EFFECTS OF INQUIRY-BASED INSTRUCTION IN AN ENVIRONMENTALLY FOCUSED AGRISCIENCE CURRICULUM ON STUDENTS’ CONTENT KNOWLEDGE ACHIEVEMENT, CRITICAL THINKING ABILITY, AND ENVIRONMENTAL ATTITUDE

By

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To those who teach to make a difference
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member. Her expertise in inquiry and science instruction brought forth a needed perspective toward my research.

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The purpose of this study was to determine the effects of inquiry-based instruction (IBI) on students’ content knowledge achievement, critical thinking ability, and environmental attitude. The use of IBI was compared to direct instruction (DI) during an eight-week, environmentally focused agriscience curriculum. The population for this study was all high school students enrolled in agriscience courses in the United States. The accessible population was students enrolled in the CASE® Natural Resources and Ecology course and whose teachers completed the CASE® Institute for Natural Resource and Ecology certification between the years 2013 and 2017. This study was quasi-experimental and used a nonequivalent control group, pretest-posttest design.

A convenient sample of 13 teachers was collected. Each teacher was randomly assigned to deliver a set of lesson plans that utilized either an IBI or DI approach. A total of 16 lesson plans were designed for each treatment. Lesson plans were grouped into four modules, each lasting approximately two weeks. Prior to the delivery of the treatment, teachers administered pretests on critical thinking, using the
Critical Thinking in Environmental Education Instrument, and on environment attitudes, using the Environmental Attitude Inventory. Posttests using each instrument were administered after the eight-week treatment.

ANCOVA statistical procedures were used to compare the effects of IBI and DI. Results of the ANCOVA indicated that IBI and DI are equally effective on students’ content knowledge achievement, critical thinking ability, and environmental attitude.
CHAPTER 1
INTRODUCTION

The global landscape has been changing at a rapid rate, leading to many complex agricultural and environmental challenges (National Research Council [NRC], 2009). The role of agriculture in providing food, fiber, and natural resources to meet the demands of a growing global population of over 7.5 billion has become paramount. Emerging environmental change, degradation, and resource depletion, as well as increasing environmental regulation, have added unique challenges to the future of agriculture production (NRC, 2009). In a world facing increasingly complex agricultural and environmental challenges, individuals will need to be equipped with scientific knowledge, problem solving skills, and environmental sensitivity required to address them (Bright & Tarrant, 2002; Ernst & Monroe, 2006; Mc Tighe & Schollenberger, 1991; National Science Teachers Association [NSTA], 2003).

Science education has been vital in preparing a public that is scientifically literate and able to think critically to solve complex problems (NRC, 2012). Inquiry-based instruction (IBI) has been endorsed as a preferred teaching approach in science education to achieve this goal (Duschl, 2008; Forbes & Davis, 2008; Forbes & Zint, 2010; Hodson, 2003; Minner, Levy, & Century, 2010) but has lacked adequate empirical evidence regarding its effectiveness in public education over alternative methods (Cobern et al., 2010). This study investigated the use of IBI as a teaching method in an environmentally focused agriscience curriculum within school-based agricultural education (SBAE) and examined its influence on students' content knowledge achievement, critical thinking ability, and environmental attitude.
This chapter will describe agricultural and environmental issues that require a scientifically literate public that can think critically. It will also discuss trends in educational initiatives designed to increase student achievement in science. Furthermore, this chapter will examine trends in SBAE and agriscience instruction. Lastly, this chapter will explain the need for a preferred instructional approach in SBAE for teaching environmental concepts that encourage students to think critically and responsibly in order to solve complex agricultural and environmental issues.

**Agricultural and Environmental Issues**

In an increasingly urbanized world, agriculture production and the food supply have become deeply embedded within societal systems and have been impacted by complexities associated with wide spread income inequality, urban sprawl, shifts in consumer demands, and changing political landscapes (NRC, 2009). Despite declining trends in extreme poverty and hunger, around 795 million people remain undernourished (Food and Agriculture Organization [FAO], 2015). The elimination of poverty, hunger, and malnutrition has continued to be of global concern, as indicated in the United Nation’s post-2015 Sustainable Development Goals (United Nations, 2015). The rise of a globally connected society with numerous technological advancements has presented many opportunities for agriculture to meet the demands of a world food system that operates for the well-being of all people.

However, adding complexity to achieving this task, environmental issues, such as climate change, extreme weather patterns, and environmental degradation, have caused hardships in agricultural production and have been predicted to cause additional concern (United States Department of Agriculture [USDA], 2013).
Agricultural practices have also been identified as leading contributors to environmental degradation. According to the World Economic Forum (2010), agriculture contributes to 30% of global greenhouse gas emissions and 70% of worldwide water withdrawals, while also being a large factor in the depletion of soil fertility, species diversity, and water quality. As a result, the likelihood of additional agricultural regulations that aim to minimize environmental damage has increased (Aneja, Schlesinger, & Erisman, 2009).

The World Economic Forum’s (2010) new vision for agriculture report stated that “Agriculture can be a positive driver of food security, environmental sustainability and economic opportunity. It is the only sectorial investment that addresses these three pressing issues simultaneously. Each part ... is vital to the long-term viability and success of agriculture” (p. 12). The interrelationship of agriculture production, societal systems, and environmental issues has led to the need for future generations to be globally competent, possess 21st century skills, and to understand the multidisciplinary nature of agriculture (Roberts, Harder, & Brashears, 2016). Education, and in particular, applied education in the sciences, can serve as a contextual platform to expose students to think critically about multidisciplinary issues in agriculture and the environment.

Science Education and Inquiry-based Instruction

According to the NRC (2012), one of the principal goals of science education “has been to cultivate students’ scientific habits of mind, develop their capability to engage in scientific inquiry, and teach them how to reason in a scientific context” (p. 41). Science is a discipline centered in investigation, empirical techniques, and reliance on data. Therefore, science education should serve as a model for scientific inquiry,
while capturing the essence of discovery in the classroom and constructing new student knowledge (Cobern et al., 2010; Handelsman, Miller, & Pfund, 2007). The design of educational programs to best meet the goals of general and science education has evolved due to the pressures of increased student performance (Hanushek, Peterson, & Woessmann, 2010). Federal and state educational policy, along with local authority, has pursued the goal of meeting America’s need for college and career-ready students. Mass efforts to quantify students’ “college and career readiness” have led to increased school accountability through standardized testing, which has attempted to strengthen the lens of classroom and teacher accountability.

In the last decade, students have continuously underperformed in science achievement (National Assessment of Educational Progress Report, 2009; National Center for Education Statistics, 2015). In The National Assessment of Educational Progress Report (2004), student science achievement declined between 1996 and 2000. In the 2015 report of national and state results on science performance for fourth-, eighth-, and twelfth-grade students, The National Center for Education Statistics (2015) found no significant change in science achievement for twelfth-grade students in the last six years. The trend of student underperformance in science achievement has sparked measures of educational reform in science education (American Association for the Advancement of Science [AAAS], 1990; Duschl, 2008; NRC, 2000).

The NRC (2012) has called for the implementation of IBI approaches in science education. Through IBI approaches, students actively experience scientific inquiry to explore and form scientific knowledge. IBI has also become heavily emergent in state and national learning standards (Next Generation Science Standards [NGSS], 2013).
Although there have been multiple perspectives on what defines IBI in education (Llewellyn, 2002), IBI has been clearly viewed as a student-centered and teacher-guided approach to learning. IBI approaches commonly engage students in investigating real world problems, requiring students to reason, obtain information, derive principles, and apply them to possible solutions. Schunk (2012) described the learning outcomes of inquiry teaching as “formulating and testing hypotheses, differentiating necessary from sufficient conditions, making predictions, and determining when making predictions requires more information” (p. 268).

The promotion of IBI approaches has been evident in environmental education (EE). According to the North American Association for Environmental Education [NAAEE] (2000), EE seeks to foster student learning of environmental concepts through inquiry-based classroom practice. The ability of EE to bring authentic problems and natural educational experiences to students aligns with exploratory and IBI teaching approaches (Payne, 2006). In EE, students can conduct authentic scientific fieldwork that provides experiences to construct new and meaningful scientific knowledge (Dresner & Moldenke, 2002), while making the living and non-living world around them relevant (Hodge & Lear, 2011). Authentic and place-based scientific fieldwork using IBI approaches has contributed to an increase in student environmental awareness (Howley, Howley, Camper, & Perko, 2011). The use of IBI in science and environmental education has become a consistent theme in science education reform for over the past thirty years (NAAEE, 2000; NGSS, 2013; NRC, 1988; NRC, 2000, NRC, 2012). However, research has indicated that the amount of classroom teaching using IBI approaches has remained minimal in a majority of classrooms (Capps & Crawford,
2013; Cory & Zint, 2010). One of the leading challenges that has contributed to a lack of classroom implementation is teachers’ low confidence in their ability to teach through IBI (Forbes & Davis, 2008). Professional development programs with a focus in teaching through IBI have been shown to increase teachers’ confidence and classroom use of IBI (Ernst, 2009; Forbes & Zint, 2010; Haney, Wang, Keil, & Zoffel, 2007).

**Agricultural Education and Inquiry-based Instruction**

Integration of science, technology, engineering, and math (STEM) education into agricultural education has emerged as a consistent focus in SBAE (Roberts et al., 2016). In fact, priority three of the 2016-2020 American Association for Agricultural Education (AAAE) National Research Agenda (NRA) posed the question “What are effective models for STEM integration in school-based agricultural education curriculum?” (Roberts et al., 2016, p. 31).

The debate of what is to be taught in agricultural education curricula has continued to occur, as non-traditional agricultural education curricula have emerged to meet the needs of a changing student demographic, teacher demographic, and educational policy reform (Anderson, 2013; Brown & Kelsey, 2013). Research that investigates the effect of specific curricula on targeted student performance could provide empirical evidence that can guide important curricular decisions.

Research in agricultural education should not only critically analyze the curriculum that is taught, but should also investigate the effectiveness of the methods for how content is taught. As curriculum integration has continued to expand in agricultural education, new methods for teaching these concepts should be analyzed. The 2016-2020 AAAE NRA called for research in examining the effectiveness of instructional strategies that are currently not highly used in agricultural education but
that have served as effective strategies in other disciplines (Roberts et al., 2016).

According to the National Association of Science, the preferred method of teaching science education has shifted from traditional teaching approaches, such as direct instruction (DI), to approaches that favor active learning (NRC, 1996).

Agricultural education has been rooted in the work by John Dewey, an educational philosopher who claimed that students could benefit through the inductive process of observing the natural world and drawing conclusions from it (DeBoer, 2000). Active learning has been central to the vision of SBAE. The use of IBI as a form of active learning has gained attention in SBAE (Roberts, et al., 2016; Wells et al., 2015). Although limited in research, the use of IBI in SBAE can create relevant and problem-based learning environments that emphasize cognitive development, critical thinking, and intellectual growth in students (Parr & Edwards, 2004; Wells et al., 2015).

Statement of the Problem

Experimental research on the effectiveness of curriculum design and teaching methods in agricultural education has been vital to establishing a wide body of empirical evidence that can support best practices in SBAE (Thoron & Myers, 2011). In fact, the AAAE NRA proclaimed “utilizing research to draw a connection between the impacts of our academic programs and student preparedness and success is essential for survival and sustainability of agriculture ...” (Roberts et al., 2016, p. 32). According to Thoron and Myers (2011), a long-standing need has existed for research-based evidence focused on teaching methods and student learning within agriscience. For SBAE, the National Council for Agricultural Education (2015) proposed eight Agriculture, Food, and Natural Resource Career Clusters. Among them, the Environmental Service Systems and Natural Resource Systems (ENR) cluster has promoted the need for
environmentally focused education within SBAE. ENR courses have provided SBAE programs an excellent opportunity for the integration of core sciences into the agricultural curriculum (Nolin & Parr, 2013).

