and student about their current understanding and monitor gains in knowledge. Multiple types of formative assessments were used to encompass a variety of learning styles. For statistical analysis, one summative pretest and posttest was administered at the beginning and end of the semester (Appendix 4A).

The summative assessment was a nine question, 30 point, short answers assessment based on a video shown at the beginning of the assessment. A scoring rubric (Appendix 4B) was developed for use with the assessment. After the student pre-tests were analyzed, the instructor chose to focus on 1) the development of the hypothesis based on a question/observation and 2) its corresponding prediction.

Formative assessments were used to empower students and to encourage them to become a partner in the learning process (Stiggins, Arter, Chappuis, & Chappuis, 2006). The p*rocess of science with video* activities are examples of formative assessment the writer used to empowered students. Students individually completed the *Process of Science Guide* (Appendix 3A) after viewing a video clip, then discussed with peers their ideas and developed multiple hypotheses. Another type of formative assessment was the written formal lab report submitted by students at the conclusion of the inquiry labs.

The final step using the backward design process was to construct activities directly related to the assessment and learning targets. The writer started with a couple of short of lectures on safety, characteristics of life, the process of science and basic chemistry to provide students with information for future activities. After the development of the introductory activity the writer tested it on a group of public school teachers at the Northeast Michigan Great Lakes Stewardship Initiative Summer Institute for Community-based Education and made changes based on feedback. A *Process of Science Guide* (appendix 3A) worksheet was developed to describe the phases and thinking one should go through when solving a science problem or question. Students could consult the *Process of Science Guide* while they were working on developing their specific lab design. Studies have found that students with access to a process worksheet guide generally performed better on learning tasks (Kischner, Sweller, & Clark, 2006). After developing and compiling the components of the units it was time to organize the items and determine the relevant order of activities. This writer decided to arrange the components and activities to coincide with the order the content topics were presented in the assigned textbook.

DEMOGRAPHICS

The research was conducted at Alpena Community College (Huron Shores Campus) in Oscoda, Michigan. Alpena Community College (ACC) has an annual enrollment of just over 2,000 students, with a retention rate of 62%. Over 50% of the students attending ACC receive federal grant aid and 42% receive state grant aid. There is little ethnic diversity with 96% of the student body listed as white, 1% Asian, 1% Black, 1% Hispanic and 1% Native American. The Huron Shores Campus serves students primarily from Alcona and Iosco counties.

Iosco and Alcona Counties are both rural counties with small towns, the largest with a population of 2,000 people. Both counties depend heavily on the summer tourist season for survival and have a median income $10,000 below Michigan's average. Like the counties, the area schools are struggling. Figure 1 compares Alcona and Iosco to the Michigan state

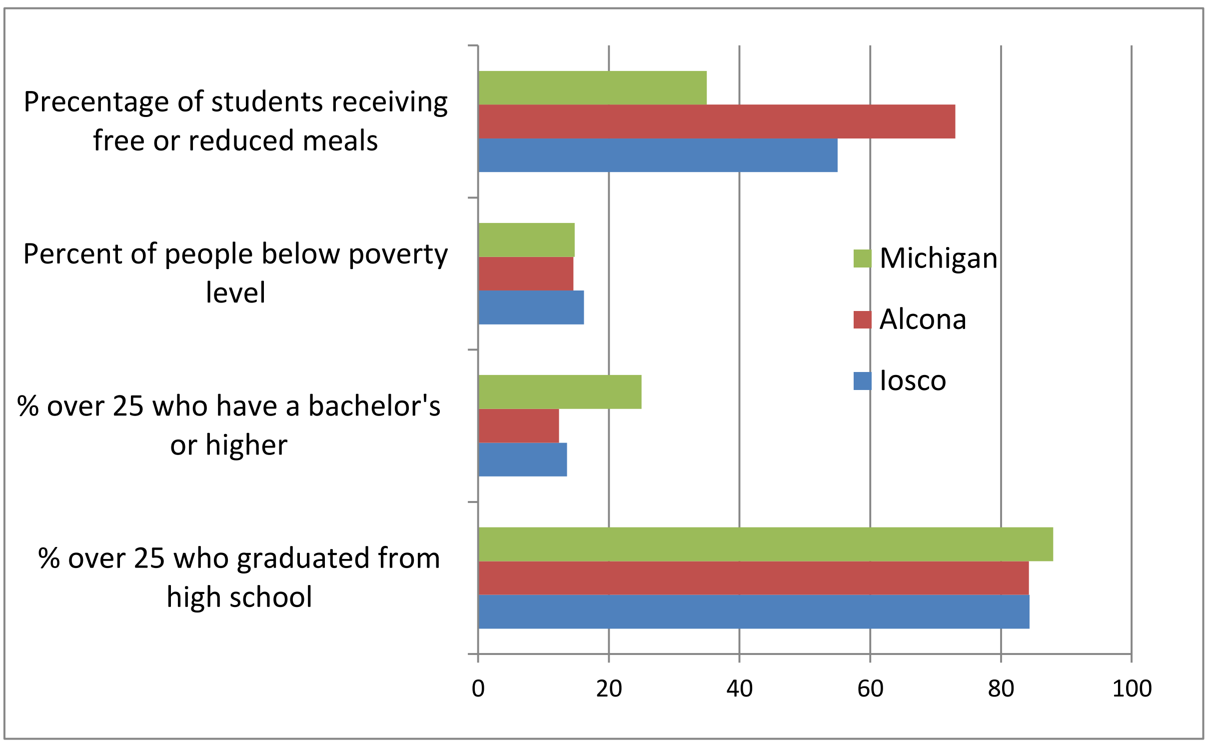


**Figure 1: Comparison of Alcona and Iosco Counties with the Michigan State Data on Poverty and Education.** For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this thesis.

information taken from 2010 census data. On average 55% of the students in Iosco schools and 73% of Alcona Community School students receive free or reduced lunches. Only 12-14% of the populations in Iosco or Alcona Counties have a bachelor's degree or higher which is barely half Michigan's average of 25%. Although both counties are struggling, the proximity to ACC does give local high schools the opportunity to provide students with additional educational opportunities.

High School students who have completed the required high school courses in their junior and senior years can dual enroll at ACC. Dual enrollment means the students attend classes at ACC but their tuition is paid by the local school district. Students are responsible for the cost of the books and their own transportation. Dual enrollment expands the classes available to local students in our smaller local school districts. It also enables motivated students the opportunity to graduate from high school with college credits.

Biology 114 is a required course for admission into the cooperative nursing program with classes on the main campus. It also meets the *science with lab* requirement of most degree courses. The consent forms (Appendix 1A) were distributed during the first class meeting. They were signed and returned to the writer in a sealed envelope to be held until the completion of the semester. All students who completed the course consented to the use of their data (n=11) and provided an accurate representation of the students that normally complete Bio 114.

## IMPLEMENTATION

Emphasis on the process of science included biological content on variation within a species, the characteristics of life, basic chemistry and plants. The lab exercises and practice activities completed throughout the semester of Biology 114 lead to the culminating process of science labs. Biology 114 is a four credit course which met twice a week, Tuesdays and Thursday from 5:00 p.m. to 6:30 p.m. for lecture and Tuesday from 6:30 p.m. to 8:30 p.m. for Lab. Table 1 contains the breakdowns of the unit by activity, assignment type, time needed to complete each assignment and the intended outcomes.

*Consent* (Appendix 1A)

The objective for this activity was to present information about the writer's project, answer questions and provide consent forms to the class for authorization signatures. Students signed and returned the consent forms to the instructor in sealed envelopes that were opened after the semester was completed. All students present returned consent forms.

*Pretest* (Appendix 4A)

The objective for this activity was to collect data for statistical purposes. The pretest was frustrating for many students who did not like the fact they did not know the answers. However, as the semester progressed and students participated in additional formative assessments they began to appreciate the opportunity for self-evaluation. All students present took the pretest, (n=11).

**Table 1: Components of the *Incorporating an emphasis on the process of science* unit; assignment name, type, time spent for each assignment and intended outcomes**

| Activity Name | Activity Type | Time | Unit Goals Addressed |
|---|---|---|---|
| Unit Pretest and Consent Forms | Assessment | 45 minutes | Student pretest for statistical analysis and consent. |
| Process of Science | Formal Lecture | 30 minutes | Students will identify the purpose of each part of the process of science. |
| Process of Science with video (Ladybug) | In class guided practice with discussion | 45 minutes | Students will gain experience using the process of science. |
| Safety contract & class discussion | Class discussion | 20 minutes | Students will identify locations and uses of safety equipment in the lab. |
| Scientific Method – Seed Variation | Lab | 120 minutes | Students will describe seed variation and apply the process of science. |
| A View of Life – Chapter 1 and Basic Chemistry – Chapter 2 | Formal Lecture with discussion | 90 minutes | Students will identify the characteristics of life and why basic chemistry is important for life. |
| Characteristics of Life | Class Discussion with Lab Activity and self- evaluation opportunity | 60 minutes +10 minutes for data collection and plant care during the next two scheduled classes. | Students will gain experience using the process of science incorporating their knowledge of the characteristic of life. |
| Basic Chemistry | Class Discussion with Lab Activity | 60 minutes +10 minutes for data collection and plant care during the next two scheduled classes. | Students will gain experience using the process of science incorporating their knowledge of basic chemistry. |
| Process of Science with video (Caterpillar) | In class guided practice with a partner and self-evaluation opportunity | 45 minutes | Students will gain experience using the process of science and improve their ability to communicate clearly. |
| I Wonder if…? | In class activity | 15 minutes | Students will refine their questioning skills |

**Table 1 (Cont'd)**

| | | | |
|---|---|---|---|
| Process of Science with video (Wasp) | In class guided practice with discussion and self-evaluation opportunity | 30 minutes | Students will gain experience using the process of science and increase their ability to communicate clearly. |
| Design a lab - Plants | In class small group developed inquiry lab activity | 120 minutes + 10 minutes each class as needed to complete lab | Students will use the process of science to develop a plant experiment to answer their question. |
| Process of Science with video (American Bittern) | Independent writing with formative assessment | 30 minutes (at home) | Students will demonstrate their knowledge of the process of science. |
| Process of Science with video (water spider) | In class practice with discussion and self-evaluation opportunity | 30 minutes | Students will practice using the process of science. |
| Bacteria, viruses and Fungi | Formal Lecture | 90 minutes | Students will identify the basic characteristics of bacteria, viruses and fungi. |
| Design a Lab – Bacteria | In class small group developed inquiry lab activity | 120 minutes + 10 minutes each class as needed to complete lab | Students will use the process of science to develop a bacteria experiment to answer their question. |
| Post Test | Assessment | 30 minutes | Student posttest for statistical analysis |

## ANALYSIS OF ACTIVITIES

*Process of Science* (Appendix 2A)

The objective of this activity was for students to learn the process of science, its components and circular nature. The writer presented the components through a PowerPoint slide presentation, The *Process of Science,* answered questions and asked clarification questions. The assessment for this objective was instructor observations and classroom discussion. Students asked how the process of science was different from the traditionally taught scientific method. This ignited lively discussion about the nature of man, our curiosity and ability to learn through observations. The instructor asked the students, "What happens when you run at a seagull on the beach?" All the students state the bird would fly away. When asked how they knew this, they all admitted it had not been formally taught but learned through repeated trials and observation. The discussion concluded with the basic understanding that the process of science gives structure and explanation to an informal process we use multiple times each day. Assessment of this activity was instructor observation and classroom discussion. This activity was a success, based on instructor observations and questions asked, as all students appeared to understand the process of science by the end of the classroom discussion.

*Process of Science* (Appendix 3A) *with Ladybug Video Clip from Microcosmos* (Appendix 2B)

The objective of this activity was for students to gain experience using the process of science. The instructor passed out the *Process of Science Guide*, a worksheet to help student communicate the components of the process. Students were shown a short video clip of a ladybug attempting to eat aphids that were under the protection of ants. The video clip was shown a second time and students were asked to record their questions and complete the worksheet. After students had completed the worksheet, the instructor guided the students through it in a whole class discussion. Students were encouraged to self-check their worksheet making changes as they desired. The assessment of this activity was formative and included the worksheet and classroom discussion. This activity was a success because all students gained experience applying the process of science.

*Safety Contract* (Appendix 1B)

The objective of this activity was for students to learn the location and uses of the safety equipment in the lab. The instructor passed out two copies of the student's safety contracts and read it with the students. The appropriate and proper use of all safety equipment was discussed. The students were attentive during the discussion and asked questions. At the conclusion of the discussion, the students signed and returned one copy of the safety contract. The assessment of this activity was instructor observation and the return of a signed copy of the safety contract. This activity was a success because all students signed and returned a copy of the safety contract.

*Seed Variation* (Appendix 3B)

The objectives of this activity were for students to learn about seed variation and to apply the process of science. The instructor passed out the *Seed Variation lab,* allowed students time to read the assignment and ask questions. Students completed the lab exercise and a *Process of Science Guide* based on their observations during the lab exercise. Students compiled the data from their lab and submitted a formal report the following week using the *Lab Reporting Rubric* (Appendix 4C). They also planted seeds to be used the following week in their experiments. The assessment of this activity was instructor observations and the formal lab report submitted by students. This activity was a success based on instructor observations and the depth of the discussion in the formal lab reports. Students scored an average of 20% higher than in previous years on lab activities with increased depth of understanding in their discussions and conclusions.

*A view of Life and Basic Chemistry*

The objectives for these activities were for students to learn the six basic characteristics of life and the basic chemistry of life. The instructor introduced a brainstorming activity by showing the students a rock and a dog, while asked which was alive and why. The introduction ended when the students had identified the six basic characteristics of living things. This was followed with a formal lecture along with classroom discussion that developed each characteristic. Students took notes of their own or on the *Chapter 1 – View of Life outline* (Appendix 3C) and *Chapter 2 – Basic Chemistry outline* (Appendix 3D) made available by the instructor through Blackboard. Assessment of this knowledge was done when the students designed and completed their *Characteristics of Life and Basic Chemistry Labs*.

*Characteristics and Basic Chemistry Lab Activities* (Appendix 3E and 3F)

These lab activities were intended to help students learn to apply the process of science. Students used their knowledge to design two experiments using plants. Students used the plants they seeded the previous week in experiments they designed to answer a question about the characteristics of life, using the *Characteristics of Life with Plants lab* (Appendix 3E) and the impact of basic chemistry using the *Basic Chemistry and pH with Plants lab* (Appendix 3F). They began by using the *Process of Science Guide* (Appendix 3A) to generate and discuss questions with their lab partner. Each group then selected one of their questions to test and designed an experiment. After receiving instructor approval, each group began their experiment. After compiling the data, each student completed a formal lab report using the *Lab Reporting Rubric* (Appendix 4C). Students also recorded additional questiosn that arose throughout the experiment, observations and data collection. Assessment for these activities was instructor observations and student lab report. Students in this semester scored an average of 20% higher on lab reports than previous semesters using a similar rubric. The discussion and conclusion sections portrayed an increased overall understanding of the material and the process of science.

*Process of Science with Caterpillar Video Clip from Microcosmos* (Appendix 3B)

The objective of this activity was for students to gain experience using the process of science. The instructor passed out the *Process of Science Guide* (Appendix 3A) and students were shown a short video clip of a caterpillar hatching. The video clip was shown a second time, then students were asked to record their questions and complete the worksheet. After students had completed the worksheet, the instructor guided a whole class discussion following the process. Students were encouraged to self-check their worksheet making changes as they desired. The assessment of this activity was formative and included the worksheet and classroom discussion. This activity was a success because all students improved their application of the process of science since the ladybug video. However the instructor observed that many students did not appear confident in their ability to develop questions or hypotheses and did an impromptu activity called *I Wonder If…?*

*I Wonder If…?* (Appendix 3G)

*I Wonder If…?* was a short in-class activity designed to help the students refine their question and hypotheses writing skills. Students were asked to think about an everyday situation where they wondered why someone was doing something and record at least three I Wonder if…? statements. Students had more confidence in their ability to write questions and hypotheses when they were not connected to a scientific topic. The assessment for this activity was done through instructor observation and the questions students submitted. This activity was a success based on the questions written in the following activities and labs.

*Process of Science with Wasp Video Clip from Microcosmos* (Appendix 3B)

The objective of this activity was for students to gain experience using the process of science. The instructor passed out the *Process of Science Guide* (Appendix 3A) and students were shown a short video clip of a wasp on a flower. The video clip was shown a second time then students were asked to record their questions and complete the worksheet. The instructor collected the worksheets after students had completed them. The assessment of this activity was the worksheet as a formative assessment. This activity was a success because all students improved their application of the process of science, improving their scores by an average of 6% on the *Process of Science Guide* (Appendix 3A) since the caterpillar video.