Although the need for ENR courses within SBAE has been documented (NCAE, 2015), empirical research that examined the use of specific instructional approaches in ENR, and within SBAE, was negligible at the time of this study. Learning outcomes of ENR courses should focus on factors that prepare students to understand and manage the complex agricultural and environmental challenges in the world today (NRC, 2009), as well as prepare students for careers in environmental and agricultural disciplines.

As agriculture has been responding to multiple demands and expectations from a variety of stakeholders, a concern for environmental degradation and resource sustainability has emerged (NRC, 2009). The agricultural industry has been centered in the discussion around environmental sustainability and protection. Agricultural education across all levels must share the responsibility to either provide viable solutions to these complex problems or educate and prepare the individuals who will.

ENR courses should provide students the content knowledge needed to master a basic understanding of science, agriculture, and the environment. Furthermore, ENR courses should focus on increasing students’ ability to think critically. Students’ critical thinking skills will be essential for managing the increasingly complex issues in a global society and in making informed decisions about environmental stewardship (Bright & Tarrant, 2002; Ernst & Monroe, 2006; NSTA, 2003). Lastly, as youth have become less connected to the natural world (Lou, 2005), ENR courses should provide students with meaningful educational experiences that establish environmental relevance,
environmental sensitivity, and positive attitudes toward environmental protection (Chawla & Cushing, 2007).

The problem that this study addressed was the need for effective teaching methods within SBAE ENR courses that equip students with the knowledge, skills, and environmental sensitivity to provide solutions to complex agricultural and environmental challenges of the 21st century.

**Purpose of the Study**

The purpose of this study was to determine the effects of IBI in an environmentally focused agriscience curriculum on students’ content knowledge achievement, critical thinking ability, and environmental attitude. The following objectives and hypotheses guided this study:

**Statement of Objectives**

1. Compare the content knowledge achievement of high school agriscience students taught using an IBI approach to a direct instruction (DI) approach.
2. Compare the critical thinking ability of high school agriscience students taught using an IBI approach to a DI approach.
3. Compare the environmental attitude of high school agriscience students taught using an IBI approach to a DI approach.
4. Examine the relationship between students’ content knowledge achievement, critical thinking ability, environmental attitude, and demographic makeup.

**Statement of Hypotheses**

The research questions that this study investigated are presented as null hypotheses. During statistical analysis, the following null hypotheses were tested using a .05 level of significance.

H_{01} There is no significant difference in students’ content knowledge achievement based upon the teaching method used.
Students taught using an IBI approach will have higher content knowledge achievement compared to students taught using a DI approach.

There is no significant difference in students’ critical thinking ability based upon the teaching method used.

Students taught using an IBI approach will have higher critical thinking ability compared to students taught using a DI approach.

There is no significant difference in students’ environmental attitude based upon the teaching method used.

Students taught using an IBI approach will have a more positive environmental attitude compared to students taught using a DI approach.

**Significance of the Study**

This study holds significance for secondary agriscience teachers seeking effective methods of instruction in an environmentally focused agriscience curriculum. The use of IBI approaches has been heavily supported in science education (NAAEE, 2000; NGSS, 2013; NRC, 2012) but has not been addressed in environmentally focused curricula within SBAE settings. Results of this study can provide agriscience teachers with guidelines on how IBI could impact student achievement in environmentally focused curricula. The integration of environmental, agricultural, and scientific concepts embedded within the curriculum of this study can help provide a bridge between environmental science and agriscience concepts.

This study can also provide justification for the use of IBI approaches for teachers outside of SBAE who teach environmental subjects. Furthermore, this study holds significance for teacher educators who instruct preservice teachers on effective teaching methods and curriculum development. As environmental issues have become more immersive in the agricultural industry (NRC, 2009), agriculture curricula will likely address environmental issues to better teach the multidisciplinary approach to real-
world, authentic-based problems. Teacher educators should be well positioned to provide preservice teachers with effective instructional approaches to teach students about environmental concepts. Teacher educators can also provide in-service training to practicing teachers on this topic.

Lastly, this study holds significance to stakeholders of agricultural and environmental education. In an era of data-driven performance where classrooms and teachers must demonstrate educational merit, agricultural education programs must be well positioned to justify their worth by measurable student achievement. Teaching methods used within SBAE that are shown to increase students’ critical thinking ability and content knowledge achievement can provide empirical evidence that justifies teaching agricultural and environmental content.

**Definition of Terms**

For the purpose of this study, the following terms are operationally defined and will be used according to the definitions below:

**Content Knowledge.** The level of the correct responses on the content knowledge test administered following the treatment. In this study, content knowledge achievement will be measured by a series of researcher developed pretests and posttests.

**Critical Thinking Ability.** The National Council for Excellence in Critical Thinking defines critical thinking as the “intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action” (Foundation for Critical Thinking, 2015). Critical thinking ability was measured through the Critical Thinking in
Environmental Education (CTTEE) instrument (Cheak, 1999). The CTTEE consists of 27 multiple-choice items with sections measuring students’ ability to identify bias, make inferences, and provide conclusions.

**Environmental Attitude.** Ugulu, Sahin, and Baslar (2013) defined environmental attitude as the “general feelings toward ecology and the environment, feelings and concern for specific environmental issues, and feelings toward acting to remedy environmental problems” (p. 416). Environmental attitude was measured through the Environmental Attitude Inventory (EAI) scale (Campbell, Walizcek, & Zajicek, 1999). The EAI has been used to document high school agriscience students’ attitudes toward environmental protection. The EAI consists of 15 statements toward protecting the environment and is measured on a Likert-type scale.

**Environmental Education (EE).** Environmentally-based education that uses the environment and environmental issues as a learning context. EE commonly integrates a variety of academic subjects and uses local environmental issues (Powers, 2004), while developing students’ skills and behaviors necessary to understand and accept the relationships between people, culture, and the natural environment (Ugulu, et al., 2013).

**Inquiry-based Instruction (IBI).** According to the National Research Council (1996), IBI 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” (p. 23).
School-based Agricultural Education. SBAE is described as the “formal agricultural education programs offered in public schools (as opposed to non-formal agricultural education programs offered by business or other non-school agencies)” (Phipps, Osborne, Dyer, & Ball, 2008, p. 537).

Scientific Literacy. The public understanding of science and the interaction of the public with science to live more effectively (DeBoer, 2000), while also applying scientific knowledge to public issues (Hazen & Trefil, 1991).

Limitations of the Study

The results and interpretations of this study were subject to the following limitations:

- The data obtained from this study were limited to intact student groups included in a purposively selected sample of teachers involved in this study.

- Students’ background experiences, prior knowledge, and skills varied.

- The content knowledge pretests and posttests were researcher designed and therefore posed a threat to the instrument’s validity. The instrument was reviewed by a panel of experts in agriscience for face and content validity in an effort to reduce this threat.

- Lessons were not delivered by the researcher, and multiple teachers delivered the lessons. To reduce the threat of fidelity of implementation, teachers attended professional development linked to the curriculum and the teaching method under investigation. Teachers were also given detailed lesson plans that were detailed and easy to follow. Lastly, teachers audiotaped themselves during treatment delivery and audiotapes were analyzed to ensure appropriate delivery. However, all but one teacher failed to return the audiotape, leading to an increased threat for fidelity of implementation.

- Although mortality rates were not a major limitation to this study, completion rates for paired samples pretests and posttests were a limitation. The average response rate for the completion of individual instruments was 76.6%, while the average paired samples completion rate was 62.8%. The experimental group had a paired samples completion rate of 66.7% and the control group had a paired samples completion rate of 58.7%. The inability to link many students’ pretests with their posttests resulted in omitted scores and was a limitation to this study.
The teaching ability of teachers in this study was not measured. The teachers who participated in this study had previously attended professional development using the CASE curriculum and reached out to participate in this study. Many of these teachers could have potentially been described as exemplary teachers, modeling ideal teaching in any circumstance. The high effectiveness of exemplary teachers in many circumstances could have undermined the teaching method under investigation and serves as a limitation to this study.

Assumptions of the Study

The following assumptions were made for the purpose of this study:

- Students participating in this study preformed to the best of their ability during instruction and assessment.
- Teachers participating in this study accurately delivered the instructional materials to the best of their ability and followed guidelines presented by the researcher.
- Variables measured in this study, including content knowledge achievement, critical thinking ability, and environmental attitude were accurately assessed.

Chapter Summary

This chapter provided a summary of the complex agricultural and environmental challenges that have manifested into wicked problems of the 21st century (NRC, 2009). The ability to address the complex challenges related to agriculture and the environment has become dependent upon the preparation of a competent professional workforce and scientific community that are agriculturally and environmentally literate and that possess 21st century skills (Roberts et al., 2016).

The large historical gap in science achievement in youth (NAEP, 2004, 2009; NCES, 2015) has become concerning due to the dire need for a population that understands basic fundamentals of science and the scientific process used in problem solving (NRC, 2012). Along with students’ science literacy and content knowledge, critical thinking skills have been identified as a vital learning outcome in science and environmental education (Bright & Tanner, 2002; Ernst & Monroe, 2006; NSTA, 2003).
Critical thinking skills allow individuals to make informed choices in daily life and to effectively offer solutions to multifaceted problems.

Another identifiable trend in youth has been an increased lack of environmental connection and relevance to the natural world (Chawla & Cushing, 2007; Louv, 2005). The next generation of leaders must have strong environmental sensitivity and relevance, as recognized through positive environmental attitudes and behaviors.

The trend of poor science achievement has led to science education reform that has called for the use of IBI as a preferred instructional approach (NRC, 2012; NGSS, 2012). IBI in science education can model authentic scientific experiences that allow students to engage in scientific reasoning and to partake in inquiry to explore and form scientific knowledge. The NAAEE and the AAAE have supported the use of IBI within EE and SBAE programs. The emergence of environmental issues that are intertwined with agriculture have created a strong need for SBAE programs to include curricula with environmental components. SBAE is positioned to be at the pinnacle of teaching real-world agricultural and environmental issues that challenge the agriculture industry in providing a safe and abundant food supply to the growing demands of the world.

The purpose of this study was to determine the effects of IBI in an environmentally focused agriscience curriculum on high school students’ content knowledge achievement, critical thinking ability, and environmental attitude. This study is valuable to agriscience and EE teachers who teach environmentally focused curricula. This study also holds value to teacher educators who provide preservice teachers with effective teaching strategies designed for specific learning contexts and outcomes. In an era of increasingly complex agricultural and environmental challenges,
coupled with concerns about students’ scientific achievement, critical thinking ability, and environmental attitude, environmentally focused curricula must utilize proven teaching methods that address identified learning outcomes.

Chapter 2 will provide the theoretical and conceptual framework that guided this study. A literature review of relevant material will also be provided that served as the basis for this study.
CHAPTER 2
REVIEW OF LITERATURE

Chapter 1 provided a summary for the justification of this study. The purpose of this study was to determine the effects of IBI in an environmentally focused agriscience curriculum on high school students’ content knowledge achievement, critical thinking ability, and environmental attitude.