*Design a Lab – Plants* (Appendix 3H)

The objective of this activity was for students to demonstrate an understanding of the process of science through the development of an experiment to answer their question. The *Design a Lab with Plants* (Appendix 3H) began with students sharing the questions they recorded during the previous labs involving plants. The instructor recorded all the questions on the board and led a classroom discussion on the clarifications needed and the feasibility of testing each in the classroom given the time remaining in the semester. Next, students selected the question they were interested in testing. The instructor limited two students to a question, forming the groups for this lab exercise. Students used the *Process of Science Guide* (Appendix 3A) to determine the hypothesis they wanted to test. It also helped them think about the variables they would need to control and the data they would need to collect or not collect. After developing a list of materials, the procedure and the data to be collected, students met with the instructor. The instructor asked for clarification as needed and signed off on the lab allowing students to begin. After completing the lab a formal lab report was completed using the *Lab Reporting Rubric* (Appendix 4C) and submitted. The assessment of this activity was instructor observations and the formal lab report submitted by the student. The activity was a success based on instructor observations of the students' ability to design the lab experiment based on a question. Students in this semester scored an average of 20% higher on lab reports than previous semesters using a similar rubric. The discussion and conclusion sections portrayed an increased overall understanding of the content and the process of science.

*Process of Science with American Bittern from ARKive* (Appendix 3B)

The objective of this activity was for students to demonstrate their understanding of the process of science. Students were assigned to watch a video clip on the American Bittern downloaded from ARKive and posted on Blackboard. After watching the video clip students completed the *Process of Science Guide* (Appendix 3A) and submitted it the next class period. The assessment of this activity was the assignment turned in by the students. The activity was considered a success evidenced by a 3% increase in student scores demonstrating their understanding of the process of science since the wasp video.

*Process of Science with Water Spider video clip from Micorcosmos* (Appendix 3B)

The objective of this activity was for students to gain experience using the process of science. The instructor passed out the *Process of Science Guide* (Appendix 3A) and students and then students were asked to record their questions and complete the worksheet. After students completed the worksheet, they discussed their questions with a partner and completed a worksheet together. The assessment of this activity was formative and included the individual and partner worksheets. This activity was a success because all students improved their understanding of the process of science evidenced by a 6% increase in student scores since the American Bittern video.

*Bacteria, Viruses and Fungi*

The objectives for these activities were for students to learn the basic characteristics of bacteria, Viruses and fungi. The instructor presented information in a formal lecture along with classroom discussion. Students took notes of their own or on the *Chapter 17 – First Forms of Life outline* (Appendix 3I). Assessment of this content was done when the students designed and completed their Design a Lab - Bacteria activity.

*Design a Lab – Bacteria* (Appendix 3J)

The objective of this activity was for students to deepen their understanding of the process of science by applying it to developing a bacteria experiment to answer their question. The *Design a Lab with Bacteria* began with students sharing any questions they had about bacteria and antibacterial substances. The instructor recorded all the questions on the board and led a classroom discussion on the clarifications needed and the feasibility of testing each in the classroom given the time remaining in the semester. Next students selected the question they were interested in testing. The instructor limited two students to a question, forming the groups for this lab exercise. Students used the *Process of Science Guide* (Appendix 3A) to determine the hypothesis they wanted to test. It also helped them think about the variables they would need to control and the data to be collected. After developing the list of materials, the procedure and the data to be collected, students met with the instructor. The instructor asked for clarification as needed and signed off on the lab allowing students to begin. After completing the lab a formal lab report was completed using the *Lab Reporting Rubric* (Appendix 4C) and submitted. The assessment of this activity was instructor observations and the formal lab report submitted by the student. The activity was a success based on instructor observations of the students' ability to develop and implement the lab experiment. Students in this semester scored an average of 20% higher on lab reports than previous semesters using a similar rubric. The discussion and conclusion sections portrayed an increased overall understanding of the material and the process of science.

*Posttest* (Appendix 4A)

The objective of this activity was for students to complete the *Process of Science posttest* for data collection and as part of a summative assessment and final grade. All the students who completed the course completed the posttest. Students appeared confident about their success on the posttest and in the class.

RESULTS INCLUDING DATA AND MODIFIED CASE STUDIES

There were fourteen students initially enrolled in the evening Biology 114 course at ACC Huron Shores, Fall 2011. Eleven of the fourteen completed the course and submitted forms granting consent for the use of their data for this report. Students at ACC are either traditional, non-traditional or dual enrolled. The data for this study came from two dual enrolled high school students, three traditional students enrolling in class directly after high school graduation and six non-traditional students, enrolling in courses years after completing high school. Many non-traditional students are juggling a job, family and classes. The students enrolled in Biology 114 Fall 2011 were a good representation of the students population normally enrolled in Biology 114.

The average pretest (Appendix 4A) scores was 40.9% below the required passing grade. At Alpena Community College, the approved grading scale has 60.0% as passing. However students need to pass courses required for the major area with at least a 78.0%. After completion of the unit the average posttest score was 84.2% which was significantly better. The scores increased an average of 43.3% after completion of the unit with all students improving their test score. All students in the study passed the class with a score above 80%.

A paired T-Test was performed on the pre and post test scores to determine whether the data sets were significantly different. The results of the paired T-Test was T-value of T= -8.27. This T value used with a p value of 0.000, for n=11, allow for the rejection of the null hypothesis. The alternative hypothesis that the data sets for the pretest were significantly different than the posttest data set can be accepted. Accepting the alternative hypothesis indicates the unit was successful, students did learn about the process of science, as measured by this assessment, over the course of the unit.

The percent change as shown in Table 2 was similar for each student category. Dual enrolled students (n=2) scored higher than average on the pretest and had the least amount of change; they had a greater familiarity with the course content having recently completed high school biology. Traditional students (n=3) not pursuing a nursing degree scored lowest on the pretest and posttest and had low percent change in the same range as the dual enrolled students. Although the non-traditional students (n=6) score moderately on the pretest, they had the greatest percent change.

**Table 2: Student Pretest and Posttest Scores and the Corresponding Percent Change. Average Pretest = 40.9% Average Posttest = 84.2% Average Change = 43.3%**

| Student | Category | Pretest | Posttest | Change |
|---|---|---|---|---|
| F | Dual Enrolled | 46.7% | 80.0% | 33.3% |
| H | Dual Enrolled | 73.3% | 93.3% | 20.0% |
| A | Non-traditional | 23.3% | 100.0% | 76.7% |
| B | Non-traditional | 26.7% | 80.0% | 53.3% |
| E | Non-traditional | 50.0% | 70.0% | 20.0% |
| G | Non-traditional | 30.0% | 86.7% | 56.7% |
| J | Non-traditional | 40.0% | 100.0% | 60.0% |
| K | Non-traditional | 43.3% | 90.0% | 46.7% |
| C | Traditional | 33.3% | 93.3% | 60.0% |
| D | Traditional | 30.0% | 70.0% | 40.0% |
| I | Traditional | 26.7% | 60.0% | 33.3% |
| | | | | |

The non-traditional students appeared to have a different attitude in that they seemed to want to understand the information being taught. They are usually more comfortable asking questions and engaging in classroom discussions than the traditional or dual enrolled students.

Alpena Community College offers a Licensed Practical Nursing degree. This program is in demand, making competition fierce. Students need high grades in required classes to gain entrance. Biology 114 is a required course for the ACC nursing program. The writer has observed that the majority of the non-traditional students in Bio 114 were interested in pursuing a career in Nursing or other scientific field. These non-traditional students, Students A, B, E, G, J, and K, as shown in Table 2, have a strong desire to learn and understand as indicated by the high percent change. They tend to use their time efficiently during lab, engaging in classroom discussions and asking questions. The non-traditional students tend to be the ones who drive discussions and send them in interesting directions.

Students D and I, as shown in Table 2, were representative of the traditional student often enrolled in Biology 114. They both attended class regularly, but did not actively engage in classroom discussions. They remained aware of the topic under discussion but, unless questioned directly, offered no additions to the conversation. Student D and I also had no long term plans for their future, having no area of interest when asked the field they were planning to pursue. The other traditional student in this study was planning to pursue a career in nursing and was motivated to learn. Her level of participation, while better than the usual traditional student, did not reach the level of non-traditional students. The remaining type of students are those dual enrolled still in high school while taking college classes.

Dual enrollment is one way small schools can offer options to highly motivated students. The two dual enrolled students in this study were typical of this type of student. They had recently completed high school biology and were honor roll students. They did not have the same desire to learn, explore and understand as non-traditional students. Dual enrolled students are typically focused on their grade rather than on increasing their understanding. They were generally not comfortable applying the information learned. However, they did engage in the process of exploration and discovery. The combination of dual enrolled, traditional and non-traditional students in the classroom increased the depth and breadth of classroom discussions as life experiences and education mesh.

Thorough analysis of the data includes checking pre and posttest scores by questions. Table 3 shows the percentage of students who got each question correct and percent change between the two tests. All of the students showed an increase in percentage indicating an improvement in knowledge over the course of the unit.

**Table 3: Student Pre and Posttest scores and the percent change by question (n=11).**

| Question Number | Pretest | Posttest | Change |
|---|---|---|---|
| 1 | 97.7% | 100.0% | 2.3% |
| 2 | 90.9% | 100.0% | 9.1% |
| 3 | 63.6% | 100.0% | 36.4% |
| 4 | 31.8% | 88.6% | 56.8% |
| 5 | 36.3% | 75.8% | 39.5% |
| 6 | 6.8% | 79.5% | 72.7% |
| 7 | 6.1% | 66.7% | 60.6% |
| 8 | 13.6% | 79.5% | 65.9% |
| 9 | 9.1% | 66.7% | 57.6% |

Students scored well, as shown in Table 3, on questions 1, 2, and 3 on both the pre and posttests. This was expected as the questions increased with complexity and difficulty as they progressed. Question 1 required each student to record three questions based on the video clip. Question 2 asked them to choose one question on which to develop a hypothesis. Question 3 asked students to write a prediction to go with the hypothesis. The following questions, 4-9, asked students to think about how the data might look if the hypothesis were supported, refuted or if the data were inconclusive and to explain their reasoning. Without a good understanding of the process of science, students should not have scored well on questions 4-9. The pretest scores reflected this as students did not score high on these questions. The data analysis was completed with an item analysis of each question using the assessment scoring rubric (Appendix 4B). Detailed information on each question can be seen in Figures 2-10. Students earned various points for each question based on the depth of their answer. The percentage of students earning the greatest possible points will be on the right side of the graphs and the students who scored lower will be on the left.