This chapter describes the theoretical framework that was used to guide this study. This chapter also provides a review of literature on factors that are relevant to this study. A thorough examination of empirically-based research on the following areas as related to IBI is discussed: environmental education, agricultural education, factors affecting teaching and learning, critical thinking, content knowledge retention, and attitude. Lastly, a conceptual model was created that represents the relational phenomenon of factors associated with teaching and learning using an IBI approach in agriscience.

**Constructivism**

The theoretical framework that guided this study was the philosophical perspective of constructivism. The constructivist approach to learning emphasizes that in order for meaningful learning to occur, individuals must construct their own understandings through active thinking (Cobern et al., 2010). Constructivism itself is not considered a true theory by many (Simpson, 2002; Staver, 1998), but rather a philosophical viewpoint about the nature of knowledge and learning (Hyslop-Margison & Strobel, 2008). The foundation of the constructivist framework is centered on the works by Piaget (1952), Vygotsky (1978), Dewey (1929), and Bruner (1966). Each of these early contributors influenced the modern view of constructivism (Tobias & Duffy, 2009),
which has led to pedagogical implications in education (Hyslop-Margison & Strobel, 2008; Phipps et al., 2008).

A key principle of the constructivist perspective is that in order for learning to take place, meaningful knowledge must be constructed by the learner, as opposed to being transmitted and absorbed (Cobber et al., 2010). An individual's ability to construct knowledge is dependent upon the behavioral and mental engagement of the learner (Cakir, 2008), as well as the learner's exposure to social interactions and experiences (Schunk, 2012). Engaged exposure to new interactions allows individuals to produce knowledge based upon preexisting beliefs and beliefs stemming from the new interactions (Cobb & Bowers, 1999; Geary, 1995).

Theory of Cognitive Development

The late work by psychologist Jean Piaget served as the psychological basis of constructivism (Fosnot, 1996). Piaget’s theory of cognitive development laid forth the groundwork for explaining the cognitive process that enables individuals to form new constructions. Piaget believed that individuals are continuously developing physically, biologically, and cognitively (Piaget, 1970). Cognitive development depends on four factors: biological maturation, experience with the physical environment, experience with the social environment, and equilibration (Schunk, 2012). According to Piaget (1978), individuals use existing mental schemes to guide behavior and to interpret experiences. The central factor leading to cognitive growth is equilibration, which aligns mental structures with external environmental reality through assimilation and accommodation. Assimilation occurs when individuals fit external reality with existing mental schemes, whereas accommodation occurs when individuals change mental schemes to make sense of the reality (Schunk, 2012). Although both assimilation and
accommodation lead to cognitive growth, new information that fits into existing schema is more easily understood and retained (Slavin, 1998).

Piaget’s theory of cognitive development describes an individual’s ability to process increasingly abstract concepts as being stage dependent (Piaget, 1952). The four stages of cognitive development, as proposed by Piaget, are sensorimotor, preoperational, concrete operational, and formal operational (Schunk, 2012). The first stage of development, sensorimotor, is present from a child’s birth. The sensorimotor stage includes spontaneous actions and represents primary attempts to understand the world. In the preoperational stage, children can imagine and reflect on previous experience, although perceptions of reality mostly remain in the present. In this stage, language development occurs rapidly, and an understanding occurs that other individuals can think and feel differently than themselves. The third stage of cognitive development, typically occurring in children from the age of seven to eleven, is the concrete operational stage. During this very formative stage, children experience rapid cognitive growth and skill acquisition. Furthermore, children rely heavily on mental schema from prior experiences in making sense of new phenomenon. The last stage proposed by Piaget (1952) is formal operational. This stage, typically starting in children’s early adolescence and lasting through adulthood, can be characterized by the ability to think about hypothetical situations, multiple dimensions, and abstract properties (Schunk, 2012).

**Sociocultural Theory**

Lev Vygotsky’s Sociocultural Theory contributed the importance of social interaction as a fundamental component of the constructivist perspective. While still centered in the environment of the individual, Vygotsky’s theory expressed the role of
interpersonal interactions, cultural-historical factors, and individual factors as influencers of cognitive development (Tudge & Scrimsher, 2003). Cognitive growth occurs as individuals reorganize mental schema, knowledge, and characteristics, based upon interactions with individuals in their environment (Schunk, 2012). Social interactions, especially the cultural and historical context of those interactions, transform an individual’s meaning of concepts in congruence with a cultural basis (Gredler, 2009; Moll, 1990). According to Vygotsky (1962), higher order mental functions originate in the social environment.

Another contribution of Vygotsky’s theory is the zone of proximal development. Vygotsky described the zone of proximal development as “the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving guidance or in collaboration with more capable peers” (Vygotsky, 1978, p. 86). Each learner has a zone that is bounded by the cognitive development level needed for learning the concept and the cognitive ability of the learner. Social interactions offering guidance or collaboration can advance an individual’s cognitive thought into new cognitive territory that otherwise would not be capable (Gredler, 1997).

**John Dewey**

John Dewey, a prominent educational philosopher whose work contributed in shaping agricultural education, believed that learning is best achieved through exposing students to experiences (Phipps et al., 2008). Dewey was one of the first to apply the constructivist perspective to educational practice. According to Dewey, educational programs should provide learners with situational problems that allow them to construct their own knowledge as they encounter and solve problems. Furthermore, Dewey
believed that education should be centered around a social process. Dewey believed
that the most effective learning occurs when individuals discuss and reflect on
experiences together. Dewey also promoted the idea that educational experiences
should be tailored to students’ interests and that students should provide input on what
and how to learn. Dewey’s philosophy toward education has served as a foundational
component to the problem-solving approach used in SBAE (Boone, 1990; Phipps et al.,
1988), and has many similarities to the scientific method and inquiry-based teaching
practices (Parr & Edwards, 2004; Roberts, 2006).

**Inquiry-based Instruction**

The theory base of constructivism has led to varying methods in educational
practice that promote students to become actively involved in their own learning. One
such methodology that came to fruition, centered in the epistemological framework of
constructivism that permeated education in the 1970s, was IBI (Llewelly, 2007; Minner,
Levy, & Century, 2009). Throughout the nearly next half-century, education reform in
science education was centered in the constructivist approaches to learning and touted
IBI as the *sine qua non* for science instruction (American Advancement of Science,
1990; NRC, 1988; NRC, 2000). The study described herein utilized IBI as the primary
teaching approach under investigation.

**Conceptualizing Inquiry-based Instruction in Science Education**

Despite the popularity of IBI over the last several decades, researchers and
practitioners alike have been slow to agree upon a precisely shared understanding of its
defining characteristics (Minner et al., 2009). Although multiple perspectives have
shaped the definitions of IBI in education (Llewellyn, 2002), scholars have agreed that
IBI is a student-centered and teacher-guided approach to learning that places the
responsibility for learning upon the student. The focus of instruction shifts to students’
learning and thinking processes, as opposed to merely students’ acquisition of specific
information. The IBI approach assumes that if students are comfortable with the process
of learning and are actively engaged, then they will be able to form knowledge about
new concepts and will transfer knowledge from other concepts (Doolittle & Camp, 1999;
Easterly & Myers, 2011). The student-centered approach to learning can foster
students’ personal investment in the learning process, which develops students’
concentration, enthusiasm, and curiosity toward learning (Minner et al. 2009).
Furthermore, IBI commonly engages students in investigating real world problems that
require them to reason, obtain information, derive principles, and apply them to possible
solutions. During this process students are expected to build on prior knowledge, use
logic, and think creatively (Minner et al., 2009).

Schunk (2012) addressed learning outcomes of inquiry teaching as “formulating
and testing hypotheses, differentiating necessary from sufficient conditions, making
predictions, and determining when making predictions requires more information” (p.
268). The elements of IBI closely align to the process of inquiry used by scientists to
make discoveries (Cobern, 2010) and has been identified as an effective instructional
strategy to meet the goals of science education (NRC, 2012). According to Alberts
(2009), the goals of science education are to prepare students to:

1. know, use, and interpret scientific information to explain the natural world;
2. generate and evaluate scientific evidence and explanations;
3. understand the development of scientific knowledge; and
4. participate in scientific practice and discourse.

An explicit emphasis on IBI in teaching and learning has been a central
component to science education reform for the last half century (AAAS, 1990; Duschl,
According to Forbes and Zint (2010), science education reform has called for integrative, substantive, and project-based approaches in education that allow students to make connections between abstract science content and real-world applications. Atkin and Karplus (1962) were among the first to design teaching methods that were analogous to how scientists invent and use new concepts about nature. Their early work included two processes: invention – the initial introduction of a new term, and discovery – the following verification or extension of that term. Karplus soon expanded upon this design by including three distinct phases that included exploration, invention, and discovery (Karplus & Their, 1967). This process of instruction became known as the Science Curriculum Improvement Study (SCIS) Learning Cycle.

In the mid-1970s, Karplus again modified the three phases in an effort to make each stage clearer in classroom practice. The phases of the SCIS Learning Cycle became exploration, concept introduction, and concept application. The learning cycle approach emphasized the investigation of phenomena, acquiring evidence to back up claims, and designing and testing experiments. Early studies on the effectiveness of the learning cycle approach reported student increases in content retention, attitudes toward science, and improved scientific reasoning and processing skills, compared to traditional approaches (Abraham & Renner, 1986; Lott, 1983; Raghubir, 1979).

The SCIS Learning Cycle was soon revised and expanded by the Biological Sciences Curriculum Study (BSCS). The revised model, referred to as the BSCS 5E Instructional Model, frames a sequence and organization of a program, unit, or lesson to include five phases: engagement, exploration, explanation, elaboration, and evaluation. According to Bybee et al. (2006), each phase contributes to students’ better
understanding of scientific knowledge, attitudes, and skills. The phases of the learning sequence, as described in the report, *The BSCS 5E Instructional Model: Origins and Effectiveness*, are shown below (Bybee et al., 2006).

- **Engagement:** The teacher or a curriculum task accesses the learners’ prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. The activity should make connections between past and present learning experiences, expose prior conceptions, and organize students’ thinking toward the learning outcomes of current activities.

- **Exploration:** Exploration experiences provide students with a common base of activities within which current concepts (i.e., misconceptions), processes, and skills are identified and conceptual change is facilitated. Learners may complete lab activities that help them use prior knowledge to generate new ideas, explore questions and possibilities, and design and conduct a preliminary investigation.

- **Explanation:** The explanation phase focuses students’ attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill. Learners explain their understanding of the concept. An explanation from the teacher or the curriculum may guide them toward a deeper understanding, which is a critical part of this phase.

- **Elaboration:** Teachers challenge and extend students’ conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.

- **Evaluation:** The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objective.

Reform-oriented classroom inquiry in science education has been led by similar educational sequencing. According to the NRC (2000), essential features of classroom inquiry provide learners the opportunity to:

1. engage in scientifically oriented questions,
2. develop and evaluate explanations to questions,
3. formulate explanations from evidence to address questions,
4. evaluate their explanations and alternative explanations reflecting scientific understanding, and  
5. communicate and justify proposed explanations.

National and state learning standards have also emphasized student understanding of scientific concepts through inquiry-guided approaches that mirror the process of science discovery, evaluation, and communication (NGSS, 2012).

**Environmental Education and Inquiry-based Instruction**

Environmental education (EE) is a form of school-based education that uses the environment and environmental issues as a learning context. EE commonly integrates a variety of academic subjects and uses local environmental issues and real-world learning experiences (Ernst, 2009; Powers, 2004), while developing students' skills and behaviors necessary to understand and accept the complex relationships between people, culture, and the natural environment (Ugulu, Sahin, & Baslar, 2013). Furthermore, according to Ernst and Monroe (2006), EE adopts local environments as a primary context for student exposure and includes project and issue-based learning experiences that are learner-centered. Putting students at the forefront of investigating environmental issues in their local communities has been shown to establish student relevance, motivation, and engagement (Powers, 2004). Furthermore, EE has been shown to reduce classroom management problems and increase standardized measures of academic achievement (Lieberman & Hoody, 1998).

The NSTA (2003) stated that EE should promote student observation, investigation, experimentation, and innovation through the natural environment. According to the NAAEE (2000), the instructional design that best supports the goals of EE is an inquiry-based approach. Through IBI, students can become engaged in not
only learning about complex environmental issues and their scientific dimensions, but they can analyze, propose, and implement solutions for them (Forbes & Zint, 2010). Furthermore, IBI in EE allows students to conduct authentic scientific field work on issues stemming from interactions within natural and social systems (Ernst & Monroe, 2006; Dresner & Moldenke, 2002). Immersion in these topics provides meaningful experiences to students, fostering the construction of new scientific knowledge and thinking skills (Berman, 1991), while connecting students to the natural world. Students’ connection to the natural world is integral in establishing environmentally responsible behavior and concern for the protection of the environment (Blanchet-Cohen, 2008; Mayer & Frantz, 2004).

Even given the overwhelming support of IBI in EE and science education, research has indicated that the actual practice of teaching through IBI approaches has been minimal in a majority of science-oriented classrooms (Capps & Crawford, 2013; Cory & Zint, 2010). Forbes and Davis (2008) found that teachers lack confidence in their ability to use instructional strategies determined to be most effective in EE. Professional development opportunities have appeared to be a leading solution to develop teacher confidence toward using IBI (Ernst, 2009; Milner, Songergeld, Demir, Czerniak, & Johnson, 2012). Professional development programs that allow teachers themselves to become immersed in inquiry-based practices within environmental issues can enhance teachers’ confidence to engage students in IBI (Forbes & Zint, 2010). In a study of a two-year professional development program requiring teachers to design and implement environmental IBI lessons, Haney et al. (2007) found that throughout the program
teachers greatly enhanced their confidence in the knowledge, skills, and abilities needed to effectively teach EE.

Agricultural Education and Inquiry-based Instruction

SBAE can be described as the “formal agricultural education programs offered in public schools (as opposed to non-formal agricultural education programs offered by business or other non-school agencies)” (Phipps et al., 2008). Within SBAE, agriscience applies to agricultural instruction with a strong foundation in science. In agricultural education, science practices are integrated and applied to a learning context within agriculture, natural resources, and the environment.

SBAE has experienced a strong history of experiential learning, stemming from vocational preparation through hands-on and problem-based learning (Parr & Edwards, 2004). Modern SBAE has become well blended in both vocational and academic pursuits. In 1988, the NRC called for curricular expansion of agricultural education, including the need for the “teaching of science through agriculture” (p. 5). The 1996 National Science Education Standards (NRC, 1996) also noted the importance of agricultural education, documenting the need for science literacy in agriculture. The inclusion of teaching science in agriculture has continued, as can be seen in priority three of the 2016-2020 AAAE report calling for effective models for STEM integration in SBAE (Roberts et al. 2016). Efforts to prepare students in agricultural careers beyond production agriculture and into careers involving agricultural research and science have been highly evident (NRC 1998; NRC 1996; Roberts et al., 2016).

Reports from the NRC (1996; 2009) indicated that traditional teaching methods have fallen short in preparing students for college and career readiness within agriculture. In a search for high-quality and pragmatic learning through hands-on
applications in agriscience that reconciles student deficiencies in critical thought, cognitive ability, and real-world skill development, agricultural education has leaned toward IBI (Wells, et al., 2015). IBI in agriscience can expose students to agricultural issues that develop scientific content knowledge (Thoron & Myers, 2011; Witt, Ulmer, Brashears, & Burley, 2014), scientific reasoning ability (Thoron & Myers, 2012a), argumentation skills (Thoron & Myers, 2012b), and positive perceptions of agriscience (Thoron & Burleson, 2014).

Factors Affecting Teaching and Learning

A complete review of factors affecting student learning extends far beyond teaching methods. Researchers in education have investigated multiple factors that can influence the effectiveness of the teaching and learning process and outcomes associated with it. Biggs (2003) proposed The Presage-Process-Product (3P) model that identifies factors affecting the teaching and learning process, as shown in Figure 2-1. The model illustrates the relational phenomenon of factors affecting teaching and learning (Trigwell, 2010), and has been empirically validated for virtually all academic disciplines (Biggs, 2003).
Figure 2-1. The Presage-Process-Product (3P) model demonstrating teaching and learning as a relational phenomenon (Biggs, 2003).

**Presage Factors**

Presage factors can be described as characteristics of students, teachers, and the learning environment that affect the learning process. Characteristics of students can include background factors and cognitive factors. Education research has investigated the influence of background and cognitive factors on learning outcomes. Background factors such as students’ age (De La Paz, 2014; Kooij & Zacher, 2016; Mermilod, Bugaiska, & Bonin, 2013), gender (Arbaugh, 2000; Bedel, 2016; Burkam, Lee, & Smerdon, 1997; Pearson & West, 1991), race (Baylor, Shen, & Huang, 2003; Flanagan, 2016; Harris, La Londe, & Moyer, 2015), and socioeconomic status (Lam, 2014; Thoron & Myers, 2011b; von Stumm & Plomin, 2014) have been shown to contribute to differences in learning outcomes.
Cognitive factors, such as students’ learning ability (Pense, Calvin, Watson, & Wakefield, 2012; Pense, Watson, & Wakefield, 2010), prior experience (Lenaert, van de Ven, & Vlaeyen, 2015; Wagler et al., 2008), motivation (Baeten, Dochy, & Struyven, 2012; Ciampa, 2013; Ng, Liu, & Wang, 2016; Shih & Gamon, 2001), interest (Walkington, C. A., 2013; Linvill, 2014; Sallee, Edgar, & Johnson, 2013), and attitude (Lovelace & Brickman, 2013; Yildirim, 2017) have also been shown to affect learning outcomes.

Another presage factor, teacher characteristics, can also influence the learning outcomes of students. Teacher factors, such as educational training (Rice, 2003; Ronfeldt, Reininger, & Kwok, 2013; Wayne & Youngs, 2003), knowledge of the subject matter (Sadler, Sonnert, Coyle, Cook-Smith, & Miller, 2013), and years of teaching experience (Croninger, Rice, Rathbun, & Nishio, 2007; Hanushek & Rivkin, 2006; Rockoff, 2004) have been shown to impact student learning. Lastly, personal teacher characteristics, such as efficacy toward teaching (Muijs & Reynolds, 2002; Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998) and student expectations (Kuklinski & Weinstein, 2001; Scheerens, Seidel, Witziers, Hendriks, & Doornenkamp, 2005), have been shown to influence student outcomes.

Characteristics of the environment include school and community characteristics. School characteristics, such as level of safety (Kraft, Marinell, & Shen-Wei Yee, 2016), teacher turnover rate (Guin, 2004; Ronfeldt, Loeb, & Wyckoff, 2013; Simon & Johnson, 2015), and cultural diversity of students (Kotok & DeMatthews, 2017; Reid & Kagan, 2015) have been linked to differences in student performance. Lastly, classroom characteristics, such as class size (Hornsby & Osman, 2014) and resource availability
(Dee, Jacob, & Schwartz, 2013; Jung, Brown, & Karp, 2014), can influence student outcomes.

**Process Factors**

Process factors can be described as the activities that influence classroom teaching. The design and delivery of instructional content has been demonstrated to be an important process factor. Previous studies have indicated that teaching method (Boone, 1988; Burris, 2005; Mueller, Knobloch, & Orvis, 2015) and curriculum design (Baker, Brown, Blackburn, & Robinson, 2014; Schafbuch, Vincent, Mazur, Watson, & Westneat, 2016; Zohar & Nemet, 2002) play a role in student achievement.

**Product Factors**

Product factors are all learning outcomes associated with the teaching and learning process. Product factors can be distinguished between cognitive outcomes (e.g., knowledge achievement, attitudes, skill development) and non-cognitive outcomes. The product factors that were assessed in this study included content knowledge achievement, critical thinking ability, and environmental attitude.

**Content Knowledge Achievement.** The ability for students to learn and retain content is an important component of any educational program. Assessments that evaluate student knowledge are status quo in determining learning outcomes. This has been highly evident throughout educational programs in the United States, as demonstrated by rigorous content-based standardized testing. Students should remember and understand fundamental concepts appropriate with what they are learning in order to advance to higher order levels of learning. Bloom (1956) illustrated this concept in his Taxonomy of Learning Domains. Knowledge and basic understanding of fundamental agriscience and environmental concepts must first be
established before students can effectively progress into the higher domains of learning that include apply, analyze, evaluate, and create (Bloom, 1956). Students' agricultural and environmental literacy hinges upon their ability to effectively master a basic understanding of science, agriculture, and the environment. Kollmuss and Agyeman (2002) found that increasing an individual's environmental knowledge leads to more positive attitudes towards the environment.

**Critical Thinking Ability.** The National Council for Excellence in Critical Thinking (Foundation for Critical Thinking, 2015) defined critical thinking as the “intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action” (para. 3). Critical thinking skills are essential at managing the labyrinth of environmental issues in a global society and in making informed decisions about environmental stewardship (Ernst & Monroe, 2006; NSTA, 2003). Critical thinking skills have also been suggested as a vital component to both environmental literacy (Ernst & Monroe, 2006) and agricultural literacy (Shoulders & Myers, 2013).

According to the NSTA (2003), all learners should be taught how to think critically about complex issues. Research has indicated that most educators believe that the primary goal of education is to teach students how to think critically and independently (Sternberg & Baron, 1985; Pithers & Soden, 2000). McTighe and Schollenberger (1991) believed that improving students’ critical thinking ability is fundamental in the United States, due to societal changes that will require citizens and decision-makers to solve complex challenges.
Learning that promotes critical thinking skills should be facilitated in a way that does not advocate for specific solutions, but rather allows students to analyze knowledge from a variety of subject areas and sources to conduct scientific inquiry and to make responsible and informed decisions (Ernst & Monroe, 2006). In addition, Berman (1991) suggested that critical thinking skills can be increased by encouraging students to act on knowledge through authentic tasks and to reflect on what they learn. Evaluations of EE programs have used student gains in critical thinking skills, as opposed to environmental knowledge, as indictors of program achievement (Bright & Tanner, 2002; Ernst & Monroe, 2006). Increased levels of students’ critical thinking ability satisfy the goals of both EE and traditional education.

Environmental Attitude. Research has indicated that environmental attitudes affect environmental behavior. Individuals who have positive environmental attitudes (i.e., positive environmental beliefs and values) have been shown to demonstrate increased levels of pro-environmental behavior (Bruskotter & Fulton, 2008). Steg and Vlek (2009) proclaimed that environmental behavior interventions are more successful when targeted toward increasing the values, beliefs, and attitudes of individuals, rather than behaviors themselves. De Poorter added that public awareness through EE programs is well warranted as a method to increase environmental attitudes over time. In fact, Ballantyne and Packer (1996) suggested that one of the three dimensions of EE is to increase students’ environmental values and attitudes, since youth have become less connected to nature and, therefore, lost environmental connections and relevance to the natural world (Louv, 2005). Chawla and Cushing (2007) believed that EE can
foster greater student appreciation for the environment when students are immersed in meaningful educational experiences.