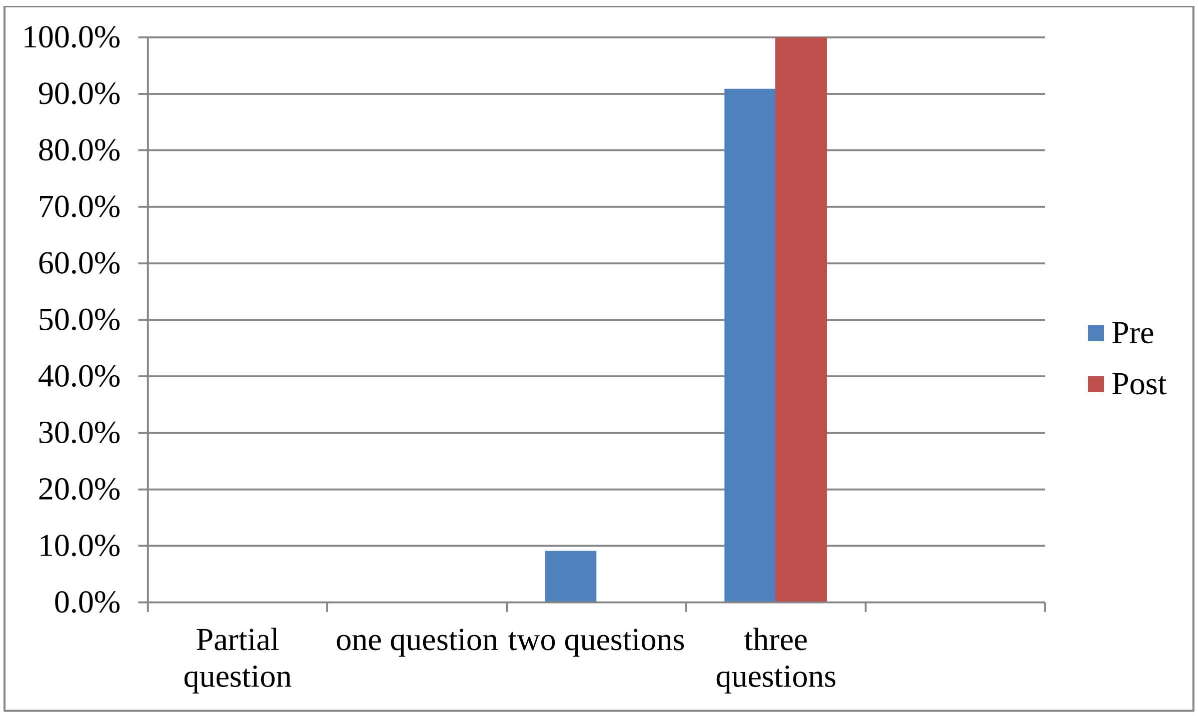


**Figure 2: Question 1 - Write at least three questions based on observations from the video clip.**

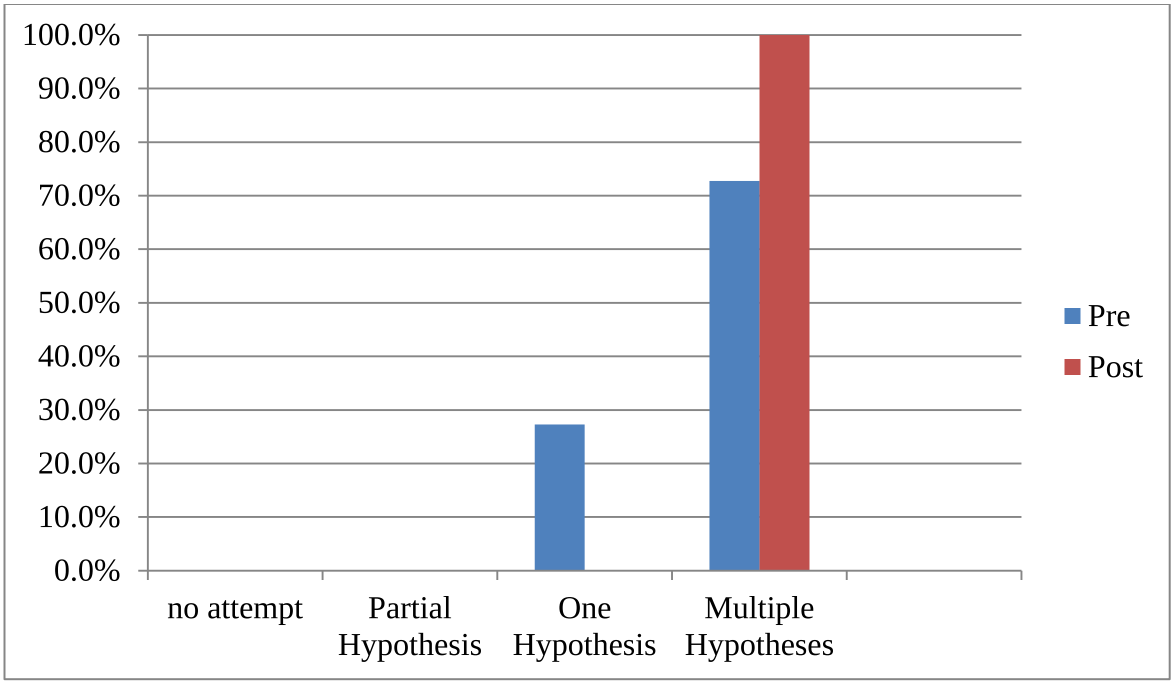


**Figure 3: Question 2 – Choose one of your questions then write hypotheses addressing that question.**

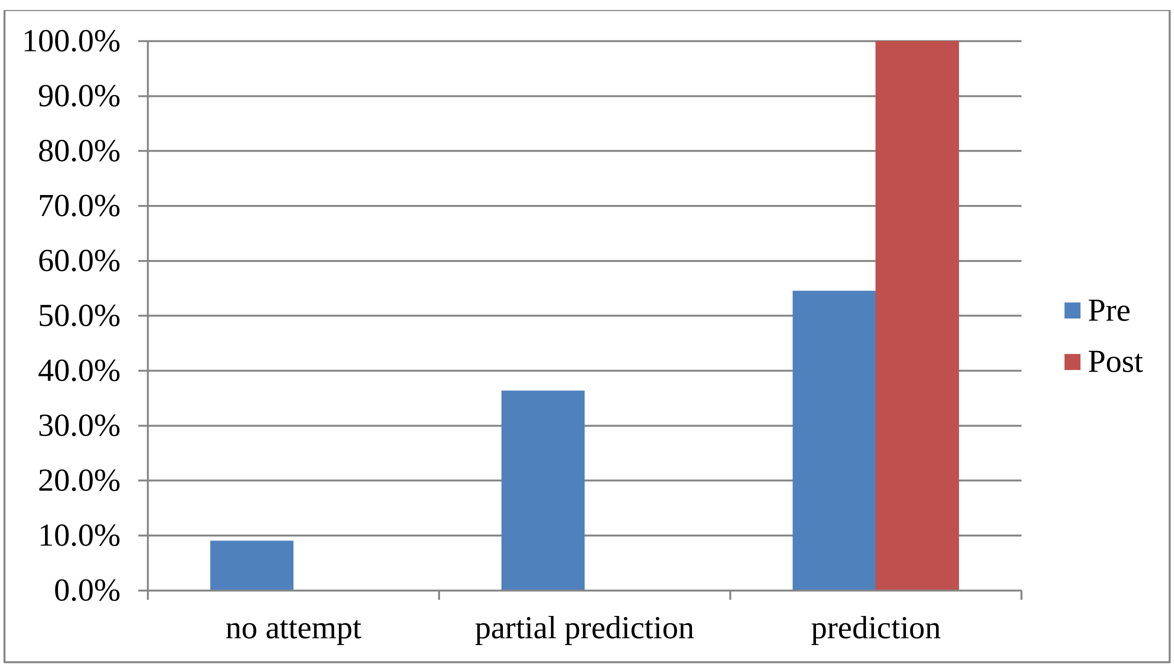


**Figure 4: Question 3 - Choose one hypothesis and write the prediction.**

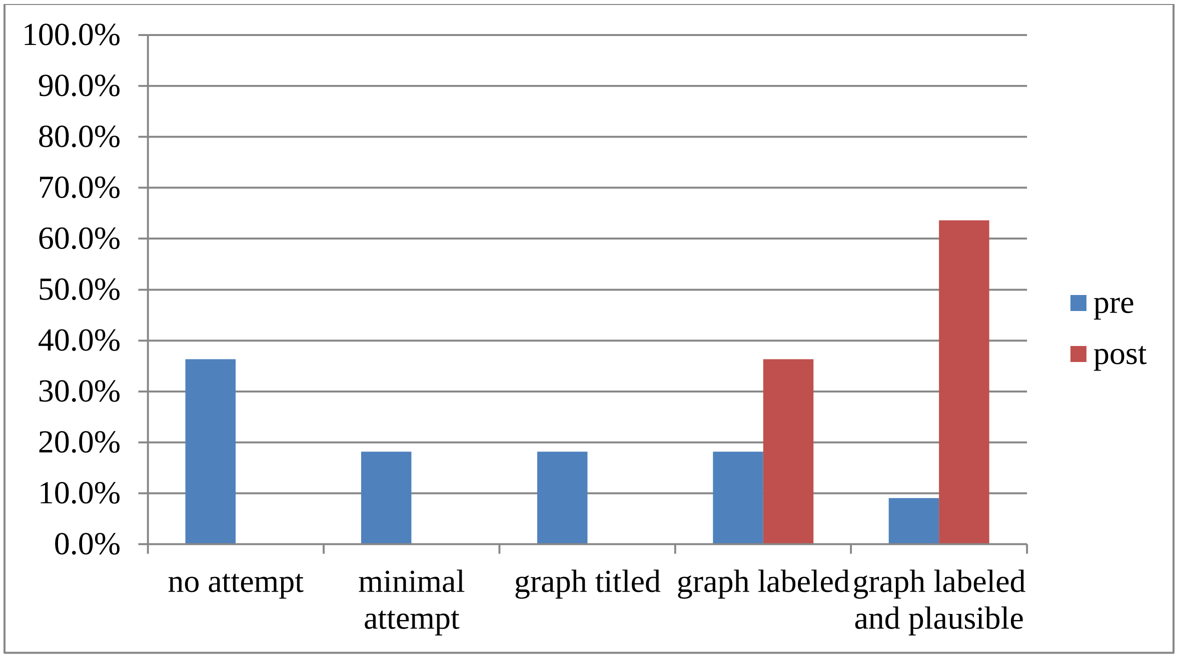


**Figure 5: Question 4 - Graph hypothetical data for your prediction if it is supported.**

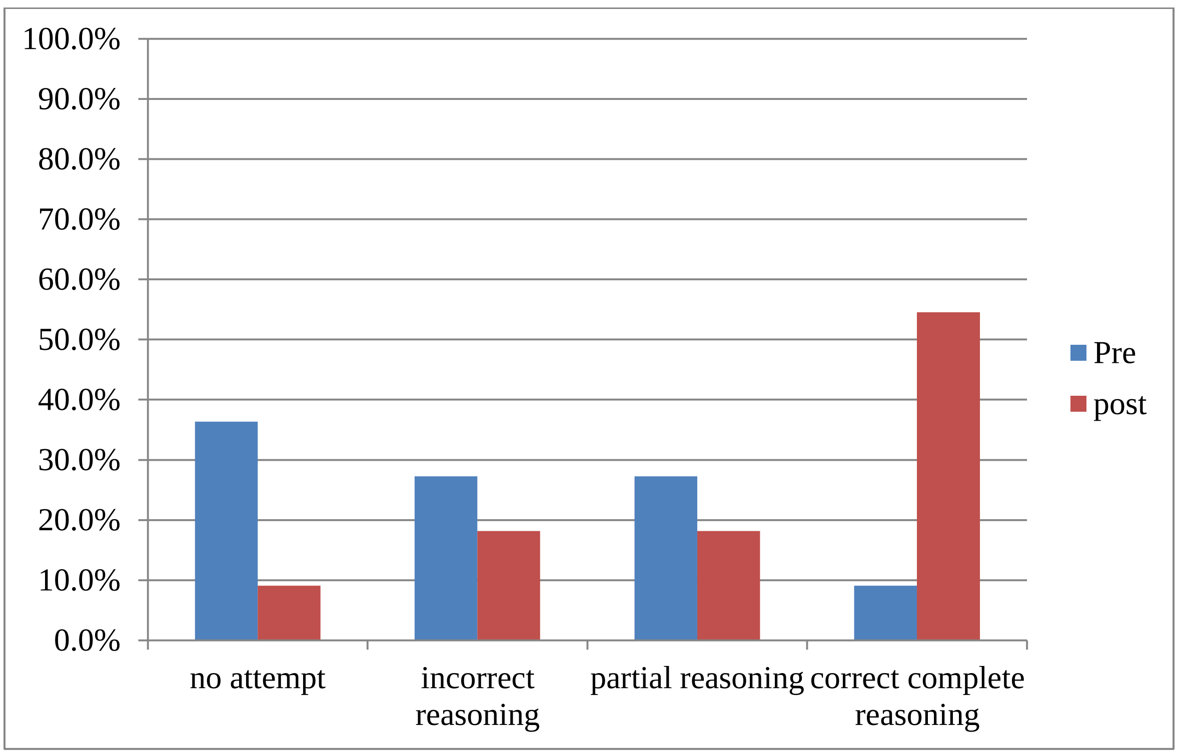


**Figure 6: Question 5 - Explain your reasoning for your graph in question 4.**

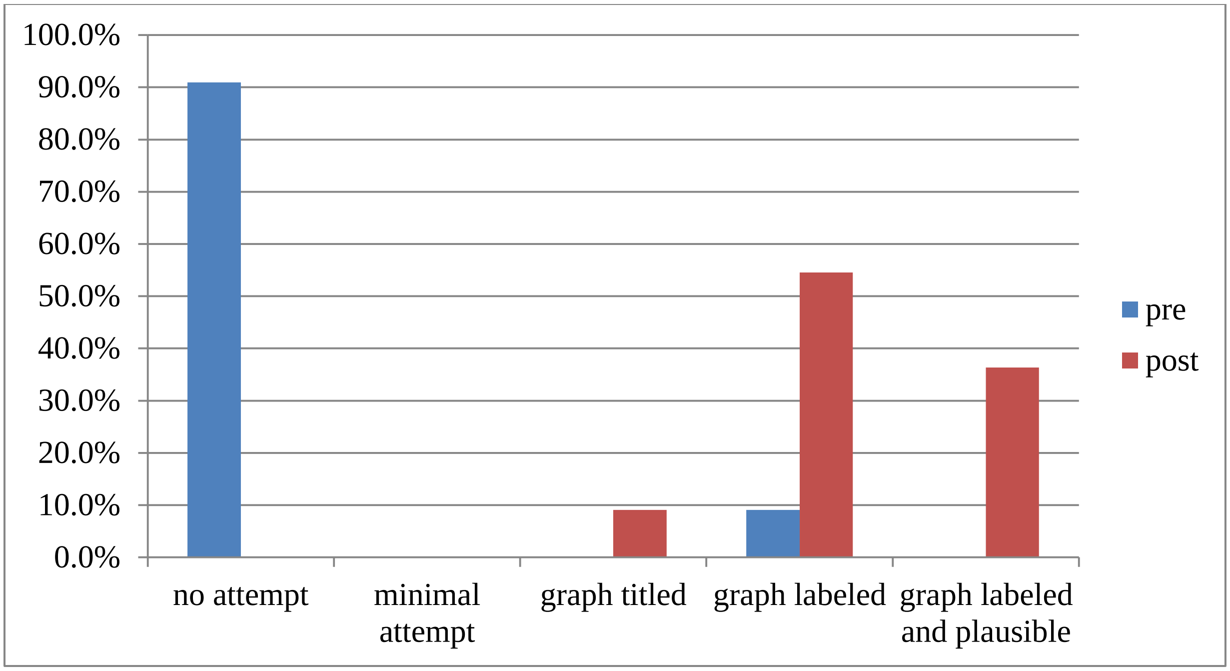


**Figure 7: Question 6 - Graph hypothetical data for your prediction if it is refuted.**

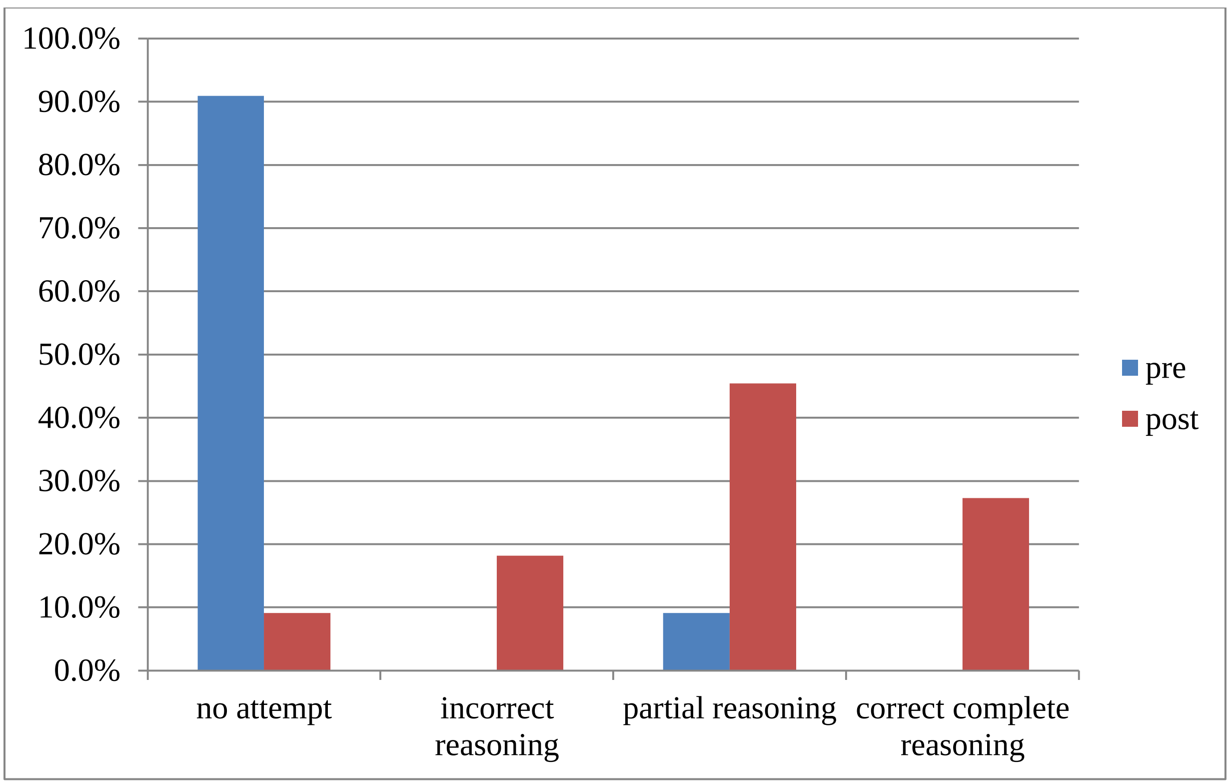


**Figure 8: Question 7 - Explain your reasoning for your graph in question 6.**

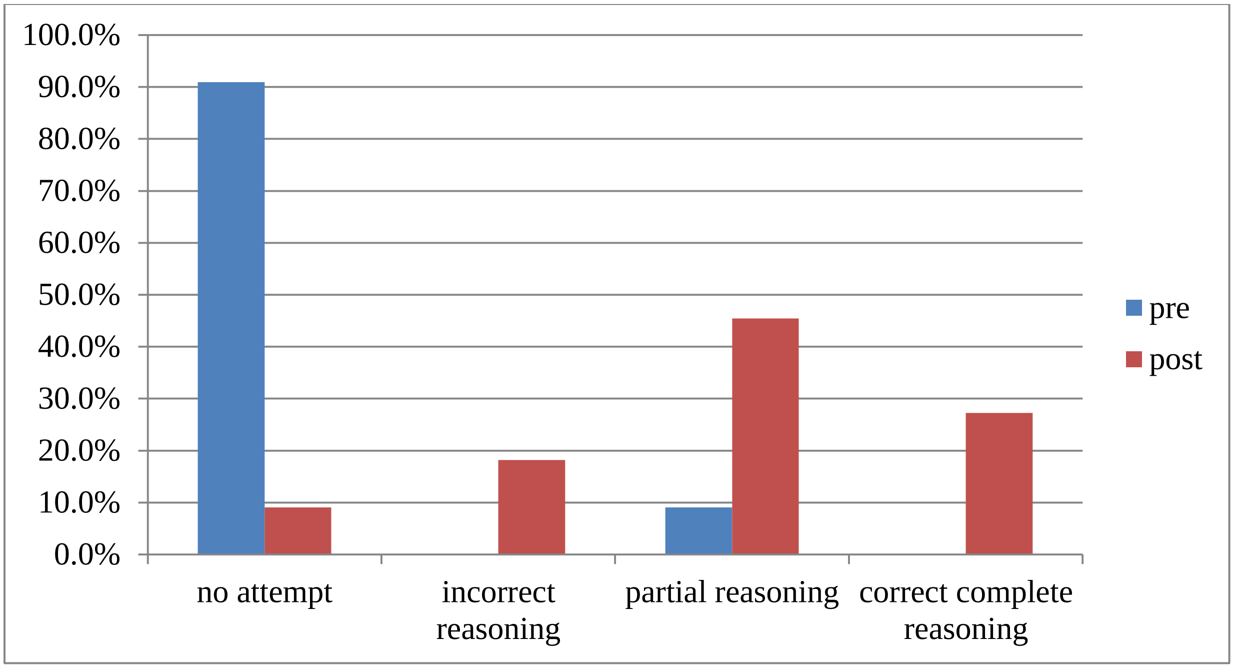


**Figure 9: Question 8 - Graph hypothetical data for your prediction if the data is inconclusive.**

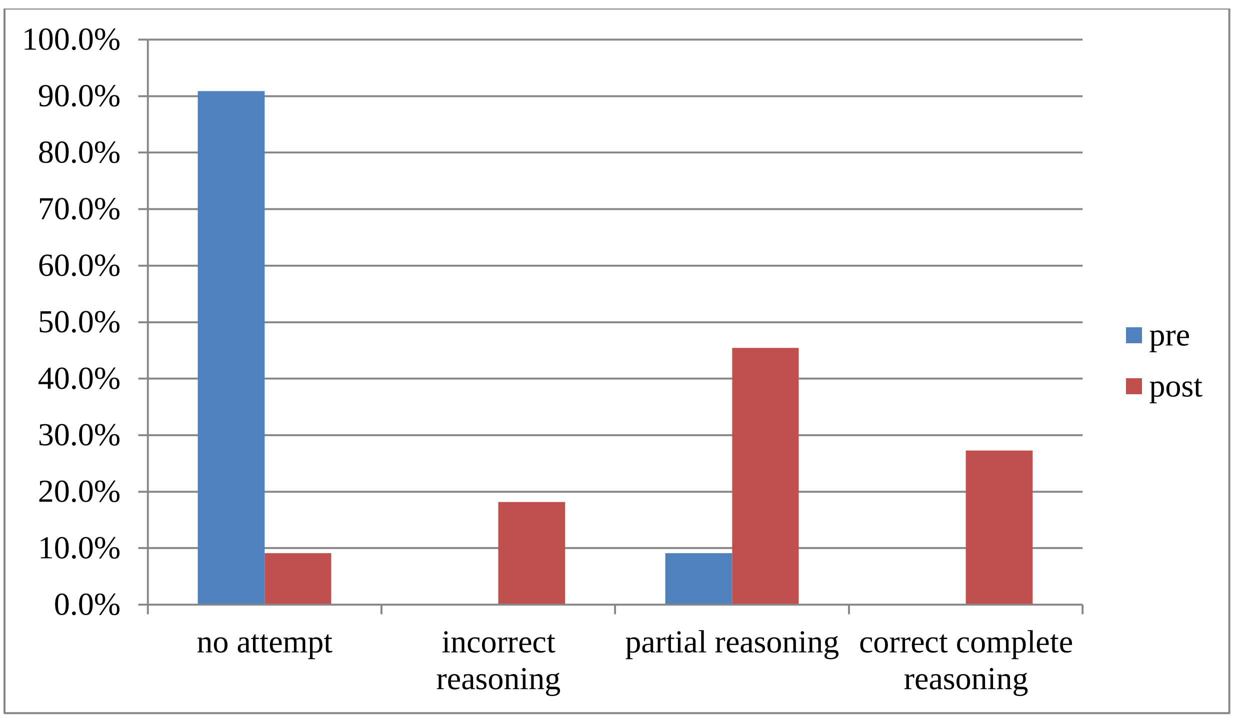


**Figure 10: Question 9 - Explain your reasoning for your graph in question 8**

## DISCUSSION

Overall, the instructor thought the unit was successful. Students were engaged and most seemed to enjoy the activities selected to help teach them the process of science. Modifications to the unit as originally designed were required due to administrative decisions, supply issues and to enhance the understanding of the students.