**Previous Research**

**Educational Design and Critical Thinking Ability**

Thoron and Myers (2012a) conducted a quasi-experimental study to determine the effects of inquiry-based agriscience instruction on students’ ability to demonstrate scientific reasoning. The researchers exposed 15 intact classrooms containing 305 students to a twelve-week study that included seven units of classroom instruction. Classrooms were randomly selected to receive teaching methods that were either based on the IBI approach or the subject matter approach. Students’ scientific reasoning ability was assessed using Lawson’s Classroom Test of Scientific Reasoning (Lawson, 1992). At the end of the twelve-week study, results indicated that students receiving IBI scored higher in scientific reasoning ability than students receiving the subject matter approach.

Vieira and Tenreiro-Vieira (2014) conducted a mixed-methods study investigating the effect of learning experiences on middle school students’ critical thinking skills and science literacy. The researchers used a one group, pretest-posttest design and exposed 22 students enrolled in a science education course to a series of learning activities containing explicit requests and questions that promoted critical thinking. The Cornell Critical Thinking Test was used as the instrument to measure students critical thinking ability and was administered prior to and after the treatment. Results indicated that students increased critical thinking scores after being exposed to the learning activities.
Bati and Kaptan (2015) investigated the degree that modeling based science education influences the development of students’ critical thinking skills. The researchers used a pretest-posttest quasi-experimental design with the use of a control group. Four 7th grade classrooms were used that contained 114 students. Two classrooms were exposed to modeling based science education and two classrooms were exposed to regular science classroom instruction. Students were administered the Cornell Critical Thinking Test before and after the intervention. The duration of the intervention was approximately 16 classroom hours. Results indicated a statistically significant improvement between pretest and posttest scores for students exposed to modeling based science instruction, however, there was not a significant difference between posttest scores for students exposed to modeling based science instruction and for students exposed to traditional instruction.

In a study examining the effects of environment-based education on students’ critical thinking skills and disposition toward critical thinking, Ernst and Monroe (2004) supported the use of environment-based education for improving critical thinking. Eleven Florida high schools participated in a study that included 404 9th or 12th grade students. The researchers used a pretest-posttest nonequivalent control group design for 9th grade students and a posttest only nonequivalent comparison group design for 12th grade students. The Cornell Critical Thinking Test was used to assess students’ critical thinking ability. The duration of the treatment was a full school year. When controlling for GPA, gender, and ethnicity, environment-based education programs had a positive effect on students’ critical thinking ability.
Arslan (2012) investigated the influence of environmental education on students’ critical thinking. The Critical Thinking Test in Environmental Education was used to assess the critical thinking ability of 346 8th grade students enrolled in Turkey’s secondary schools. Socio-economic status, gender, and school type were compared. Results demonstrated that students of higher socio-economic status scored higher in critical thinking, females scored higher than males, and students attending private school scored higher than students attending public schools. Arslan concluded that demographic variables influence critical thinking abilities in environmental education.

**Educational Design and Content Knowledge Achievement**

Cobern et al. (2010) conducted a study to compare whether an inquiry approach or direct approach to experientially-based instruction is more effective for developing students’ science concepts. Researchers designed IBI to follow components seen within the Karplus learning cycle (Lawson, Abraham, & Renner, 1989) and 5E learning cycle (Bybee et al., 2006) that guide students to ‘invent’ scientific concepts by ‘discovering’ relationships and laws. DI provided students scientific concepts first, followed by prescribed laboratory exercises. One-hundred and eighty students were exposed to a unit of instruction for a two-week period. Intact classrooms of roughly 20 students each were taught using the IBI approach or the DI approach. To ensure fidelity of the treatment, teachers were allocated the teaching method used in their classroom, according to their preference and comfort level of using the method. Cobern et al. (2010) reported that both approaches increased levels of students’ science concept understanding. Results did not indicate a statistically significant difference between the two approaches of experientially-based instruction.
In a four-year study, Minner, Levy, and Century (2009) conducted a synthesis of research from 1984 to 2002 on IBI in science. The researchers developed a framework of inquiry-based science instruction that was composed of similarities with previous literature. The following criteria for previous research were identified: (a) the presence of science content; (b) student engagement with science content; and (c) student responsibility for learning, active thinking, or student motivation with at least one component of instruction – question, design, data, conclusion, or communication. The researchers identified 138 studies that fit the criteria. A synthesis of the studies indicated that students’ conceptual learning of science is improved through active participation in the investigative process. Results also indicated that hands-on experiences with science or natural phenomena were more likely to increase students’ conceptual learning, compared to passive techniques.

Myers and Dyer (2006) conducted a quasi-experimental study to determine the effect of laboratory approaches on students’ science process skill achievement and content knowledge achievement. In the nonequivalent control group design, Myers and Dyer tested three levels of lab treatments following instruction via the subject matter approach. The three treatments included no laboratory experimentation, prescriptive laboratory experimentation, and investigative laboratory experimentation. The population identified in this study was students enrolled in an introductory agriscience course. The purposive sample consisted of ten schools in Florida and included 501 students enrolled in an introductory agriscience course. Three-hundred and fifty-two students were exposed to one of the three treatments for four to six weeks. Students’ science process skill achievement was measured by pretest and posttest treatments
using the Test of Integrated Process Skill (Dillashaw and Okey, 1980). Myers and Dyer (2006) found that students exposed to the investigative laboratory approach or the subject matter approach with no laboratory activities scored higher in content knowledge achievement and science process skills compared to students exposed to the prescriptive laboratory approach.

In 2011, Thoron and Myers compared students’ agriscience content knowledge outcomes after exposure to instruction via the subject matter approach or IBI approach. Thoron and Myers (2011) used a quasi-experimental design that consisted of seven high schools across the United States. A purposive sample of 15 agriscience courses was used in the study. Teachers participated in a five-day teacher training at the National Agriscience Teacher Ambassador Academy (NATAA). The five-day training ensured teacher familiarity of the teaching content and the effectiveness of teacher delivery for both teaching methodologies under investigation. In addition, audio recordings of treatment administrations were used to ensure treatment validity. Participants were exposed to either the subject matter approach or IBI approach for a time frame of 12 weeks. Students were assessed by a series of seven researcher-developed pretests and posttests using electronic instruments. Thoron and Myers (2011) reported that students taught through the IBI approach scored higher in content knowledge achievement, compared to students taught through the subject matter approach.

Easterly and Myers (2011) investigated the effectiveness of IBI teaching in agriscience on students with special needs. The study’s design was a one-group pretest-posttest that used an IBI approach as the treatment. Ten teachers who attended
the NATAA were purposively selected to deliver a 10 to 12-week unit. Teachers were audio recorded during the treatment to ensure appropriate treatment methods were followed. Pretests and posttests for each treatment were given to 170 students throughout the duration of the study. Students who had an Individual Education Plan (IEP) were considered special needs students. Posttest results indicated no statistically significant differences in content knowledge achievement between students with IEPs and students without IEPs. Easterly and Myers (2011) concluded that IBI does not adversely affect content knowledge achievement for students with special needs.

**Conceptual Model**

The conceptual model designed for this study illustrates the process of teaching and learning through IBI in an environmentally focused agriscience curriculum. The Presage-Process-Product (3P) model developed by Biggs (2003) was used as a basis for the conceptual model. Biggs (2003) proposed that presage, process, and product factors experience a relational phenomenon during teaching and learning. Presage and process factors influence learner outcomes. Characteristics of the environment were added to the model to represent community, school, and classroom characteristics that have been shown to influence learning outcomes. The process component of the model was expanded to represent the 5E model that was utilized in this study as a specific method of IBI. Furthermore, IBI was identified as a constructivist approach to learning. Skill, knowledge, and attitudes were added to the model under product factors. Skills, knowledge, and attitudes have been identified as essential product factors in agricultural and environmental education (Ballantyne & Packer, 1996; Ernst & Monroe, 2006; NSTA, 2003). Figure 2-2 displays the conceptual model that was utilized in this study.
Chapter Summary

This chapter provided an overview of the philosophical perspective of constructivism and its major contributing theories that were used as the theoretical foundation for this study. This chapter also provided a summary of IBI as seen within science education, EE, and SBAE. The synthesis of literature for this study overwhelmingly indicated that IBI is supported in environmental and agricultural education. The review of literature also indicated the importance for individuals to have critical thinking skills, knowledge of agricultural and environmental concepts, and positive environmental attitudes in order to address complex agricultural and environmental challenges of the 21st century. The conceptual model developed to guide this study presented the relationship between important variables in teaching and learning using an IBI approach in an environmentally focused agriscience curriculum.
CHAPTER 3
RESEARCH METHODS

Chapter 1 introduced and explained the need for this study. The problem that this study addressed was the need to equip individuals with the knowledge, skills, and environmental sensitivity to provide solutions to complex agricultural and environmental challenges of the 21st century. The purpose of this study was to determine the effects of IBI in an environmentally focused agriscience curriculum on students’ content knowledge achievement, critical thinking ability, and environmental attitude.

Chapter 2 presented a theoretical framework, review of literature, and a conceptual model that were used to guide this study. The primary theory that this study utilized was constructivism. The theoretical framework also included the theory of cognitive development (Piaget, 1952), sociocultural theory (Vygotsky, 1962), and the Presage-Process-Product model presented by Biggs (2003). A review of literature focused on the following areas related to IBI: science education, environmental education, agricultural education, critical thinking, content knowledge, and attitude. The conceptual model designed for this study represented the relational phenomenon of factors associated with teaching and learning using an IBI approach in agriscience.

This chapter provides the research methods that were used to complete this study. The study was quasi-experimental and used a nonrandomized control group, pretest-posttest design with intact agriscience classrooms. This chapter includes information on the study’s population and sample, research design and procedure, instructional design, instrumentation and data collection, and data analysis process.
Population and Sample

The population of this study was all high school agriscience students in the United States. The accessible population included students of agriscience teachers who attended the Curriculum for Agricultural Science Education (CASE®) Institute for Natural Resources and Ecology (NRE) certification between the years 2013 and 2017. CASE® provided a contact list of attendees who completed the CASE® Institute for NRE certification between the years 2013 through 2017. The list included (a) name, (b) email, (c) year of CASE® Institute completion, (d) workplace, (e) workplace address, and (f) work phone. All CASE® Institute attendees identified on the list who were not agriscience teachers were discarded. The total number of agriscience teachers who completed the CASE® Institute for NRE certification between the years 2013 and 2017 was 167.