The first modification was due to an administrative decision. Upon checking in just before the start of classes the instructor discovered that over the summer the administration had decided that all Biology 114 classes would use the lab manual compiled by the instructor on the main campus. The writer reminded the administration of the letter sent over the summer agreeing to allow the instructor to use her Biology 114 class in thesis research. Special permission was given to allow this for the fall 2011 semester. However, materials requested by the instructor had not been ordered.

The required manual does include a lab involving plants so there were plant lights but not the correct seeds. The writer was able to obtain enough seeds for the lab exercises then discovered the plant lights sent from the main campus were wired incorrectly and only half of the system worked. The lights were repaired and the lab completed two weeks later than planned. As the labs began, the next modification became apparent.

The last day to drop a class fell midway through the labs and three students decided to drop the class. This left some students without a lab partner. The instructor discussed results with those students playing the role of their lab partner for the data analysis part of the lab. After the class size stabilized the remaining activities went well.

The *Design a Lab for Bacteria* was not part of the original thesis research. This was added after the following conversation with students. The instructor had just returned the graded lab reports from the *Design a Lab for Plants* activity and students had shared their findings with their peers. At the end of the discussion some asked if they could do another "design a lab" activity. The students agreed, excited about the prospect of another lab exploring their own question. The instructor had planned to use a canned lab testing antibiotic discs and *E.coli* but agreed that another "design a lab" would be good. The canned lab had students spread *E.coli* on nutrient agar adding antibiotic disks and measure the area of no growth around each disk over a period of time. Instead students brainstormed question about bacteria then selected a question to test.

The final modification was due to a problem with the incubator. Due to the addition of the *Design a Lab activity for Bacteria*, a second incubator was needed. It was requested to be delivered from the main campus. The incubator was plugged in before lecture and showed a stable 37 C after lecture and at the end of the lab. Two groups put their petri dishes in this second incubator. When the instructor checked the incubator prior to the next class period, two days later, and the petri dishes were melted and the incubator temperature read 97 C. The incubator was reset and observed. When the temperature remained stable, students in those groups redid their dishes beginning their experiment a week later. This helped to reinforce the need for good notes before and during an experiment and that unexpected things happen.

After years of teaching the process of science, this was the first time the instructor had evidence that the students really got it. The instructor observed that the students were actively engaged in learning and using the process of science. The majority of the students reported, in classroom discussions, they had a better understanding of the process of science. They also indicated an understanding of how the thinking emphasized in the process of science was a valuable tool to be used throughout their life. The excitement exhibited by some students after the *Design a Lab for Plants* as they requested another similar activity was inspiring. Students were actively engaged in sharing what they discovered in both *design a lab* activities. Each group had a different hypothesis and everyone was interested in learning what the other groups had found. As a teacher, it was very rewarding to hear my students having scientific discussions and considering possibilities from their classmates. Students were talking about what they had learned and realizing that they had the capabilities to find the answers to questions on their own.

During the classroom discussion after the last class students were asked what they felt had benefitted them the most. They all identified the *Design a Lab* activities. Most had never experienced the full process of science in such a self-directed way prior to this class. The instructor found it interesting that they did not identify the pieces that lead to their success in these activities. The *Design a Lab* activities would have been an exercise in frustration for both the instructor and students if the students had not been prepared. The instructor set the students up for success by providing practice and repeated exposure to the process of science prior to the independent lab activities.

The instructor, after discussing the initial results with the director of the Huron Shores Campus was given permission to modify and continue to implement part of the unit for the remainder of the year. Although the required lab manual will need to be used beginning the fall of 2012, the instructor will continue to use the *Process of Science Guide* and video clips and try to find time to include the *Design a Lab* activities.

The semester began the same as most with the instructor making the same assumptions she had every semester. She assumed the students had a basic understanding of the scientific method AND had used it in previous science classes. Unfortunately, this was not the case as evidenced by the students struggle to complete the first lab report and the *Process of Science*

*Guide* (Appendix 3A). It may be helpful for students if the *I Wonder If…?* (Appendix 3G) is incorporated earlier in the semester. This impromptu activity increased the confidence students had in their ability to write questions and formulate hypotheses as evidenced by the increased scores on the *Process of Science* activities that followed. In the following semesters time will be included to fully discuss the process of science as part of the scientific method and its components. The instructor learned that many students had never written a formal lab report and were unfamiliar with how to arrange the information or analyze their data.

A complete sample lab conclusion had been written on the whiteboard by the end of student questions based on the *Laboratory Reporting Rubric* (Appendix 4C). In the following semesters time will be included to fully discuss the process of science as part of a formal lab report using the *Laboratory Reporting Rubric.* Data analysis was another part of the process of science with which many students struggled. The instructor is hesitant to include an example lab report but may make available some sample conclusion/discussions.

Most students were able to represent data supporting the stated hypothesis on the *pretest* (Appendix 4A), Figure 5, but could not fully explain why it did, Figure 6. None of the students were able to represent data that refuted or was inconclusive with regards to the stated hypothesis, Figures 7-10. The instructor found that most students were competent collecting data but were confused about how to proceed when the collecting was completed. Discussions about data will be incorporated into three areas in the following semester: 1) a discussion on the data and incorporating the data into the conclusion/discussion part of the lab will be added in following semesters before the first formal lab report is due; 2) representations of supporting, refuting and inconclusive data and its analysis will be included after the first *Process of Science with Video Clip* and; 3) discussion of the three forms of results, supporting, refuting or inconclusive, that may be realized in their data.  The lesson learned during this study will enable me to more effectively teach students to make the best use of the limited time available.

During the study, the instructor found that classroom discussions had a greater value than expected.  When students were engaged in the discussion, they were thinking about the material in multiple ways.  They were not just regurgitating information they were defending, justifying and revising their knowledge.  It is difficult at times to get the level of interest and involvement needed so that students are fully engaged in learning.  The instructor found two approaches that worked with this group of students.  First was to make an outrageous statement relating to the material; the second was to use formative assessments that empowered students, like the *Process of Science Guide* with which students could monitor their own progress.

During the research phase the instructor had an opportunity to present the idea of using the process of science from observation to data analysis based on a short video clip to a small group of teachers.  They expressed a frustration shared my many science teachers.  They do not have enough time to fully engage students in the process of science.  After the presentation which engaged the teachers in the process of science and ONLY took 45 minutes from observation to data analysis, the teachers were interested.  Some have requested copies of the PowerPoint and the *Process of Science Guide* (Appendix 3A) which were shared.

It's interesting for the writer to realize this entire study was triggered by one Frontier Series Lecture at Michigan State University by Dr. Fred Dyer on the "scientific method".   The presentation by Dr. Dyer contained information that many frustrated science teachers have recognized for years!  However, this instructor never realized how increasing the emphasis on just one area, the process of science, could have such significant impact on the students.  The instructor while anticipating an increase in overall scores from the *pretest* to the *posttest* she did not expect an increase of 37.1%, as shown in Table 2. The greatest changes occurred in the students' ability to represent and explain data for a stated hypothesis, as shown in Table 3. These unexpected results have changed how this instructor teaches science.

## CONCLUSION

The hypothesis, increasing the emphasis on the process of science will improve student's understanding of the process of science, was supported by data collected in this study. The pre and posttest data in Table 2 showed an average increase of 43.3% after the completion of the unit. The T value T = -8.27 with a p value of 0.000 for the pre and posttest data dictate the acceptance of the hypothesis. Further analysis of the test data showed that the questions, while difficult, were within the capabilities of the students. This was supported by the improvement of 100% of the students from the pre-test to the posttest. Questions four through nine on graphing and explaining hypothetical data showed the highest gains in student test scores from pre-test to posttest. This indicates that students had significantly improved their ability to use the process of science. They thought about and communicated data relating to their hypothesis to a greater degree from the pre-test to the posttest.

**APPENDICES**

# APPENDIX 1

# FORMS

## APPENDIX -1A
## STUDENT CONSENT AND ASSENT FORM

Dear Students:

I would like to take this opportunity to welcome you back to school and invite you to participate in a research project, **Process of Science**, which I will conduct as part of Biology 114 this fall semester. My name is Tracy D'Augustino, one of the Bio 114 instructors. I am also a master's degree student at Michigan State University. Researchers are required to provide a consent form like this to inform you about the study, to convey that participation is voluntary, to explain risks and benefits of participation, and to empower you to make an informed decision. You should feel free to ask the researchers any questions you may have.

**What is the purpose of this research?** I have been working on effective ways to teach the process of science and I plan to study the results of this teaching approach on student comprehension and retention of the material. The results of this research will contribute to teachers' understandings about the best way to teach about science topics. Completion of this research project will also help me to earn my master's degree in Michigan State University's Division of Math and Science Education (DSME).

**What will students do?** You will participate in the instructional activities emphasizing the process of science. You will complete the usual assignments, laboratory experiments and activities, class demonstrations, and pretests/posttests just as you do for any other unit of instruction. There are no unique research activities – participation in this study will not increase or decrease the amount of work that students do. I will simply make copies of students' work for my research purposes. I am asking for permission from both students and parent/guardian, if applicable, to use copies of student work for my research purposes. This project will continue from August through December 2011.

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

**What are the potential risks?** There are no foreseeable risks associated with completing course assignments, laboratory experiments and activities, class demonstrations, and pretests/posttests. In fact, completing course work should be very beneficial to students. The consent forms (where you say "yes" or "no") will be stored in a locked file cabinet and will not be opened until after I have assigned the grades for this unit of instruction. That way I will not know who agrees to participate in the research until after grades are issued. In the meantime, I will save all of your written work. Later I will analyze the written work only for students who have agreed to participate in the study and whose parent/guardian, if applicable, have consented.

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

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

**Who can you contact with questions and concerns?** If you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher Tracy D'Augustino: 5800 Skeel Ave , Oscoda, MI 48750; daugustt@alpenacc.edu; 989-739-1445 and /or Dr. Merle Heidemann: 118 North Kedzie Lab , Michigan State University, East Lansing, MI 48824; heidema2@msu.edu; 517-432-2152 x 107].

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail irb@msu.edu or regular mail at 207 Olds Hall, MSU, East Lansing, MI 48824.

**How should I submit this consent form?** If you agree to participate in this study, please complete the attached form. Both the student and parent/guardian, if applicable, must sign the form. Return the form to the Alpena Community College Huron Shores Office in the sealed envelope by Sept 1, 2011.

Name of science course: Biology 114
Teacher: Tracy D'Augustino
School: Alpena Community College

**Students should complete this following consent information:**

I ________________________________________ voluntarily agree to participate in this study.
(print your name)

**Please check all that apply:**

**Data:**
___________ I give Tracy D'Augustino permission to use data generated from my work in this class for her thesis project. All data from my work in this class shall remain confidential.

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

**Photography, audiotaping, or videotaping:**

___________ I give Tracy D'Augustino permission to use photos, audiotapes, or videotapes of myself in the class room doing work related to this thesis project. I understand that I will not be identified.

___________ I do not wish to have my images used at any time during this thesis project.

I voluntarily agree to participate in this thesis project.

________________________________________ __________________________
(Student Signature) (Date)

*****Important*****
**Return this form in the sealed envelop to the Alpena Community College Huron Shore Office.**

APPENDIX -1B
STUDENT LABORATORY SAFETY CONTRACT

**Prepare for Laboratory Work**
Study laboratory procedures prior to class.
Never perform unauthorized experiments.
Keep your lab bench organized and free of apparel, books, and other clutter.
Know how to use the safety shower, eye wash, fire blanket and first aid kit.

**Dress for Laboratory Work**
Tie back long hair.
Do not wear loose sleeves as they tend to get in the way.
Wear shoes with tops.
Wear safety goggles during all laboratory sessions.
Wear gloves when using chemicals that can be absorbed through skin.

**Avoid Contact with Chemicals**
Never taste or “sniff” chemicals.
Never draw materials in a pipette with your mouth.
Never carry dangerous chemicals or hot equipment near other people.

**Avoid Hazards**
Keep combustible away from open flames.
Use caution when handling hot glassware.
Turn off burners when not in use.
Keep caps on reagent bottles. Never switch caps.

**Clean Up**
Consult teacher for proper disposal of all materials.
Wash hands thoroughly following experiments.
Leave laboratory table clean and neat.

**In Case of Accident**
Report all accidents and spills immediately.
Place broken glass in designated containers.
Wash all acids and bases from your skin immediately with plenty of water.
If chemicals get in your eyes, wash them for at least 15 minutes at the eyewash.

I, ______________________________________________, agree to: (a) Follow the teachers instructions, (b) protect my eyes, face, hands and body during laboratory, (c) conduct myself in a responsible manner at all times in the laboratory, and (d) abide by all safety regulations specified above.

APPENDIX -1C
ALPENA COMMUNITY COLLEGE
BIOLOGICAL 114 COURSE SYLLABUS
(Excerpt)

Course Number/Title: BIO 114 - Introduction to Biological Science

Course Instructional Objectives:

Upon successful completion of this course, students will:

A. be prepared for further coursework in the area of biology or to satisfy science requirements.
B. have a base knowledge of the principles of biology to make them more aware of their bodies or health, their fellow organisms, their surroundings, and major issues which they face as citizens of modern society.

Core Competencies:

I. How to learn effectively: Students will gather information from the library, videos, or other media as background information for lab reports and/or term papers.

II. How to solve problems: Students are required to generate hypotheses, collect information, propose evaluations, and analyze data to draw conclusions when conducting lab experiments.

III. How to use mathematical concepts: Students perform basic algebraic operations when calculating metabolic or transpiration rates or in analysis of the data from their lab projects.

IV. How to communicate effectively: Students communicate written and graphically in their lab reports and/or lecture papers. They also communicate in small groups during lab experiments where they are required to work as a team.

V. How to interact with the world: Students will understand the role organisms have in their respective habitats and how those habitats relate to the world at large. Students will understand the environmental and medical issues that we currently are facing. Students will gain an understanding of various organisms and their values or contributions to life.