Designed Sample

The sample size needed for this study was determined using the Hays’ (1973) formula. Using the formula, a sample size that is practically and statistically significant without finding significance due to an inflated sample size was calculated. The Hays’ (1973) formula is as follows:

\[ n = 2\left[Z_{(1-\alpha/2)} - Z_\beta\right]^2 + \Delta^2 \]

The formula was utilized to reduce the probability of committing a Type I error to .05, to achieve a desired power of .90, and to detect variance in the independent variable at a level greater than .10. The sample size was determined by using the z-score for the desired alpha level \( Z_{(1-\alpha/2)} \) and desired power \( Z_\beta \), while using the effect size.
size in units of the standard deviation ($\Delta$). The following formula was used to calculate $\Delta$.

$$\Delta = 2\sqrt{w^2} / \sqrt{1-w^2}$$

Using this formula, $w^2$ represents the variance seen in the dependent variable in relation to the independent variable. The following calculations were used to determine the appropriate sample size for this study.

$$\Delta = 2\sqrt{0.01/(1-0.10)} = 0.66$$

$$n = 2[1.96-(-1.64)]^2 / 0.66^2 = 59.5$$

The practical sample size deemed appropriate to reach statistical significance without finding significance due to inflated sample sizes was calculated to be 60 subjects for each treatment. In comparable studies, Park (2005), Shoulders (2012), and Thoron (2010) doubled the recommended sample size due to mortality rates as high as 50% seen in similar research designs (Boone, 1988; Dyer, 1995; Flowers, 1986; Myers, 2004). Therefore, the sample size for each treatment was doubled from ($n=60$) to ($n=120$), with a total designed sample of 240 students. Thoron (2010) provided a conservative estimate of 12 students per classroom in a typical rural school. Therefore, the number of teachers ($T$) to be included in this study, provided that each teacher exposes one class to either the treatment or the control, is calculated below:

$$T = (240/12) = 20$$

The calculations resulted in a designed teacher sample size of 20.

**Data Sample**

A convenience sampling method was used to recruit teachers. Teachers were recruited to be a part of the study through emails and phone calls. Initial contact was
made to each teacher who completed the CASE® Institute for NRE certification between the years 2013 and 2017 ($n = 167$). Four months prior to the anticipated start of the study, a personalized email (Dillman, Smyth, & Christian, 2014) was sent to each teacher on the list provided by CASE®. The email contained (a) why the teacher was selected as a candidate to be a part of the nation-wide research study, (b) the expected start date of the study, (c) description and requirements of the study, and (d) a link to complete a short informational survey to assist with the study. Also included in the email was an attachment with researcher biographies (Appendix B). After daily survey responses or email replies dropped to zero, follow-up emails were sent to non-responders (Dillman, Smyth, & Christian, 2014). Three email blasts were sent during a time period of three weeks.

The informational survey was used to assess the characteristics of teachers who expressed interest in participating in the study. Each respondent was asked to complete the following questions in a survey created through Qualtrics.

1. Please indicate if you will be teaching the CASE® Natural Resources and Ecology (NRE) course during spring 2018 (or a course with a different name that uses the CASE® NRE curriculum).
2. How many class sections of the CASE® Natural Resources and Ecology (NRE) course will you be teaching during spring 2018?
3. Approximately how many students do you anticipate being enrolled in your CASE® Natural Resources and Ecology (NRE) course(s) during Spring 2018?
4. Would you consider being a part of this research study during the first few months of 2018?
5. With resources and detailed plans provided, which of the following CASE® Natural Resources and Ecology (NRE) lessons will you be able to teach during the first few months of 2018 (please select all that apply): (a) The Energy of Life, (b) All Natural Flora, (c) Flourishing Fauna; and (d) Agricultural Stewardship?
6. Please indicate the best way for us to reach you for further information regarding this study (i.e., preferred email address and/or phone number and best time to call).

Of the 167 emails sent, ten email addresses were invalid, and 112 email recipients did not reply or complete the informational survey. A total of 45 teachers expressed interest in the study by completing the survey or replying via email. Of the 45 teachers expressing interest in the study, 22 indicated that they would not be teaching the CASE® NRE curriculum during the spring of 2018. Twenty-five teachers indicated that they would be teaching the CASE® NRE curriculum during the spring. Twenty-one teachers indicated they would be teaching one class section of CASE® NRE, and two teachers indicated they would be teaching two or more sections during the timeframe of data collection. The estimated number of students enrolled in each section ranged from three to 27.

Twenty-one teachers met the following requirements to participate in the study: (a) the teacher completed the CASE® Institute for NRE certification between 2013 and 2017, (b) the teacher planned to teach the CASE® NRE course to high school agriscience students during spring 2018, and (c) the teacher was willing and able to deliver the study’s treatment for a duration of eight weeks during the spring of 2018.

A follow-up phone conversation was attempted with each of the 21 teachers to discuss the research study in more detail and to solidify each teacher’s participation. Seventeen of the 21 teachers were reached after multiple contacts. Four teachers decided they would be unable to participate in the study due to various reasons (e.g., unable to teach learning modules identified in the study, use of a student teacher, maternity leave). Thirteen teachers agreed to participate in the study. Twelve teachers indicated that they would be teaching one section of the CASE® NRE course, and one
teacher indicated teaching multiple sections. Each teacher provided an estimate of the number of students that was expected to be enrolled in their course(s) during spring 2018. The 222 total estimated participants in the study was comparable to the target sample size of 240 students (Hays 1973) and was deemed sufficient for the study.

Research Design

A quasi-experimental design was deemed most appropriate for this study, as random assignment of subjects to treatment groups was not feasible due to the use of intact classrooms. A nonequivalent control group, pretest-post-test design (Campbell & Stanley, 1963) was used. Although this design is considered one of the most widely used designs in education research (Ary, Jacobs, Sorensen, & Walker, 2014), threats to internal and external validity that stem from this design exist. Procedures were taken to reduce threats to internal and external validity and will be discussed in the following section.

Procedures

The dependent variables that were measured in this study were students’ content knowledge achievement, critical thinking ability, and environmental attitude. The independent variable that served as a treatment for this study was the teaching method used in agriscience classrooms. The treatment delivered to the experimental group was IBI. The treatment delivered to the comparison group was DI. Four learning modules were designed to last approximately two weeks each. The total duration of the treatment was designed to last approximately eight weeks, with subtle variations expected due to external factors between intact classrooms.

Before the treatment was delivered, two pretests were given to all subjects to determine a reference point for the variables of critical thinking ability and environmental
attitude. Prior to each learning module, a pretest was given to measure students’
existing content knowledge achievement for the content presented in each module.
After students completed each module, they were given a content knowledge posttest.
After the four modules were completed, students were given a posttest for critical
thinking and environmental attitude. All pretests and posttests delivered to each group
were identical. The pretest scores served as covariates to adjust posttest means.

The design of this study was as follows:

\[
\begin{align*}
O_{\text{CtPre}} & \quad O_{\text{EaPre}} \\
O_{\text{CkPreM1}} & \quad X_{M1} \quad O_{\text{CkPostM1}} \\
O_{\text{CkPreM2}} & \quad X_{M2} \quad O_{\text{CkPostM2}} \\
O_{\text{CkPreM3}} & \quad X_{M3} \quad O_{\text{CkPostM3}} \\
O_{\text{CkPreM4}} & \quad X_{M4} \quad O_{\text{CkPostM4}} \\
O_{\text{CtPost}} & \quad O_{\text{EaPost}}
\end{align*}
\]

Key:
Pre – Pretest
Post – Posttest
Ck – Content Knowledge
Ct – Critical Thinking Instrument: CTTEE (Cheak, 1999)
Ea – Environmental Attitude Inventory: EAI (Campbell, Walizcek, & Zajicek, 1999)
M1 – Module 1 Instructional Cluster (~ 2 weeks)
M2 – Module 2 Instructional Cluster (~ 2 weeks)
M3 – Module 3 Instructional Cluster (~ 2 weeks)
M4 – Module 4 Instructional Cluster (~ 2 weeks)
X – Treatment (IBI or DI approach)

In the first observation, students were administered pretests for critical thinking
achievement (O_{CtPre}), environmental attitude (O_{EaPre}), and content knowledge
achievement for the first learning module (O_{CkPreM1}). After pretests were completed,
students were exposed as intact classrooms to the treatment (X). The treatments
consisted of either IBI or DI for each of the learning modules (M1, M2, M3, M4). The
treatment type was randomly assigned to each intact classroom and was used the
entire duration of the study. The classrooms receiving IBI as the teaching method were
considered the experimental group, and classrooms receiving DI were used as the comparison group. Following the delivery of the first learning module \((X_{M1})\), students were given the Module 1 content knowledge posttest \((O_{CKPostM1})\). Before the delivery of the second learning module \((X_{M2})\), students were given the Module 2 content knowledge pretest \((O_{CKPreM2})\). A content knowledge posttest \((O_{CKPostM2})\) was given after the treatment \((X_{M2})\). The cycle of content knowledge pretest, treatment, and content knowledge posttest continued for the third and fourth learning modules \((M3, M4)\). After the four learning modules were delivered, students were administered the critical thinking posttest \((O_{CTPost})\) (Cheak, 1999) and the post Environmental Attitude Inventory instrument \((O_{EaPost})\) (Campbell, Walizcek, & Zajicek, 1999).

**Threats to Internal Validity**

Campbell and Stanley (1963) proposed threats to internal validity inherent in research designs, which include history, maturation, testing, instrumentation, statistical regression, selection, experimental mortality, and diffusion of treatments. The nonrandomized control group, pretest-posttest design used in this study includes an administration of the same pretest and posttest to both the experimental and control groups. Due to the design of this study, maturation, instrumentation, testing, and history were not serious threats to the study’s internal validity (Ary et al., 2014). Regression is only considered a threat with this research design when groups are selected on the basis of extreme scores. This study used random selection to determine which classes received IBI as the treatment and which class received DI as the treatment. Extreme scores were not used to group classes and, therefore, regression was not considered a serious threat to this study.
This study addressed threats to interaction effects. Interaction effects result in differences in posttest scores due to preexisting group differences rather than the treatment itself. In order to reduce this threat, content knowledge, critical thinking, and environmental attitude pretest scores were used as covariates. Testing effect was reduced by randomizing the ordering of questions within each instrument (Campbell & Stanley, 1963), creating a different sequence of questions for each pretest and posttest. The order of multiple choice answers was also randomized for each question. Lastly, multiple schools were used ($n = 13$) to reduce the risk of interaction with subjects.

**Fidelity of Treatment Delivery**

Another threat to this study was the fidelity of the treatment delivery. The ability of teachers to properly deliver the treatment method of IBI or DI could vary. Teachers have indicated low confidence in teaching through IBI approaches (Forbes & Davis, 2008). Professional development on using IBI has been shown to increase teacher confidence in successfully implementing IBI approaches in teaching (Ernst, 2009; Forbes & Zint, 2010; Haney et al., 2007).

Boone (2008) recommended that professional development be used to ensure that teachers effectively deliver the treatment method. This study followed the recommendation by Boone (2008) by identifying teachers who had previously attended professional development in the teaching method under investigation. All teachers participating in the study attended a CASE® Institute and received NRE certification. CASE® Institutes are hosted by affiliated universities and colleges each summer. According to CASE® (n.d.), the CASE® Institute for NRE certification lasts approximately nine days and exposes participants to IBI activities, projects, and
problems for teaching environmental and natural resource concepts through field and lab experiences.

In addition to the selection of teachers who had attended the CASE® Institute for NRE certification, detailed lesson plans for each teacher’s assigned method of treatment delivery were provided. The fidelity of the treatment was further ensured by having teachers record each lesson with an audio recording device. Audio recording devices were attempted to be collected from all teachers at the conclusion of the study. A random selection of 25% of the lessons was chosen from each recording device and analyzed to ensure that teachers appropriately delivered the correct teaching method (Shoulders, 2012; Thoron, 2010). However, as described in the study’s limitations, audio recordings were failed to be collected by all but one teacher, increasing the threat for fidelity of treatment.

**Instructional Design**

The instructional content of the study aligned with existing course design for the Natural Resources and Ecology (NRE) course by CASE®. According to CASE® (n.d), the “Natural Resources and Ecology course is a foundation course within the CASE® sequence of courses. The course provides students a variety of experiences in the fields of natural resources and ecology” (para. 1). The lessons that were utilized in this study followed the CASE® recommended sequencing, in which the content appears near the middle of the suggested year-long course. The content utilized in this study was grouped to include the following learning modules: (a) The Energy of Life, (b) Flourishing Fauna, (c) All Natural Flora, and (d) Agricultural Stewardship. The concept outlines for each instructional cluster designed by CASE® are in Figure 3-1.
CASE® The Energy of Life

1. Energy and nutrients flow through trophic levels within an ecosystem.
2. The geographic area of an ecosystem influences the complexity and type of organisms present.
3. The availability of required resources determines the carrying capacity of a given species in an ecosystem.

CASE® All Natural Flora

1. Biodiversity refers to the variety of living components in an ecosystem.
2. Plants are scientifically identified using taxonomy and various classification systems.
3. Vegetation type present in an ecosystem is influenced by the environment and the activity of animals and humans.
4. Plant populations shift in response to changes in the environment.

CASE® Flourishing Fauna

1. Wildlife require habitat, including food, water, shelter, and space, suited to their needs in order to thrive in a community.
2. Organisms use natural processes to adapt to their environments and increase chances of survival.
3. Human pressures of populations cause artificial selection within a population.
4. Various objectives influence the management of wildlife species.
5. Wildlife management includes improving habitat for a focal species.

CASE® Agricultural Stewardship

1. Sustainable agriculture practices include the efficient use of non-renewable and on-farm resources and, where appropriate, integrate natural biological cycles.
2. Agricultural stewardship balances agriculture productivity and profitability while conserving natural resources.

Figure 3-1. Concept outlines for instructional clusters designed by CASE®.

The instructional content for each of the modules were designed to be taught for a duration of approximately two weeks. For the purpose of this study, the content being taught (learning objectives, vocabulary, major activities, etc.) for each module aligned with the existing CASE® course design. A small amount of supplementary content was
added by the researcher to several of the modules in an attempt to make the duration of each module consistent.

**Instructional Plans**

The content in each of the four learning modules was segmented into four sections, and detailed instructional plans were constructed for each of the four sections. The title and objectives for each instructional plan can be seen in Appendix D. Each treatment included four modules and 16 instructional plans. The learning objectives and content in each instructional plan were the same for both IBI and DI treatments. However, how content was taught for each instructional plan varied according to each instructional approach. A total of 32 instructional plans (Appendix G; H) was constructed for the study; 16 plans were developed for the IBI treatment (Appendix G) and 16 plans were developed for the DI treatment (Appendix H). Instructional plans for each treatment were reviewed by a panel of faculty members at the University of Florida in the Department of Agricultural Education and Communication to ensure content validity. The panel of experts concluded (a) content remained consistent between both methods of delivery, (b) lesson plans were designed to appropriately reflect each method of delivery, and (c) lesson plans were practical and easy to follow.

**Direct Instruction.** Instructional plans for the control group were designed to follow recommended components in lesson design using DI (Eggen & Kauchak, 2012). Each instructional plan consisted of the following components: course title; unit title; lesson title; estimated time; objectives; equipment, supplies, references, and other resources; student preparation (interest approach); teacher directions/methods; content outline/key points; application; closure/summary; and evaluation. Instructional plans followed the four stages of implementing DI lessons identified by Eggen and Kauchak.
(2012): (a) introduction and review, (b) teacher presentation, (c) guided practice, and (d) independent practice. Each instructional plan began with a brief student preparation activity or interest approach (Schuck, 1970). Interest approaches were designed for a duration of five to ten minutes. Examples of interest approach activities included, but were not limited to bell ringer questions, review of previously taught material leading to new discussion, and short video clips (Appendix H).

Following each lesson’s interest approach, instructional plans required teachers to provide students information using DI techniques. Common methods to achieve this included having the teacher write notes on the board while having students keep notes in a notebook. Teachers were provided PowerPoint® slides and student note sheets in many of the instructional plans.

After information was presented to students by the teacher, students applied the information through an application activity. The type of application activities varied in the instructional plans but included activities that had both guided and independent practice. Existing CASE® activities were often used, as well as modified CASE® activities.

Each lesson also included a way for the teacher to evaluate student learning. Lessons concluded with a closure or summary activity. A commonly used lesson closure had the teacher call on students to give answers for conclusion questions.

**Inquiry-based Instruction.** Instructional plans for teachers using the IBI treatment included: course title; unit title; lesson title; estimated time; objectives; equipment, supplies, references, and other resources; teacher directions (5E stages); content outline/key points; and lesson summary. The BSCS 5E Instructional Model (Bybee et al., 2006) was used in each of the instructional plans. Teachers were given a
description of the 5-E Model that included information on what the teacher does and what the student does for each phase of the model (Appendix G). A description was also provided that explained how each phase of the 5-E model supports science learning. The BSCS 5E Instructional Model includes the following phases of student inquiry: Engage, Explore, Explain, Elaborate, and Evaluate. Lesson plans using the 5-E model were designed according to recommendations and examples from the book *Teaching Science Through Inquiry and Investigation, 12th Ed.* (Contant, Bass, & Carin, 2014).

**Delivery of Treatment**

Intact agriscience classrooms were randomly assigned as the experimental or control group. Contact with each teacher was made to initiate the delivery of the study’s materials. Each teacher received instructional plans for the type of treatment they would deliver. One teacher, who taught four sections of the CASE® NRE course, was assigned two classes to the experimental group and two classes to the control group and received separate instructional materials for both groups. Teachers received a hard copy of instructional plans in a binder by mail. Teachers were also given electronic access to instructional plans through a researcher-made website, using the Wix® cloud-based, web development platform.

**Instrumentation and Data Collection**

A timeline was provided to teachers (Appendix F) that described the correct sequence to administer student pretests and posttests. Teachers had the option to administer the study’s instruments via paper copy or electronically. All teachers elected to have students complete the study’s instruments electronically. Access to electronic instruments was created by the researcher using Qualtrics software. Students were able
to access each instrument by visiting a researcher-made website that served as the homepage for all assessment and survey links. Student demographic data were also collected electronically.

To access each instrument, students created a unique identification number that consisted of their school’s initials, followed by their own numerical six-digit birthdate in month, day, and year format. For example, a student attending Saint John’s High School and who had a birthdate of July 31st, 2003 would use the unique identification number SJHS073103. Teachers ensured that no students enrolled in their course had the same birthdate as another student. Data from each instrument were instantaneously available to the researcher upon student submission. Students were unable to see their pretest and posttest results upon submission. However, student results were shared with teachers through email when requested. Teachers were encouraged to use each module’s content knowledge posttest as a score for classroom grades.

Ten instruments were used to collect data for this study. Students completed four content knowledge pretests, four content knowledge posttests, a pretest and posttest for critical thinking, and a pretest and posttest to measure environmental attitude.

**Content Knowledge Assessment**

Student content knowledge achievement was assessed through four researcher-developed posttests for each learning module: (a) The Energy of Life, (b) Flourishing Fauna, (c) All Natural Flora, and (d) Agricultural Stewardship. Pretests were administered prior to each module’s treatment, served as a baseline level of knowledge for each group, and were used as covariates to adjust posttest means. Each content knowledge pretest and posttest included 20 multiple-choice questions. A total of 80 items measured students’ content knowledge. Thirty-one of the 80 questions came from
a CASE® test bank of questions that aligned with the content utilized in this study. The remaining 49 items were researcher developed. The content knowledge questions for each module aligned with the learning objectives in each module’s instructional plans. A panel of experts in the Department of Agricultural Education and Communication at the University of Florida was used to ensure that content knowledge pretests and posttests had face and content validity.

Students’ correct and incorrect scores were recorded for each item. Kuder-Richardson 20 (KR20) scores were used to establish reliability coefficients for each of the content knowledge instruments. KR20 scores have been determined to be appropriate for establishing the reliability of dichotomous data (Gall, Borg, & Gall, 1996; Huck, 2008). A post-hoc reliability analysis using KR20 scores for the content knowledge posttests yielded reliability coefficients of .80, .85, .75, and .82, respectively.

**Critical Thinking**

Students’ critical thinking skills were assessed using the Critical Thinking Test in Environmental Education (CTTEE) (Cheak, 1999). The CTTEE is considered a reliable and valid instrument designed to measure students’ critical thinking in environmental education in grades six through college freshmen. Cheak (1999) reported a Cronbach’s alpha reliability estimate of .87 and .70 for high school and college samples, respectively. Robinson (2001) further provided reliability of the instrument with sixth grade students and was able to discriminate between student’s critical thinking ability with a Cronbach’s alpha of .72.

The CTTEE instrument consisted of 27 multiple-choice items and included the sections (a) identifying bias, (b) drawing conclusions, and (c) making inferences. Each section began with a set of specific directions and a short passage, followed by a set of
multiple-choice questions with one correct answer for each question. Student scores can range from 0 to 27. The instrument was designed to be administered in standard pretest-posttest fashion. Robinson (2005) changed the order of sections in the posttest in an attempt to avoid the threat of internal validity, as a result of pretesting. Following the guidelines presented by (Cheak, 1999), this study utilized the CTTEE as a pretest and posttest. The order of sections was changed on the posttest, as suggested by Robinson (2005). The Kuder-Richardson 20 was used to establish reliability for the instrument used in this study, due to the use of dichotomous data (Gall, Borg, & Gall, 1996; Huck, 2008). The CTTEE instrument was determined to have a coefficient alpha of .78.

**Environmental Attitude**

Students’ environmental attitudes were assessed using 15 items on a Likert-type scale (1 = strongly disagree; 2 = disagree; 3 = neither agree or disagree; 4 = agree; 5 = strongly agree) (Appendix I). Each of the 15 items consisted of a statement designed to measure students’ attitudes toward the protection of the environment. The scale was developed by Campbell, Walizcek, and Zajicek (1999) through a combination of existing scales (Armstrong, 1989; Armstrong & Impara, 1991; Campbell, 1994). Campbell, Walizcek, and Zajicek (1999) administered the instrument as a pretest and posttest to measure changes in students’ environmental attitude after a 10-day, environmentally-focused unit in an introduction to agriscience course. A total of 475 agriscience students completed the assessment. The researchers reported the instrument to have a Cronbach’s alpha reliability coefficient of .64. The Cronbach’s alpha reliability coefficient for this study was calculated to be .70.
An electronic version of the Environmental Attitude Inventory (Campbell, Walizcek, & Zajicek, 1999) was created through Qualtrics. The environmental attitude inventory was administered electronically through a link that students selected on the website homepage. Teachers were asked to administer the pretest prior to both the CTTEE pretest and Module 1 treatment. Students were administered the posttest after completion of all modules and the CTTEE posttest.

**Data Analysis**

Data collected from this study were analyzed by using the Statistical Package for the Social Sciences (SPSS) version 22. Descriptive statistics in the form of means, frequencies, and standard deviations were used to describe the demographic characteristics of high school agriscience students. Objectives 1, 2, and 3 were analyzed by the use of an analysis of covariance (ANCOVA). For Objective 1, which sought to compare the content knowledge achievement of high school agriscience students taught using an IBI approach to a DI approach, posttest content knowledge scores for each module were analyzed separately. For Objective 2, which sought to compare the critical thinking ability of high school agriscience students taught using an IBI approach to a DI approach, posttest scores on the CTTEE were analyzed. For Objective 3, which sought to compare environmental attitude of high school agriscience students taught using an IBI approach to a DI approach, posttest scores on the EAI were analyzed. Pretests for each instrument served as covariates in the analyses conducted for Objectives 1, 2, and 3. For Objective 4, which sought to examine relationships between variables in the study, correlational statistics were used.
Chapter Summary

This chapter discussed the research methods that were used to address the research questions presented in this study. Areas of focus in this chapter included the study’s population and sample, research design and procedure, instructional design, instrumentation and data collection, and process for analysis of data.