# APPENDIX 2

## TEACHER NOTES AND INSTRUCTIONS

APPENDIX – 2A
PROCESS OF SCIENCE POWERPOINT SLIDES

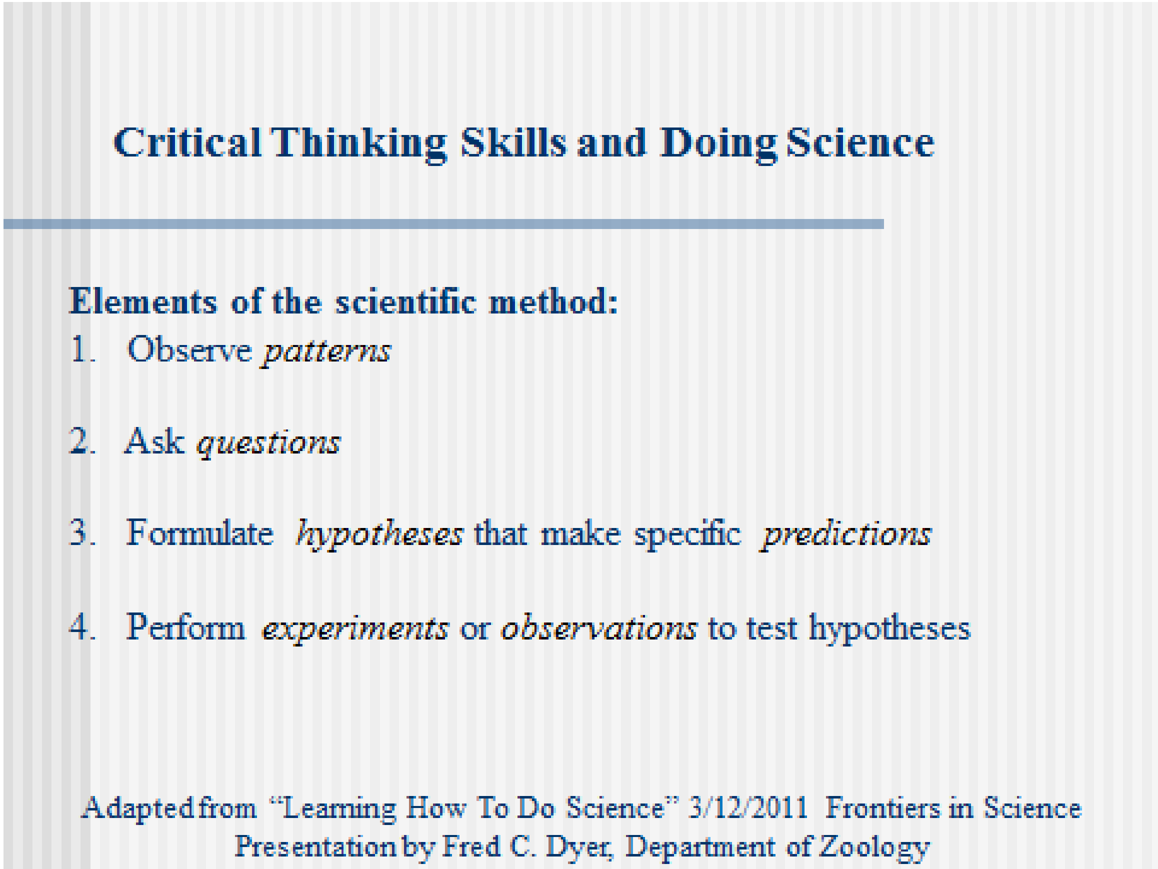


**Figure 11: Slide 1 - Process of Science PowerPoint Overview Slide**

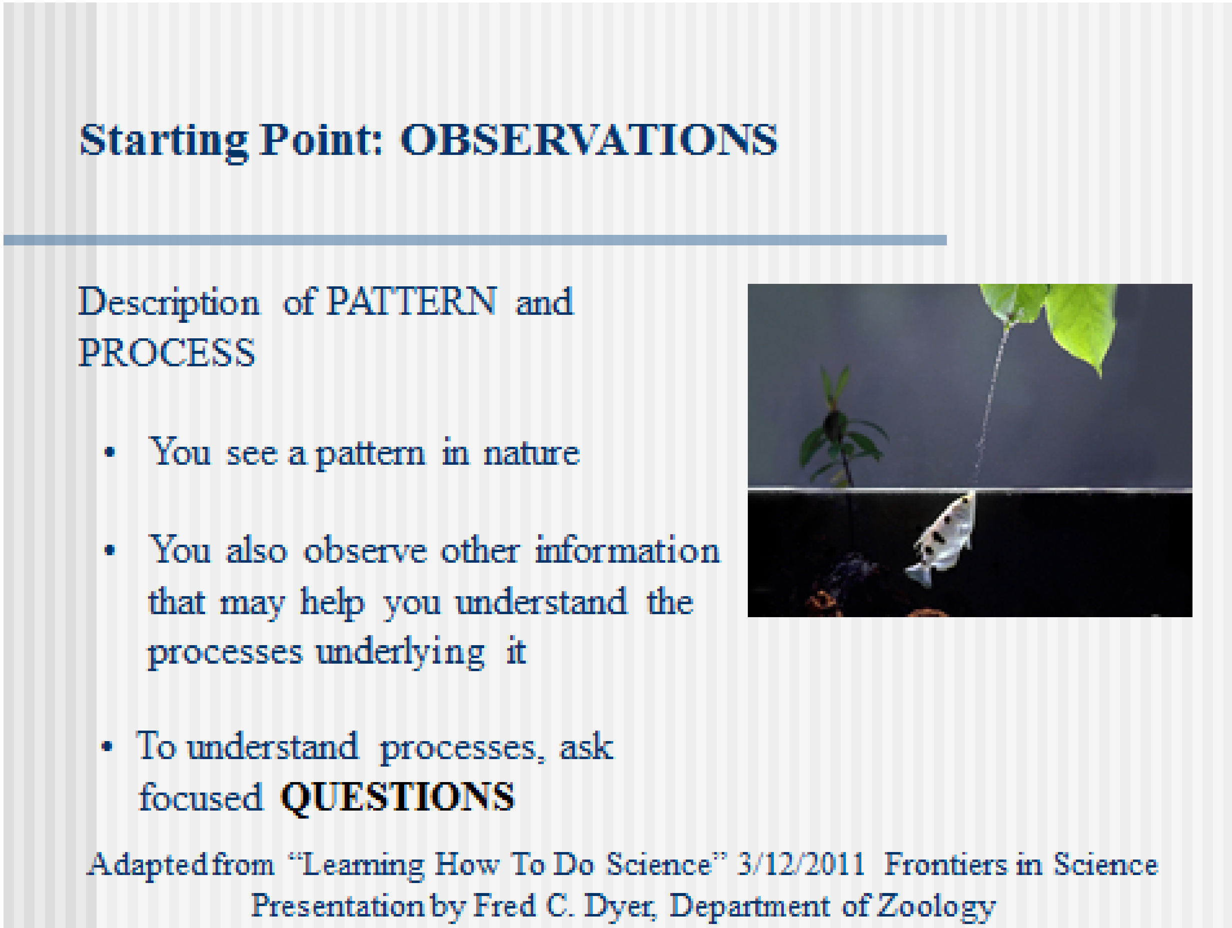


**Figure 12: Slide 2 – Process of Science Observations Slide**

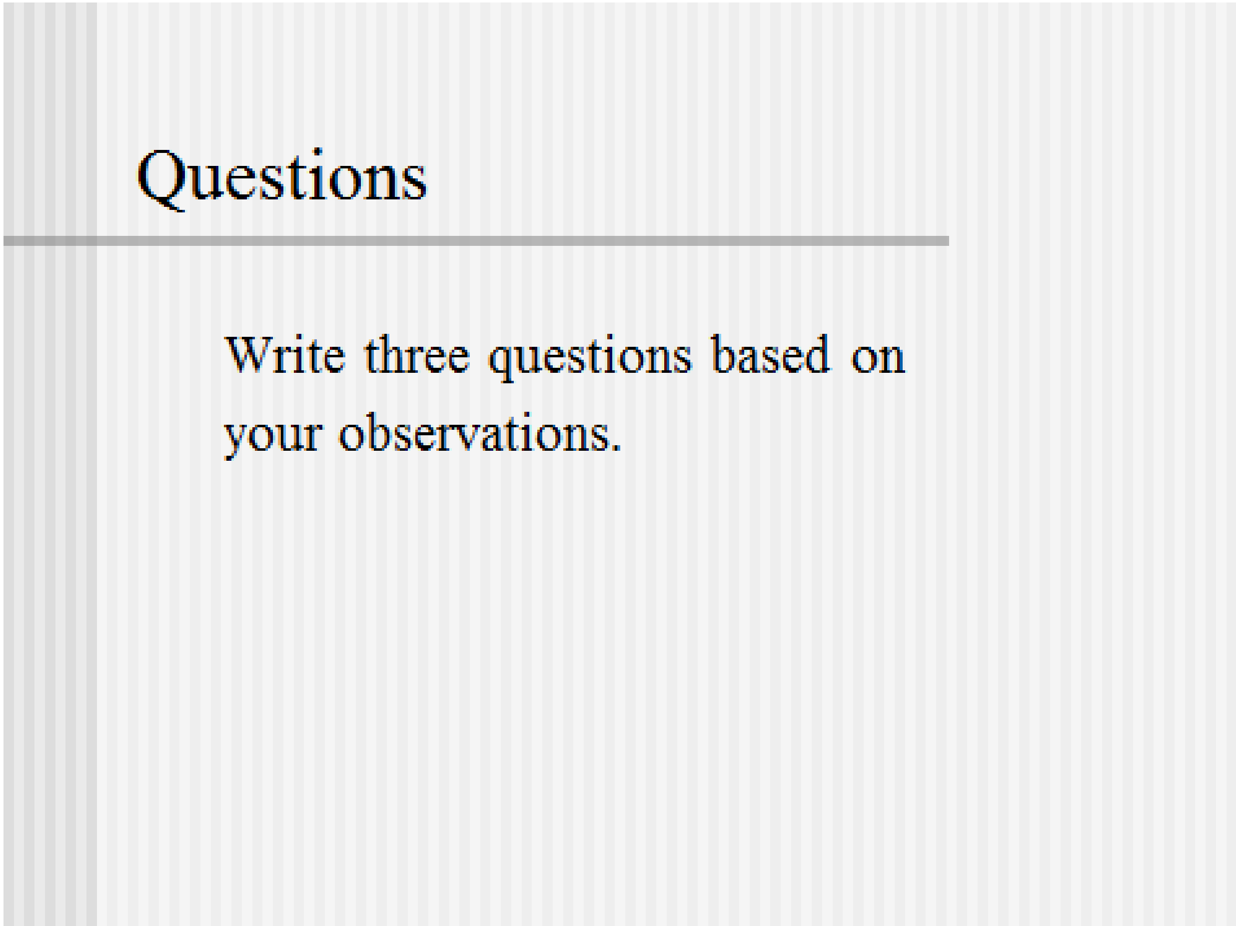


**Figure 13: Slide 3 – Process of Science Questions Slide**

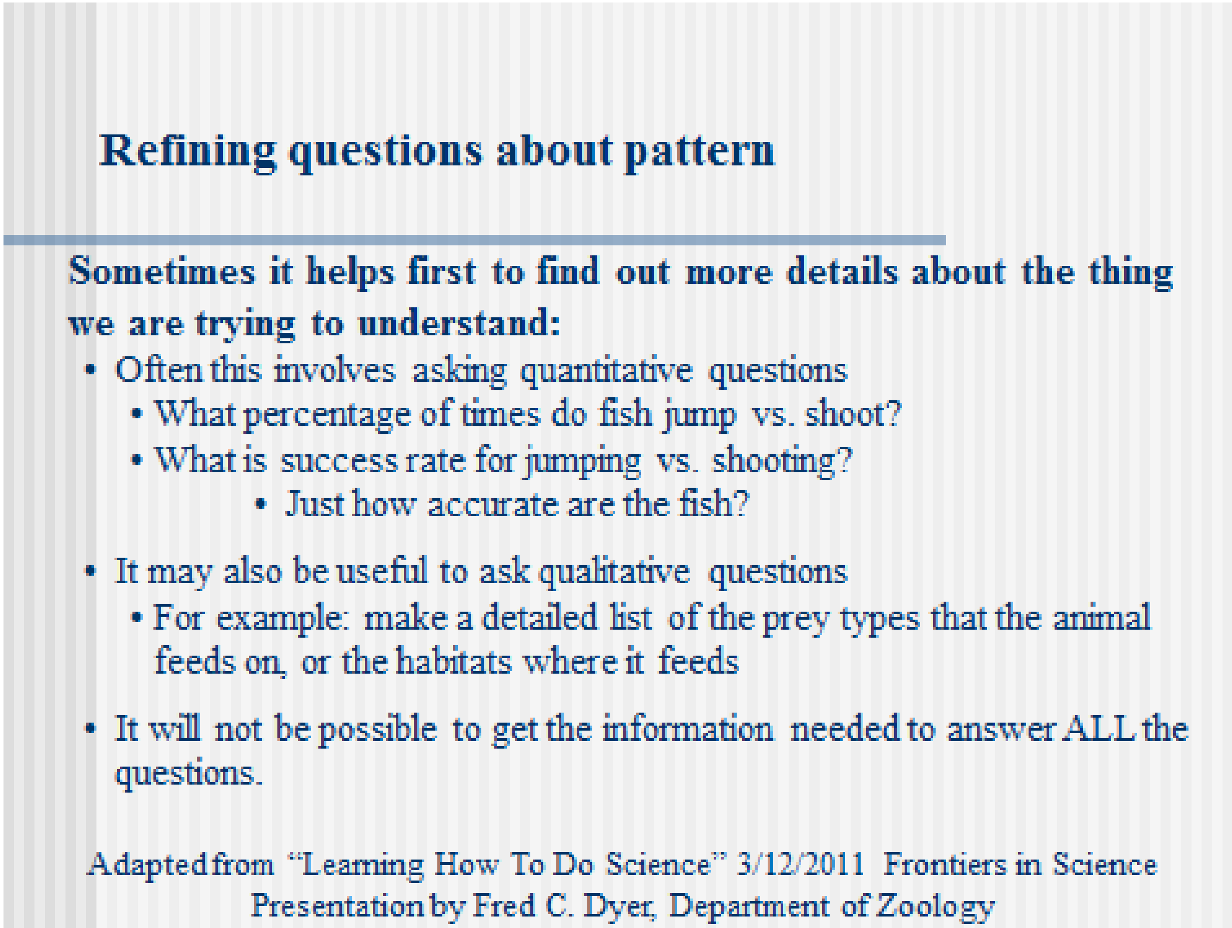


**Figure 14: Slide 4 - Process of Science Patterns Slide**

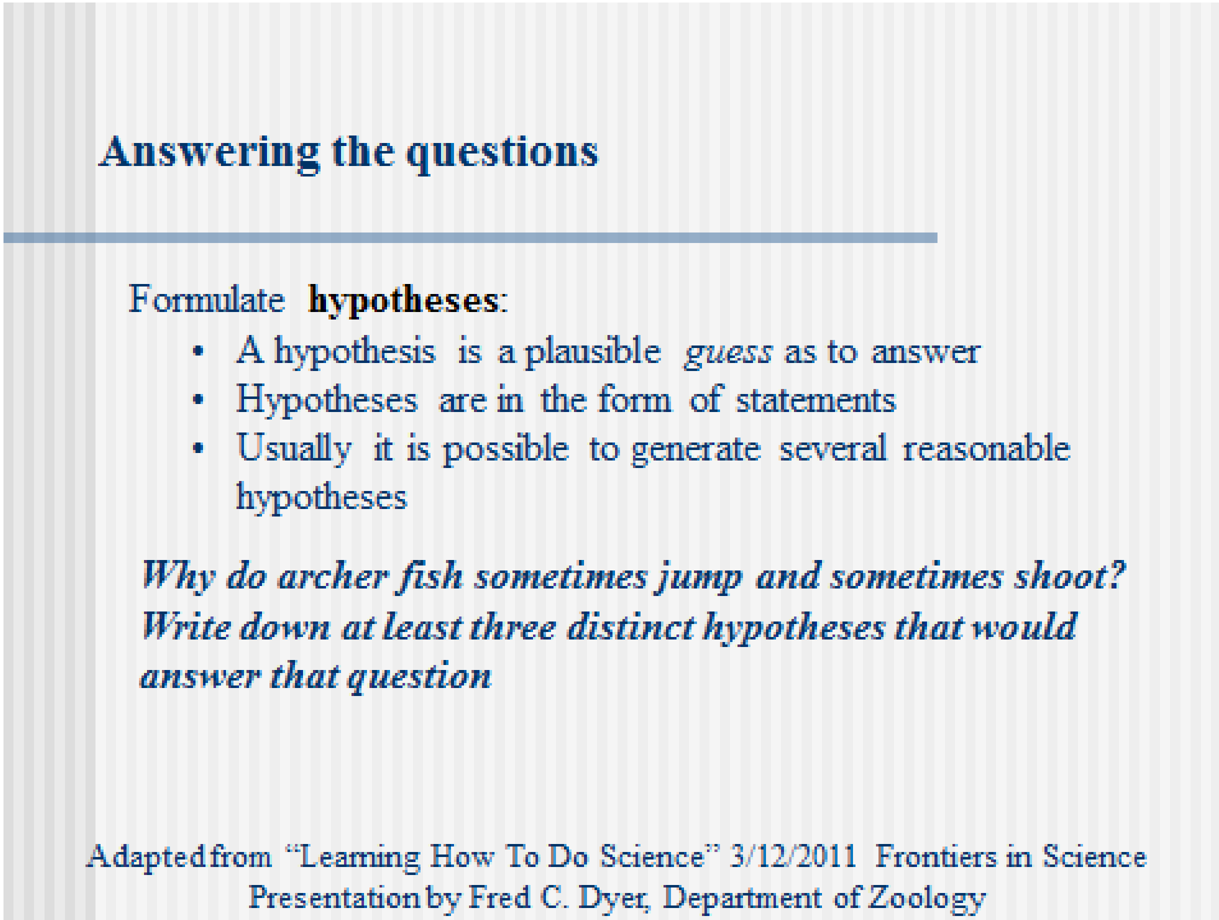


**Figure 15: Slide 5 – Process of Science Hypotheses Slide**

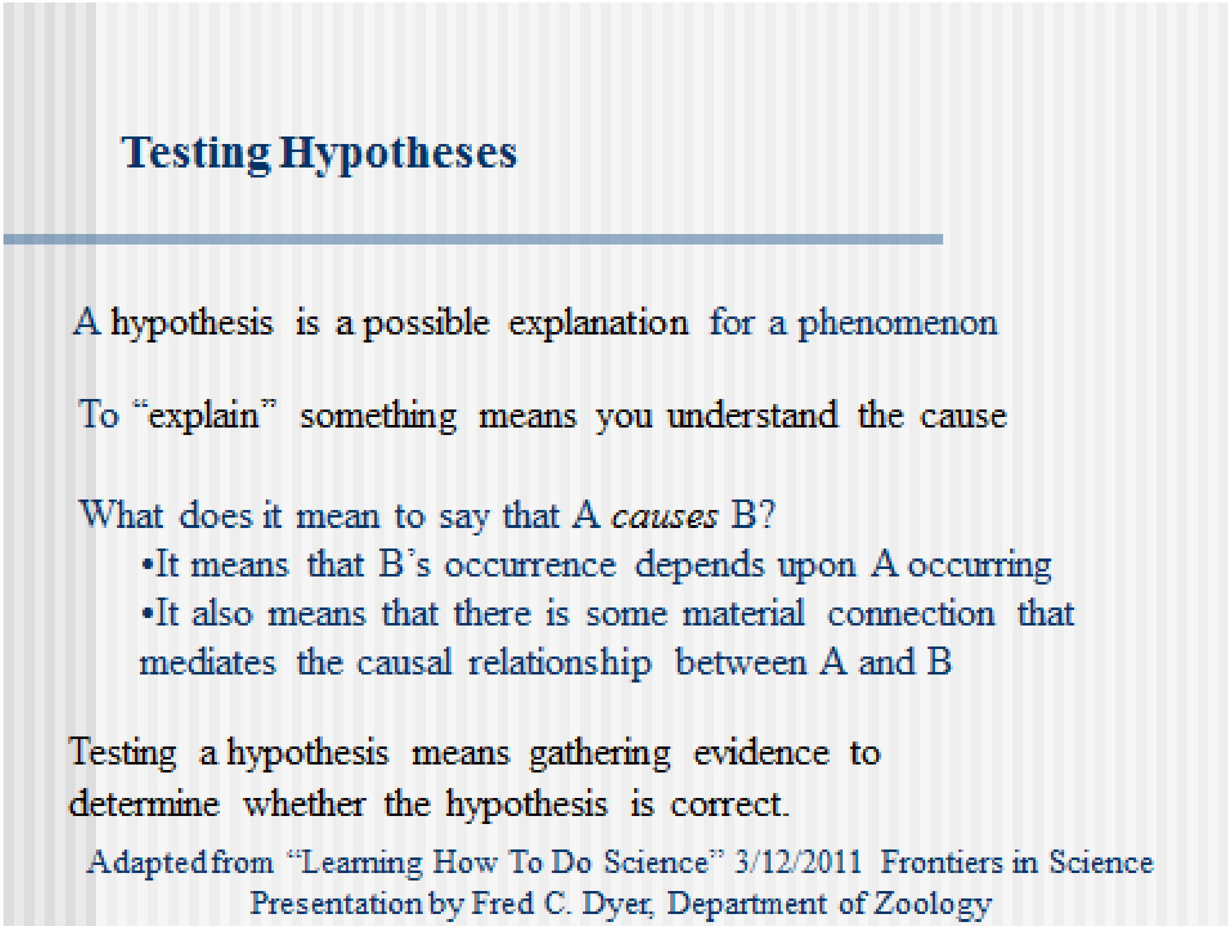


**Figure 16: Slide 6 – Process of Science Prediction Slide**

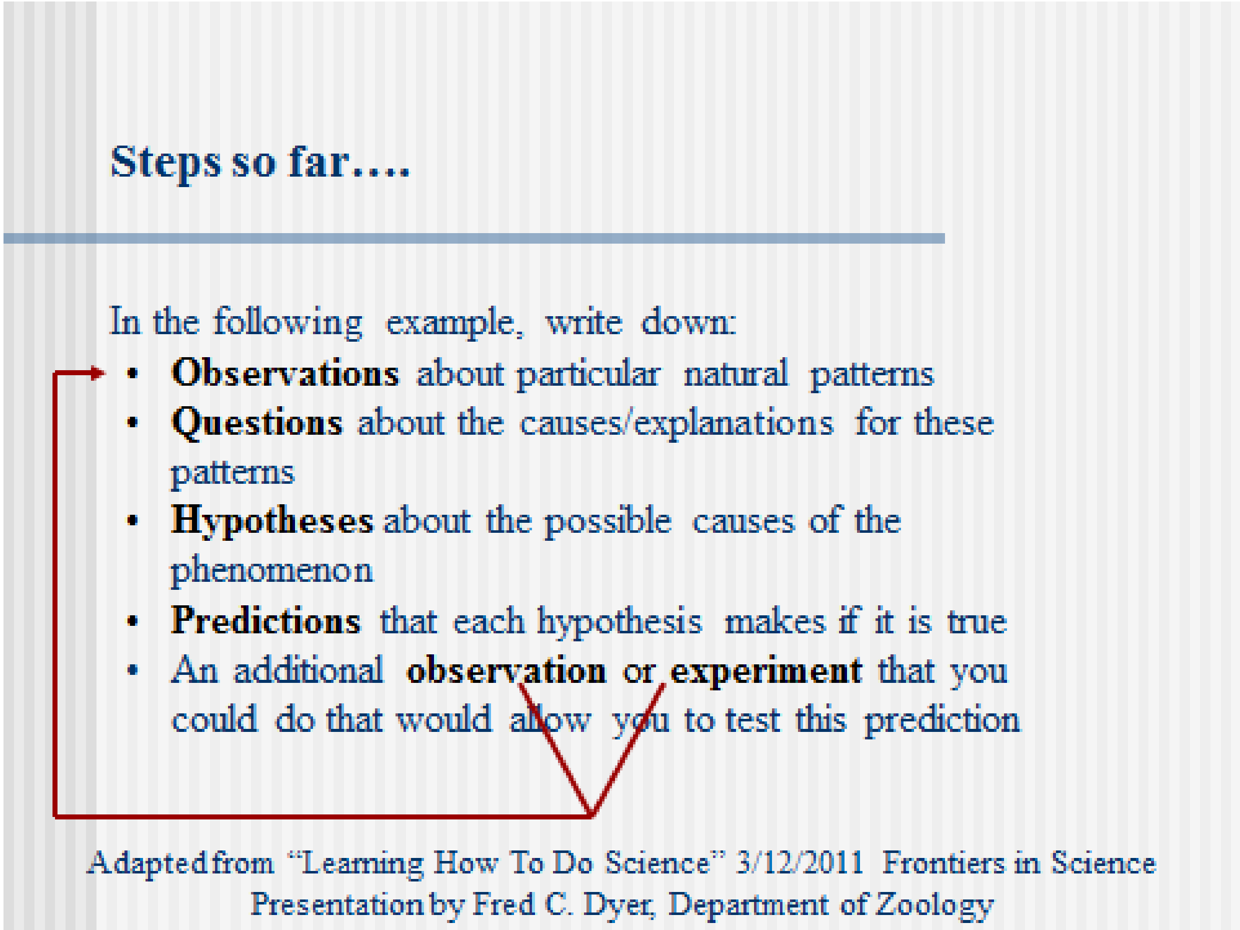


**Figure 17: Slide 7 – Process of Science Observations Slide**

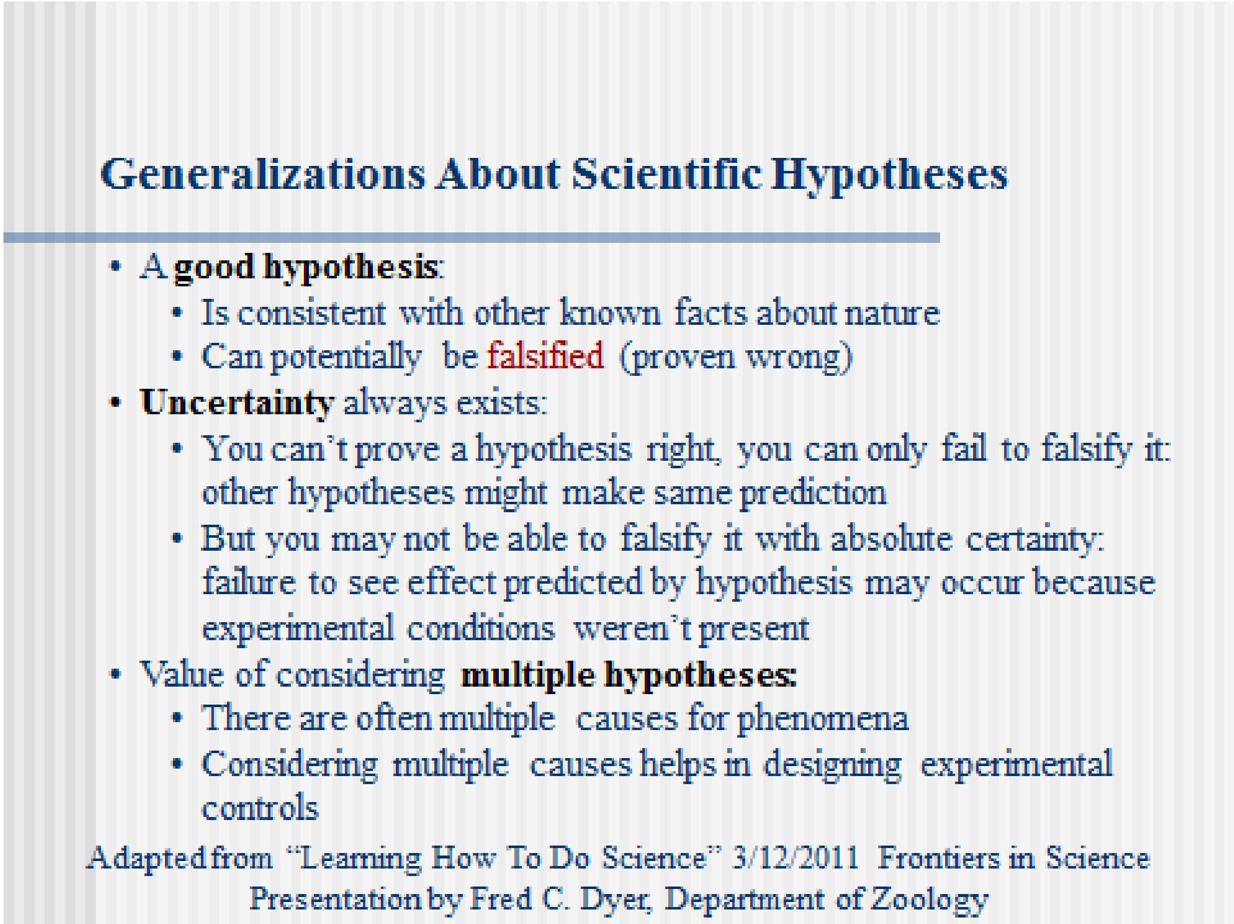


**Figure 18: Slide 8 – Process of Science Results Slide**

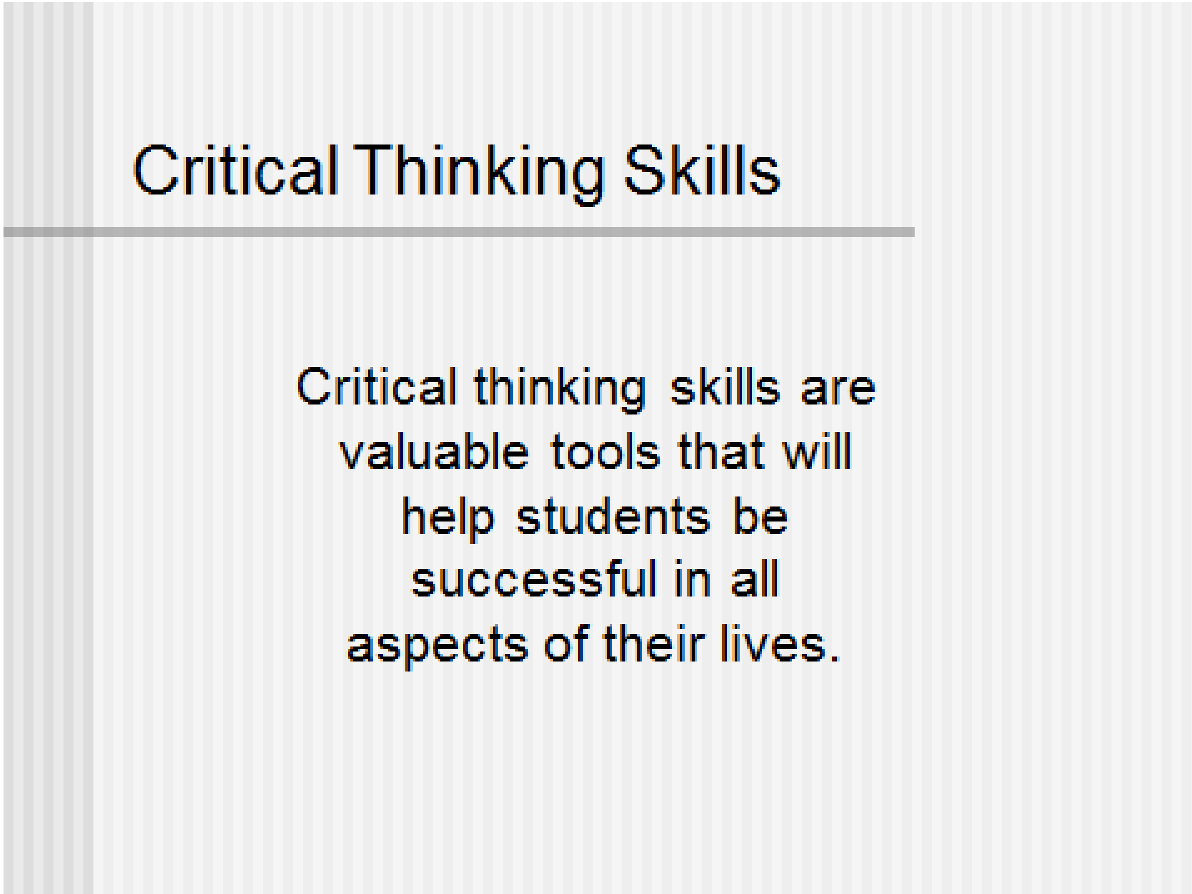


**Figure 19: Slide 9 – Process of Science Critical Thinking Skills Slide**

## APPENDIX – 2B
## VIDEO RESOURCES

ARKive Images off Life on Earth - http://www.arkive.org/
American Bittern video - http://www.arkive.org/american-bittern/botaurus-lentiginosus/

Microcosmos
Microcosmos is 1996 a documentary film by Claude Nuridsany and Marie Pérennou produced by Jacques Perrin. This film is primarily a record of detailed insect interactions set to the music of Bruno Coulais. Rated G.
Top Documentary Films - http://topdocumentaryfilms.com/microcosmos/

APPENDIX – 2C
CHAPTER 1 - A VIEW OF LIFE - NOTES

Big picture → the structure /interactions of life.
Critical thinking – process of science

Biology →the scientific study of life
Organism → any living thing
* Living organisms at the most basic level are chemical systems.
**DEMO: living or non-living**
**Brainstorm to determine characteristics of life.**

**Characteristics of life (6)**
1)**All living things are Organized**
Atom →molceule→organell→cell→ tissue→organ→organ system→Organism.

Atom → tiny particles that make up all matter
Molecule → atoms bonded together
Organelles→structure of a cell that perform specific functions.
Cell→Basic unit of structure and function in all living things
Tissue→group of similar cells that perform the same function
Organ→components of a system
Organ system→ digestive, circulatory…
Organism→an individual living thing

2)**All living things require Energy** → the capacity to do work. It takes work to maintain the organization of cells and organisms
The sun is the primary source of energy for almost all living things on earth
Metabolism→ encompasses all the chemical reactions that take place in a cell
Plants have a unique ability….
Photosynthesis→ is the process that transforms light energy into the chemical energy of food.
Animals and plants get energy by metabolizing nutrient molecules made through photosynthesis.
Stable temperature, moisture, acidity and other internal conditions are needed for metabolic process
Homeostasis→is maintaining internal conditions within certain boundaries.
Some organisms consciously regulate internal conditions…snake sunning, while others require on thought, breathing…

3)**Living things respond** → all living things respond to changes in their environment.
Birds migrating, leaves turning to the sun, movement when startled…

4) **living things reproduce**→ life comes only from life…all organisms are driven by the need to propagate the species→ a group of interbreeding individuals. All organisms have genes→ DNA (deoxyribonucleic acid) molecules. Genes are different for different species and provide the

instructions for the organism and its metabolic processes. All cells of an organism contain the same set of genes, but only certain genes are turned on based on the cells function.

5**)All living things develop**→ grow or advance through stages over time.

6) **all living things adapt**→ modifications that help an organism survive.
Natural selection→ process where modifications /adaptations are selected for over time… example over time rabbits moved north into snow country…then a mutation…a rabbit whose fur turns white in the winter. More of its offspring with the mutation survive and of course it survives longer, breeds more. Natural selection. (mutations occur in all species if it helps survival it becomes an adaptation).
Evolution→ decent with modification. As environmental conditions changed groups of species changed to survive. When the change adaptation was enough that the "species" could not breed outside its group a new species had formed.

Organization of the Biosphere→ the area of air land and water on the earth's surface where organism are found.
organism→population→community→ecosystem→biosphere
Population→groups of interacting individuals of the same species.
Community→all organisms within an area.
Ecosystem→all living and nonliving that effect an organism.
Give me an example please *weather, water, soil, air, sunlight, insects…*
Ecosystems depend on two main processes
Nutrient Cycles
Energy flow, sun-> producers (plants) ->consumers (herbivores) ->consumers (carnivores) ->decomposers
nutrients are recycled and return to the earth but energy flow is one way. Without the continuous input from the sun life would end. Producers→ convert sun energy into food energy, produce energy. Consumers→ eat other organisms for energy. Decomposers→ break down organic mater into units used by producers
Climate dictates where different ecosystems are found, grasslands, forest, deserts…
Humans have modified ecosystems for years, destroying and degrading valuable ecosystems…coral
It's important to remember ecosystems ensure environmental conditions are suitable for humans

Why taxonomy?
over 30 million species organization becomes important.
Common names are not universal.
How is it done?
Biologist group like species together in small groups, squirrels, butterflies… and those small groups into larger groups. Taxonomy→ the branch of biology that names and classifies species
Smallest too largest group.
Species→genus→family→order→class→phylum→kingdom→domain.
Three Domains of Life
Domain Bacteria→Prokaryotic cells, No kingdoms
Domain Archaea→Prokaryotic cells, No kingdoms, extremes

Domain Eukarya→Eukaryotic cells, 4 kingdoms
Kingdom Protista→ multicellular or unicellular
Kingdom Plantae→multicellular, autotrophs →producers
Kingdom Fungi→ multicellular, decomposers
Kingdom Animalia→ Multicellular, hetertrophs→ consumer
Binomial name→ two part scientific name (genus, species) based on latin
Classifying organisms helps to keep track of Biodiversity→ total number of species including the variety of genes within each species. Estimations place number of species at about 15 million but under 2 million have been identified, named and classified.

Extinction→ death of a species or larger taxonomic group. Preserving ecosystems is an important bioethical issue of our time. Preserving ecosystems preserves biodiversity and likely the human species.

biologists seek natural causes for natural phenomena.
Scientific Method (LAB)→ A formal process of inquiry consisting of a series of steps.
Observations are made and questions arise based on observation and collected knowledge
Hypothesis → tentative answer to the question
Experiment designed to test hypothesis, more observations and data is collected
Conclusion based on analyzed data supporting the data or not…leads to another hypothesis or to a scientific theory→ an explanation of the natural world that is supported by many experiments and observations
Principle or law→ a theory that is widely accepted by an overwhelming number of scientists.

The Culture of Science→ cooperation and competition

- Scientists are skeptics. Not Just the facts!!
- Depends on observations and measurements
- Requires that ideas (hypothesis) are testable

Science and society
As advances are made in science it is society's job to help determine if and when they should be used.

- PBC and the American Bald Eagle
- Antibiotics
- Antibacterial soaps… kill more good than bad.
- Bioengineered organisms…food?
- Gene therapy

APPENDIX – 2D

CHAPTER 2 – THE CHEMICAL BASIS OF LIFE - NOTES

Big picture→ how life survives/functions as we know it

Element→ a substance that cannot be broken down into another substance by ordinary chemical means. Information about elements is organized in the periodic table.

Atomic symbol→ one or two letters representing a particular element

Mass number/ atomic mass→ based on the total number of subatomic particles.

Protons→ positive charge in nucleus

Neutrons→ no charge in nucleus

electrons → negative charge orbiting the nucleus (little mass)

atomic number→ the number of protons in an element.

Isotopes→ atoms of an elements with different number of neutrons making the atoms unstable.

Unstable isotopes→ isotopes with excess neutron decay releasing radiation.

Radioactive Isotopes releasing positrons are injected into the body then detected using various scanners. They are extremely valuable to the medical field. They potential is also there to use radiation to kill biological organisms in the mail…on our food…

However they can also do damage to organisms, DNA and cause cancer…

Chernobyl Nuke plant Natural sources like radon can also cause harm.

Octet /duet rule→ first electron shell only two electron, all others 8electrons to be stable. Core electrons→inner shells, not reactive. Valence electrons→outer shell involved in chemical reactions…atoms react to become stable. Duet or octet.

CHNOPS→ basic elements of life, make up 96% of the weight of the human body and most other living matter.

Trace elements→Very small amount found in living matter, but can not live without.

Compounds→matter containing two or more elements, NaCl, $H_2O$, DNA

Electrons determine how atoms behave…

Chemical bonds→strong attractions that hold atoms together.

Ionic bond→ transfer of electrons resulting in an attraction between two or more ions of opposite charge. NaCl Ionic Bonds result in a neutral molecule.

Ions→atoms, molecules that have gained or lost electrons

The periodic table indicates what type of ion an atom will form.

Covalent bond→ sharing of electrons to fill valence shell, become stable.

Number of bonds = number of electrons needed to fill valence

Covalent molecules can form single, double and triple bonds.

Chemical reation→breaking / making of bonds. *Can not create or destroy matter.

Reactants → Products $2H_2 + O_2 \rightarrow 2\,H_2O$

Reaction for photosynthesis $6\,CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Life on Earth began in water.

Water makes up 70 -90% of all living things.

Abundance of water is the major reason Earth can support life.

Electronegativity → unequl sharing of electrons in polar molecules

$H_2O$ is polar covalent →meaning one end (H) has partial + charge and the other (O) partial – charge. Causes a bent ‘V’ structure.

Hydrogen bonds→ the attraction between the partial + and partial – sections of water
Characteristics of water due to H-bonds
**DEMOS: surface tension penny, cohesion plastic plates.**
water is a solvent→ dissolves many substances

Hydrophilic→ water love, substances attracted to water

Hydrophobic→water fear, substance not attracted to water

Cohesive → water sticks together, allows water to be moved up trees and other tall plants.
Adhesion→water is attracted to other polar substances
Surface tension→unusually high, harder to break through surface than most liquids.
high heat capacity→ takes more energy to change temperature of water. When heated energy is needed to first break the H-bonds then molecules can begin to move. As it cools H-bonds reform releasing heat, keeps our nights warmer. Enables organisms to maintain stable body temp and survive rapid temperature changes.
Less dense as a solid→ ice floats insulating bodies of water making it possible for life to survive in water.
Biological significance of ice floating → water molecules move apart when they freeze the opposite of other liquids. So what???!! Ice insulates bodies don't all freeze solid allowing life to survive below the surface.
Acids (high H+) and bases (low H+) have the potential to damage living cells. Hydrogen is very reactive.
Acid characteristics → sour taste,
Base (alkali) characteristics→ bitter taste (often poisonous), feel slippery
pH scale → logarithmic scale used to describe the acidity level of $H^+$ in a liquid substance. Each change in pH indicates a change of ten times

Ions are not formed in solids need to liquid.

Living organisms generally require a pH of 7 or neutral, even slight changes can be critical for the proper functioning of molecules.
Buffers→substances that resist changes in pH, vital for life – Blood contains carbonic acid and bicarbonate ions (weak acid and its conjugate base)

Big Picture review

APPENDIX – 2E
17 – THE FIRST FORMS OF LIFE - NOTES

Viruses → Genes in Packages either DNA or RNA within a capsid
Viruses do not meet all the characteristics of life. They are obligate intracellular parasites only able to reproduce inside a living cell
They attack, injecting its DNA or RNA into the cell and uses the cells resources to reproduces viral DNA/RNA until it bursts open releasing viral DNA / RNA.
or it attaches to the cells existing DNA, and is reproduced along with the cells DNA for cell reproduction.
A trigger will eventually cause the viral DNA to separate and reproduce until the cell bursts.
Viruses can reproduce in the cytoplasm or in the nucleus.
Bacteriophage → a virus that reproduces in a bacteria
Viruses can carry DNA or RNA
Some RNA viruses are retroviruses→reverse of normal genetic flow. They produce DNA from RNA!!
Most plants viruses are RNA.
Plant viruses easily spread through the plasmodesmata→tubes connecting cells.
Genetic engineers have designed and are working to engineer transgenic plants that are virus resistant.
Animal viruses are either DNA or RNA.
RNA viruses are colds, measles, mumps…
DNA viruses are hepatitis, chicken pox, and herpes infections.
Viruses do not respond to antibiotics. Vaccines have been designed and are being designed to prevent viruses.
Viruses mutate quickly because they interact with cell DNA and because they reproduce in great numbers, mutations occur often changing basic virus (cold) so much that it is new to our body.
New viruses are emerging regularly. Or mutating to jump species
Hantavirus→deer mice boom in population, jumped to humans 1993.
SARS→cold virus gone wild 2003
Ebola virus→outbreaks in Africa, 1995 started with monkeys
Avian flu→bird flu has jumped to humans, china, turkey 2004

Viroids → RNA not enclosed in a capsid
Prionas→ proteinaceous infectiouos particles, rogue proteins smaller than a virus, somehow they can turn other proteins to the "dark side" research is on going to find the mechanism

Prokaryotes → very simple cells, no nucleus or membrane bound organells but have greater metabolic capacity than more complex organisms. Some can survive without air or organic matter. There are two types; bacteria and archaea
Bacteria most diverse and prevalent
They have a nucleoid containing a single loop of DNA, a peptidoglycan cell wall to prevent it from bursting or collapsing due to changes in osmotic pressure, and many have flagella to move
Reproduction is through binary fission → splitting of the cell without, mitosis, spindle fibers.
Genetic recombination has three routes in bacteria,

conjugation →among closely related species a donor cells passes DNA to a recipient cell through tubes called sex pili.
Transformation → a bacteria picks up free pieces of DNA from their surrounding environment which have been secreted by live or released by dead prokaryotes
Transduction → bacteriophages carry pieces of bacterial DNA from one cell to another
Bacteria can develop resistance to antibiotics by any of the above means.
Some bacteria can form endospores → a copy of DNA and some cytoplasm encased by three heavy, protective spore coats, when environmental condition are not favorable for survival

Bacteria are either photosynthetic or chemoautotrophes
Photosynthetic bacteria can either split water, releasing O (higher energy) or H2S, releasing S (lower energy). Most are chemoautotrophes (heterotropes) obtaining energy from organic nutrients but unlike animals bacteria are saprotrophes, digest there "food" outside their body

Bacteria are either free living or symbiotic forming one of three types of relationships
mutualistic → benefiting both partners, live in human intestines
commensalistic → benefiting one partner and NOT harming the other, generally one alters the environment in such away that the other benefits
parasitic → benefiting one partner and harming the other, cause diseases

bacteria are the planets recyclers – without them life would stop
used to breakdown sewage, oil, dangerous chemicals
used to produce foods; fermentation, cheese, vitamins, insulin, vaccines

bacteria that cause diseases are called → pathogens.
Pathogens can …
all produce a toxin
some adhere to surfaces
sometimes invade organisms or cells
Antibiotic are used to combat bacterial infections but it also increases bacterial resistance to antibiotics. When penicillin was first used against the bacteria that causes staph infections about 3% were resistant now 90% or more are resistant.

Archaea
eukarya are more closely linked biochemically to archaea than bacteria (ribosome proteins)
Archaea live in extreme environments, hot springs, salt lakes, swamps…
Most have some sort of cell wall, they may form mutualistic or commensalistic relationships but are not parasites.

Protists live in the oceans and other watery environments. They exist in great diversity.
Tradionally Algae → aquatic photosynthesizer
Protozoan → unicellular chemoheterotrop, free living or parasitic
Either ingest food like amoeba or like fungi (saprotrophic)

# APPENDIX 3

## STUDENT ASSIGNMENTS AND ACTIVITIES

# APPENDIX – 3A
# PROCESS OF SCIENCE GUIDE

Description of the activity:

Write at least three questions based on things you noticed during the activity:

Choose one question (yours or your lab partners), record the question below:

Write hypotheses based on the above question:

Circle one hypothesis from above.

Write a prediction for the hypothesis.

List the variables that would need to be controlled in a potential experiment.
(Don't worry about how).

Appropriately represent hypothetical data for the prediction if your hypothesis is
a) Supported
b) Refuted
c) Inconclusive

APPENDIX - 3B

PROCESS OF SCIENCE (SCIENTIFIC METHOD) – SEED VARIATION

## Background Information

The process of science involves the critical evaluation of ideas and information. Scientists are aware that information must be valid and reliable. In order to be valid and reliable it must repeatedly be shown to be true. Most scientists use a form of the scientific method to evaluate ideas and information. The scientific method includes **observation, questions, hypothesis (statements), predictions (includes hypothetical data), tests (experiments), evaluation,** and **conclusion.**

Scientists use a variety of tools to make quantitative and qualitative observations. Quantitative observations are recorded using the international system of units (**SI** from French: *Système international d'unités*). Observations lead to questions that are used to develop the hypotheses. One hypothesis is selected for testing. It is a statement that answers a question or an explanation and arises from the observation. A hypothesis is not a fact. It is meant to be challenged, tested and refined as the results of experimentation.

Scientists make predictions based on their hypothesis and consider what the data might look like if it supports or refutes the hypothesis. Scientists must also consider what the data might look like if it is inconclusive; neither supports nor refutes the original hypothesis. Thinking about alternative hypotheses and hypothetical data help scientists determine the variables to be controlled.

Once a hypothesis has been tested it is either supported by the new information or found invalid. If not valid the hypothesis can be revised or discarded. It is important to understand that if the hypothesis is invalid the initial explanation for the original observation may still be reasonable. When a hypothesis is considered valid the experiment is repeatable by other scientists. If the experiment is not repeatable the hypothesis is invalid.

## Materials

150 pea or corn seeds
Paper towels
Trays
Radish seeds
5 Pots with soil
Plant food
Process of Science Guide

## Experimental Procedure

1. Record the mass of about 150 pea or corn seeds in an excel spreadsheet and graph as a column graph in excel.
2. Complete the Process of Science Guide.
3. Choose a hypothesis to test and design the experiment.

## Prep for Characteristics of Life and Basic Chemistry

4. Plant 5 radish seeds in each of 5 pots, cover with only a thin layer of soil.
5. Water each pot with plant food and place in the tray under the lights.
6. Check plants on Thursday. Record observations, water if needed.

**You will be deciding and designing the lab you will do during the Plant Lab. You will need to have the write up approved by the instructor no later than the Thursday Prior.

APPENDIX – 3C
1- A VIEW OF LIFE

Biology →
Organism →

* Living organisms at the most basic level are chemical systems.

Organization
Atom →molecule→organelle→cell→ tissue→organ→organ system→ organism→population→community→ecosystem→biosphere.

Atom →
Molecule →
Organelles→
Cell→
Tissue→
Organ→
Organ system →

1)All living things require Energy →

The sun is the primary source of energy for almost all living things on earth
Metabolism→

Photosynthesis→

Homeostasis→

2)Living things respond →

3) living things reproduce→

species→ .
All organisms have genes→

4)All living things develop→

5) all living things have adaptations→
Natural selection→

Evolution→

Organization of the Biosphere→

Population→
Community→
Ecosystem→

Ecosystems depend on two main processes

Producers→
Consumers→
Decomposers→
Climate

With over 30 million species organization becomes important. Biologist group like species together in small groups, squirrels, butterflies… and those small groups into larger groups.
Taxonomy→

Smallest too largest group.

Specie→genus→family→order→class→phylum→kingdom→domain.

Three Domains of Life
Domain Bacteria→
Domain Archaea→
Domain Eukarya→
Kingdom Protista→
Kingdom Plantae→
Kingdom Fungi→
Kingdom Animalia→
Binomial name→

Biodiversity→

Extinction→

Biologists seek natural causes for natural phenomena.
Scientific Method →

Hypothesis →
Experiment →

scientific theory→

Principle or law→

The Culture of Science→

Science and society
As advances are made in science it is societies job to help determine weather they should be used.

APPENDIX – 3D

2 – THE CHEMICAL BASIS OF LIFE

Big picture→

Matter→
Element→

Atom →
Atomic symbol→
Protons→
Neutrons →
electrons →
atomic number→

Octet /duet rule→

Core electrons→
Valence electrons→

Isotopes→

Unstable isotopes→

CHONPS→

Trace elements→
Compounds→

Electrons determine how atoms behave…

Chemical bonds→

Chemical reaction→

Reactants → Products $2H_2 + O_2 \rightarrow 2\,H_2O$

Reaction for photosynthesis $6\ CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$
Life on Earth began in water.
Water makes up 70 -90% of all living things.
Abundance of water is the major reason Earth can support life.

Electronegativity →

$H_2O$ is polar covalent →

Hydrogen bonds→

Characteristics of water due to H-bonds
water is a solvent→
Hydrophilic→
Hydrophobic→
Cohesive →

Adhesion→

Surface tension→

high heat capacity→

Less dense as a solid→

Heat→
Temperature→
Evaporative cooling→

Biological significance of ice floating →

Solution→
Solvent→
Solute→
8. water is amphoteric→
Acids and bases have the potential to damage living cells.
Acid characteristics →

Base (alkali) characteristics

pH scale →

.
Buffers→

Earth Before life

The Earths early chemistry made life possible.  And that life once it began changed the chemistry of the Earth.

H2O, CO, CO2, N2, CH4 and NH3

Water cooled earth and pooled

Abundant water and $CO_2$ needed for photosynthetic organisms

Produced $O_2$

APPENDIX – 3E
CHARACTERISTICS OF LIFE WITH PLANTS

**Background information: Characteristics of life**
1) **All living things are organized**
atom →molecule→organelle→cell→ tissue→organ→organ system→organism.

2) **All living things require Energy.**
It takes energy to maintain the organization of cells and organisms. The sun is the primary source of energy for living things on earth. Plants have a unique ability to do photosynthesis, the process that transforms light energy into the chemical energy of food. Animals and plants convert stored energy into usable energy by metabolizing nutrient molecules made through photosynthesis. Stable temperature, moisture, acidity and other internal conditions are needed for metabolic process. Homeostasis is maintaining internal conditions within certain boundaries. Some organisms consciously regulate internal conditions…snake sunning, while others require no thought, breathing…

3) **All Living things respond to stimuli**
All living things respond to changes in their environment; Birds migrating, leaves turning towards the sun, animals move when startled…

4) **All Living things reproduce**
Life comes only from life…all organisms are driven by the need to propagate the species, ensure the survival of THEIR genetic information. All organisms have genetic information, DNA (deoxyribonucleic acid) molecules unique to their species. Genes provide the instructions for the development of an organism and its metabolic processes.

5**) All living things grow and develop**
Living things grow or advance through stages over time until death.

6) A**ll living things adapt**
Populations of living things have variations that can help or hinder an organisms change of surviving as environmental conditions change.
Natural selection is a mechanism for evolution. The process where modifications /adaptations are selected for repeatedly over time… example over time rabbits moved north into snow country…then a mutation…a rabbit whose fur turns white in the winter. More of its offspring with the mutation survive and of course it survives longer, breeds more (mutations occur in all species if it helps survival it may become an adaptation).

**Materials:**
Pea seeds
Fast seeds
Fast Radish plants from last week
Clamp Lamp and colored bulbs or
Decorative cellophane wrap
Process of Science Guide
Black paper
Black plastic bag

**Experimental Procedure:**

1. Place about 20 each of pea and fast seeds on wet paper towels in a dish. Cover with more wet paper towels and plastic wrap. Check seeds on Thursday.
2. Complete the Process of Science Guide focusing on energy a plant receives
3. Design an experiment that interferes with the energy a plant receives.

**Future Testing**

4. Complete the Process of Science Guide writing questions that address one of the Characteristics of life. Using observations made of the fast planted last week.
5. Choose one of the hypotheses and design an experiment.

**Prep for Plant lab**

6. Plant 10 seeds in each of five pots, cover with only a thin layer of soil.
7. Water each pot with plant food and place in the tray.
8. Check plants on Thursday. Record observations, water if needed.

APPENDIX – 3F
BASIC CHEMISTRY AND PH WITH PLANTS

**Background Information:**

In chemistry we learn that many chemicals are acids or bases. An acid is a substance that releases hydrogen ions ($H^+$) while a base accepts or bonds to hydrogen ions. Ions are atoms that have either lost or gained electrons. A hydrogen atom has one proton and one electron while the hydrogen ion has lost its electron.

The pH scale is used to measure hydrogen ion concentration. A concentration of $1 \times 10^{-2}$ M (0.01) gives a pH of 2; $1 \times 10^{-7}$ (0.0000001) gives a pH of 7.

The pH scale goes from 1 to 14 with 1 being the most acidic and 14 the most basic. In actuality, a pH of less than one or greater than fourteen is possible, but rarely attained. The middle of the scale, pH 7.0 is considered as **neutral.**

**Materials:**

pH (pHydrion) paper
Distilled water
Base – Bleach, Baking Soda
Vinegar (pH 2)
Other pollutant (salt)
Short Test Tubes w/ rack
Pots with fast plants
Pipettes
Process of Science Guide

**Experimental Procedure:**

9. Complete the Process of Science Guide writing questions that addressing the impact pollutants have on plants.
10. Design an experimental procedure to test the impact of pollutants on plants.

**Prep for Basic Plant lab**

11. Plant 10 fast seeds in each pot of five pots, cover with only a thin layer of soil.
12. Water each pot with plant food and place in the tray.
13. Check plants on Thursday. Record observations, water if needed.

APPENDIX – 3G

I WONDER IF …?

Think about a situation in your life when you wondered why something happened.
Example:
Why is that car in front of me going only 45 when the speed limit is 55!!!
I wonder if it's an elderly person?
I wonder if it's some trying to conserve fuel?
I wonder if it's someone not paying attention?

Write three (or more) I Wonder If … statements.

I wonder if …

I wonder if…

I wonder if…

APPENDIX – 3H
DESIGN A LAB

Topic: Plants

1. Brainstorming: The instructor will make a list on the whiteboard of questions students had recorded during the previous plant labs.
2. The instructor will remove any questions that do not fit with the supplies and time available.
3. Students take a couple minutes to consider the top two questions they like to address in lab.
4. Students choose the question they would like to work on, limited by the size of the group which the instructor will determine based on the question.
5. After groups are determined, students will work with their group to design hypothesis, design an experiment to test their hypothesis and predict the results if their hypothesis is supported using the Process of Science Guide.
6. After the instructor has approved the lab students will begin their lab experiment.

APPENDIX – 3I
17 – THE FIRST FORMS OF LIFE

Viruses →

Bacteriophage →

retroviruses→

plasmodesmata→

Hantavirus→
SARS→
Ebola virus→
Avian flu→

Viroids →

Prionas→

Prokaryotes →

Reproduction is through binary fission →

conjugation →

Transformation →

Transduction →

Some bacteria can form endospores →

Bacteria are either photosynthetic or chemoautotrophes

mutualistic →

commensalistic →

parasitic →
bacteria that cause diseases are called → pathogens.
Pathogens can …

Antibiotic are used to combat bacterial infections but it also increases bacterial resistance to antibiotics. When penicillin was first used against the bacteria that causes staph infections about 3% were resistant now 90% or more are resistant.

Archaea

Protists live in the oceans and other watery environments. They exist in great diversity.
Tradionally Algae →

Protozoan →

APPENDIX – 3J
DESIGN A LAB

Topic: Bacteria

1. Brainstorming: The instructor will make a list on the whiteboard of questions students had about bacteria.
2. The instructor will remove any questions that do not fit with the supplies and time available.
3. Students take a couple of minutes to consider the top two questions they like to address in lab.
4. Students choose the question they would like to work on, limited by the size of the group which the instructor will determine based on the question.
5. After groups are determined, students will work with their group to develop their hypothesis, design an experiment to test their hypothesis and predict the results if their hypothesis is supported using the Process of Science Guide.
6. After the instructor has approved the lab students will begin their lab experiment.

# APPENDIX 4

# ASSESSMENT TOOLS

APPENDIX – 4A
PRE/POSTTEST – PROCESS OF SCIENCE

After watching the video, complete the following.

1) Write at least three questions based on observations from the video clip. (4)

2) Choose one of your questions, circle it then write **hypotheses** addressing that question. (3)

3) Choose one hypothesis from above, circle it, and write the prediction.(2)

4) Graph hypothetical data for your prediction if it is supported. (4)
5) Explain your reasoning. (3)

6) Graph hypothetical data for your prediction if it is refuted. (4)
7) Explain your reasoning. (3)

8) Graph hypothetical data for your prediction if it is inconclusive. (4)
9) Explain your reasoning. (3)

APPENDIX – 4B
PRE /POSTTEST – SCIENCE METHOD
SCORING RUBRIC

After watching the video, complete the following.

1) Write at least three questions based on observations from the video clip. (4)
    One point for each question connected to the video.

2) Choose one of your questions, circle it then write **hypotheses** addressing that question. (3)
    One point for each hypothesis written as an answer to the selected question

3) Choose one hypothesis, circle it, and write the prediction.(2)
    Two point for a prediction that addresses the hypothesis.

4) Graph hypothetical data for your prediction if it is supported. (4)
    One point – title for graph
    One point for each axis labeled correctly
    One point for line, bar, in the graph
5) Explain your reasoning. (3)

6) Graph hypothetical data for your prediction if it is refuted. (4)
    One point – title for graph
    One point for each axis labeled correctly
    One point for line, bar, in the graph
7) Explain your reasoning. (3)

8) Graph hypothetical data for your prediction if it is inconclusive. (4)
    One point – title for graph
    One point for each axis labeled correctly
    One point for line, bar, in the graph
9) Explain your reasoning. (3)

APPENDIX – 4C

LABORATORY REPORTING RUBRIC

(Attach to each Pre/Post Lab Report)

| | Possible Points | Earned Points |
|---|---|---|
| **Pre Laboratory Report** – Initialed day of Lab<br>Keep and turn in with Post Lab Report | **10** | |
| Purpose (What you are supposed to learn) | 3 | |
| Hypothesis | 2 | |
| Special attention to …. | 2 | |
| Experiment – Steps or an explanation of how you will do the lab. | 3 | |
| **Post Laboratory Report -** Turn in one week after Lab is completed. | **18** | |
| Results –<br>Quantitative observations (measurements)<br>-Table with data organized.<br>-Graph of results (if needed).<br>Qualitative observations (detailed descriptions)<br>-What you observed | 5 | |
| Analysis – Written description of your results may be included with your conclusion. | 5 | |
| Conclusion - Explain what you learned.<br>Did the results support your hypothesis? Why or why not?<br>How did the experiment and data support the purpose? | 8 | |

**Table 4: Laboratory Reporting Rubric – Rubric available to students and used to score lab reports**

APPENDIX – 4D
PROCESS OF SCIENCE RUBRIC

| | Possible Points | Earned Points |
|---|---|---|
| **Process of Science Guide** | **25** | |
| Description of the activity | 2 | |
| Questions relating to the Lab - Selected question indicated | 2 | |
| Hypotheses based on the question - Selected Hypothesis indicated. | 2 | |
| Prediction | 2 | |
| Variables to control | 2 | |
| Hypothetical Data Supporting data – explained | 5 | |
| Hypothetical Data refuting data – explained | 5 | |
| Hypothetical Data inconclusive - explained | 5 | |

**Table 5: Process of Science Guide – Rubric available to students and used to score *Process of Science guides***

REFERENCES

## REFERENCES

Abell, S. K., & Lederman, N. G. (2007). *Handbook of Research on Science Education*. Mahwah, NJ: Lawrence Erlbaum Associates.

American Association for the Advancement of Science. (1989). In *Science for all americans*. Retrieved February 6, 2012, from http://www.project2061.org/publications/sfaa/online/intro.htm

Barton, J., Heilker, P., & Rutkowski, D. (Retrieved 2012). *Fostering effective classroom discussion*. Retrieved March 30, 2012, from http://www.mhhe.com/socscience/english/tc/pt/discussion/discussion.htm

Bogiages, C. A., & Lotter, C. (2011, February). Modeling natural selection: Using model-based inquiry and wikis to learn about evolution. *The Science Teacher*, *78*(2), 34-40.

Bosse, M. J., Lee, T. D., Swinson, M., & Faulconer, J. (2010, May). The NCTM process standards and the five Es of science: Connecting math and science. *Sch Sci Math*, *110*(5), 262-276. Retrieved from Wilson Web.

Childre, A., Sands, J. R., & Pope, S. T. (2009, May). Backward design. *Teaching Exceptional Children*, *41*(5), 6-14. Retrieved from Wilson Web.

Cox-Petersen, A. M., & Olson, J. K. (2002). *Learning science and the science of learning chapter 10: Assessing student learning* (pp. 105-115). National Science Teachers Association.

D'Avanzo, C. (Nov 2003). Application of research on learning to college teaching: Ecological examples. *BioScience*, 53(11), 1121-1128

Dyer, Fred. "Learning How to Do Science." Michigan State University. East Lansing. 12 Mar. 2011. Lecture.

Hodson, D. (1998). Science Fiction: The continuing misrepresentation of science in the school curriculum. *Curriculum Studies*, *6*(2), 191-215.

Karsai, I., & Kampis, G. (2010). The crossroads between biology and mathematics: The scientific method as the basics of scientific literacy [Electronic version]. *BioScience, 60*(8), 632-638

Kinnaman, D E (Sept 1990). The next decade: What the future holds. *Technology & Learning*, 11, n1. (pp. 42-49)

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, Experiential and Inquiry-Based Teaching [Electronic version]. *Educational Psychologist*, *41*(2), 75-86.

Marshall, J C, & Horton, R M (March 2011). The relationship of teacher-facilitated, inquiry-based instruction to student higher-order thinking. *School Science and Mathematics*, 111, 3. (pp.93-101)

McComas, W. F. (1998). *The Nature of Science in Science Education Rationales and Strategies*. Dordrecht: Kluwer Academic.

McLoughlin, M P (Jan 7, 2009). Inquiry-Based learning: An educational reform based upon content-centered teaching. *ERIC: Reports*, p.NA. Retrieved April 26, 2011

Michaels, S., Shouse, A. W., & Schweingruber, H. A. (2008). *Ready, set, science!* (pp. 1-6). Washignton, DC: The National Academies Press

Musaante, S. (2005, October). Learning the Nature of Science. *Bioscience*, *55*(10), 833. Retrieved from ProQuest (913475291).

National Research Council. (2012). *A framework for k-12 science education: Practives, crosscutting concepts, and core ideas* (pp. 41-82). Washington, DC: National Academies Press. Retrieved March 28, 2012

National Research Council. (1996). *National Science Education Standards.* Washington, DC. National Academy Press.

Rutledge, M. L. (2005, August). Making the nature of science relevant: Effectiveness of an activity that stresses critical thinking skills. *The American Biology Teacher*, *67*(6), 329-333.

Shwartz, Y., Weizman, A., Fortus, D., Sutherland, L., Merrit, J., & Krajcik, J. (Summer 2009). Talking science: classroom discussions and their role in inquiry-based learning environments. *The Science Teacher,* 76, 5. p.44

Stiggins, R. J., Arter, J. A., Chappuis, J., & Chappuis, S. (2006). *Classroom assessment for student learning*. Portland, OR: Educational Testing Service

Tobias, S. (1990). *They're not dumb, they're different*. Ann Arbor, MI: Research Corporation.

Tanner, K., & Allen, D. (2004, Summer). Approaches to biology teaching and learning: From assays to assessments - on collecting evidence in science teaching. *Cell Biology Education*, *3*, 69-74. Retrieved from PubMed Central (PMC437645).

Understanding Science. 2012. University of California Museum of Paleontology. 3 January 2012 http://www.understandingscience.org>.

Wiggins, G., & McTighe, J. (2001). *Understanding by design* (pp.7-17). Upper Saddle River, NJ: Merrill Prentice Hall.