The population for this study included all secondary agriscience students in the United States. The accessible population was all students of agriscience teachers who completed the CASE® Institute for NRE certification between the years 2013 and 2017. A sample size of 240 students was calculated to be practically and statistically significant. The number of agriscience classrooms and teachers needed to participate in the study was determined to be 12. The collected sample size included 13 teachers and 222 students, which was deemed appropriate for the study. All teachers participating in the study attended the CASE Institute for NRE certification between the years 2013 and 2017 and taught the NRE course in a high school SBAE program during the spring of 2018.

The study was quasi-experimental and used a nonrandomized control group, pretest-posttest design. The independent variable under investigation was the teaching method. Intact agriscience classrooms were randomly assigned to be a part of the experimental group or control group. Classrooms assigned to the experimental group received IBI as the treatment, and classrooms assigned to the control group received DI as the treatment. Both treatments were designed for a duration of eight weeks.

Dependent variables under investigation were students’ content knowledge achievement, critical thinking ability, and environmental attitude. Students’ content knowledge achievement was measured for each of the four learning modules.
throughout the study. A series of eight researcher-designed, pretests and posttests assessed students’ content knowledge achievement for each module. Critical thinking ability was measured by the Critical Thinking Test in Environmental Education (Cheak, 1999). The CTTEE was used as a pretest before the treatment and as a posttest after the entire duration of the treatment. Students’ environmental attitudes were measured by the Environmental Attitude Inventory, which consisted of 15 items measured on a Likert-type scale (Campbell, Walizcek, & Zajicek, 1999). The EAI instrument was administered as a pretest before the delivery of the treatment and as a posttest at the conclusion of the study. All pretests were used as covariates to adjust posttest means.

Data were analyzed using SPSS version 22. Descriptive statistics were used to describe the study's sample. Objectives 1, 2, and 3 were each examined using an analysis of covariance (ANCOVA). Objective 4 was examined using correlational statistics. The following chapter will describe the results of the study.
CHAPTER 4
RESULTS

The purpose of Chapter 1 was to introduce and explain the need for this study. Chapter 1 discussed complex agricultural and environmental problems of the 21st century and the need to equip individuals with the knowledge, skills, and environmental sensitivity that will be required to address these challenges. The purpose of this study was to determine the effects of inquiry-based instruction in an environmentally focused agriscience curriculum. Specifically, this study examined students’ content knowledge achievement, critical thinking ability, and environmental attitudes as a result of IBI.

Chapter 2 provided literature that led to the development of the conceptual model used for this study. The model conceptualized the relational factors associated with teaching and learning using IBI in agriscience and environmental education programs. Chapter 2 also incorporated a theoretical framework. The theories included in the framework were the theory of cognitive development (Piaget, 1952), sociocultural theory (Vygotsky, 1962), and the theoretical perspective of constructivism. The Presage-Process-Product (3P) model (Biggs, 2003) was adapted for the design of this study’s conceptual framework. The 3P model (Biggs, 2003) explained the relational phenomenon of teaching and learning with characteristics of students, characteristics of instructors, instructional activities and strategies, and learning outcomes. The body of literature reviewed and presented included areas related to science education, environmental education, agricultural education, critical thinking, content knowledge, and attitude.

The purpose of Chapter 3 was to detail the research methods utilized in this study. The design of the study was a nonrandomized control group, pretest-posttest
design using intact agriscience classrooms, and was, therefore, quasi-experimental. Data were collected through a series of pretests and posttests. Instruments measuring students’ content knowledge achievement, critical thinking ability, and environmental attitude were used. Descriptive statistics, ANCOVA, and correlations were used to analyze data.

This chapter presents the results of the study. Demographic data and completion rates of the sample are discussed. Results to the following objectives are provided:

1. Compare the content knowledge achievement of high school agriscience students taught using an IBI approach to a DI approach.
2. Compare the critical thinking ability of high school agriscience students taught using an IBI approach to a DI approach.
3. Compare the environmental attitude of high school agriscience students taught using an IBI approach to a DI approach.
4. Examine the relationship between students’ content knowledge achievement, critical thinking ability, environmental attitude, and demographic makeup.

**Sample**

The population of this study was all high school agriscience students in the United States. The accessible population for this study was secondary school agriscience students of teachers who completed Natural Resources and Ecology (NRE) CASE® certification between the years 2013 and 2017. The teacher sampling frame for this study consisted of a list of agriscience teachers who completed the CASE® Institute for NRE certification between 2013 and 2017 ($n = 167$). An invitation to participate in the study was sent to all teachers identified on the list. Forty-five teachers expressed interest in the study, however 29 teachers did not meet the following requirements to participate in the study: (a) the teacher completed the CASE® Institute for NRE certification between 2013 and 2017, (b) the teacher planned to teach the CASE® NRE
course to high school students during spring of 2018, and (c) the teacher was willing and able to deliver the study’s treatment for a duration of eight weeks during the spring of 2018. A phone conversation was attempted with each of the 21 teachers meeting the parameters of the study and 17 teachers were successfully contacted via phone. After learning about the study in more detail, four teachers decided to not participate in the study due to complications. Thirteen teachers agreed to participate in the study and were sent all materials required to participate. After receiving materials, one teacher decided not to participate and was dropped from the study’s sample.

A total of 12 teachers served as the sample for the study. Eleven teachers taught one section of the NRE course, and one teacher taught four sections. Teachers who taught one section of the NRE course were randomly assigned to either the control group or the experimental group. The teacher who taught four sections was assigned the control group for two sections and the experimental group for two sections and received separate materials for both treatments. Teacher codes were used for data analysis to ensure anonymity. Six teachers were assigned to the experimental group and used IBI as the treatment. The six school codes for the experimental group were: IB-A, IB-B, IB-C, IB-D, IB-E, and IB-F. Seven teachers were assigned to the control group and used DI as the treatment. The seven school codes for the control group were DI-A, DI-B, DI-C, DI-D, DI-E, DI-F, and DI-G.

**Teacher and School Demographics**

As indicated as a requirement for teachers to participate in this study, teachers had completed the CASE® Institute for NRE certification between the years 2013 and 2017. One teacher completed the CASE® Institute for NRE certification in 2013, and three teachers became certified in 2014. Two teachers completed the institute in 2016,
and six teachers completed the institute in 2017. Table 4-1 displays the years in which teachers completed the CASE® Institute for NRE certification.

<table>
<thead>
<tr>
<th>Year of CASE® Institute Attendance</th>
<th>Number of Teacher Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>1</td>
</tr>
<tr>
<td>2014</td>
<td>3</td>
</tr>
<tr>
<td>2015</td>
<td>0</td>
</tr>
<tr>
<td>2016</td>
<td>2</td>
</tr>
<tr>
<td>2017</td>
<td>6</td>
</tr>
</tbody>
</table>

The gender of teachers was collected to further describe characteristics of individuals delivering the treatment. Four male teachers and eight female teachers participated in this study (Table 4-2).

<table>
<thead>
<tr>
<th>Gender</th>
<th>Number of Teacher Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>4</td>
</tr>
<tr>
<td>Female</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
</tr>
</tbody>
</table>

School demographics collected in this study included region, division, and locale boundary. Region and division characteristics were described according to the United States Census Bureau (2015) classification system. Regions were classified as Northeast, Midwest, South, and West. Nine divisions further defined geographical area. Locale boundaries were used to describe geographic and demographic estimates in reference to population attributes. The National Center for Educational Statistics locale boundary classification system was used (Geverdt, 2015). The locale boundary classification system uses 12 distinct categories. Primary categories include City, Suburban, Town, and Rural. Subcategories for City and Suburban are Large, Midsize, and Small. The categories of Town and Rural include subcategories of Fringe, Distant,
Table 4-3 displays school demographics for each school that participated in this study.

<table>
<thead>
<tr>
<th>School Code</th>
<th>Region</th>
<th>Division</th>
<th>Locale Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>IB-A</td>
<td>Midwest</td>
<td>West North Central</td>
<td>Town - Remote</td>
</tr>
<tr>
<td>IB-B</td>
<td>Midwest</td>
<td>West North Central</td>
<td>Rural - Remote</td>
</tr>
<tr>
<td>IB-C</td>
<td>Midwest</td>
<td>West North Central</td>
<td>Rural - Fringe</td>
</tr>
<tr>
<td>IB-D</td>
<td>Midwest</td>
<td>East North Central</td>
<td>Town - Distant</td>
</tr>
<tr>
<td>IB-E</td>
<td>Northeast</td>
<td>Middle Atlantic</td>
<td>Rural - Distant</td>
</tr>
<tr>
<td>IB-F</td>
<td>West</td>
<td>Pacific</td>
<td>City - Midsize</td>
</tr>
<tr>
<td>DI-A</td>
<td>Midwest</td>
<td>West North Central</td>
<td>Rural - Distant</td>
</tr>
<tr>
<td>DI-B</td>
<td>Midwest</td>
<td>West North Central</td>
<td>Rural - Distant</td>
</tr>
<tr>
<td>DI-C</td>
<td>Midwest</td>
<td>East North Central</td>
<td>Town - Fringe</td>
</tr>
<tr>
<td>DI-D</td>
<td>Midwest</td>
<td>West North Central</td>
<td>Rural - Fringe</td>
</tr>
<tr>
<td>DI-E</td>
<td>Midwest</td>
<td>West North Central</td>
<td>Rural - Distant</td>
</tr>
<tr>
<td>DI-F</td>
<td>West</td>
<td>Pacific</td>
<td>City - Midsize</td>
</tr>
<tr>
<td>DI-G</td>
<td>Midwest</td>
<td>West North Central</td>
<td>Town - Distant</td>
</tr>
</tbody>
</table>

The Hay’s formula (1973) was used to calculate a sample size that is practically and statistically significant without finding significance due to an inflated sample size. A sample size of 60 subjects for each treatment was calculated through the reduction of committing a Type I error to .05, to achieve a desired power of .90, and to detect variance in the independent variable at a level greater than .10. Due to high mortality rates seen in similar studies (Boone, 1988; Dyer, 1995; Flowers, 1986; Myers, 2004; Park, 2005; Shoulders, 2012), the sample size was doubled to 120 subjects for each treatment.

The 13 teachers identified to participate in the study estimated the combined number of students enrolled in the CASE® NRE courses to be 222 and was deemed sufficient for this study. Due to one prospective teacher participant dropping the study before it began and over estimations of student enrollment, the actual sample size of the study was lower than anticipated. A total of 181 students participated in the study.
Each student who participated in this study agreed to participate by either completing a consent form if they were over 18 years of age, or if under 18 years of age, having their parents complete the consent form and reading an assent form. Appendix C displays students consent and assent forms.

The number of students in each class varied considerably. Several schools had low student enrollment in the NRE course (IB-A, IB-C, DI-A, DI-B), while other schools offered multiple sections and had larger student enrollment (IB-F, DI-F). Student participation in each school’s section ranged from three to 39 students. Table 4-4 displays the number of students participating in this study by school section.

<table>
<thead>
<tr>
<th>School Code</th>
<th>Number of Students</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>IB-A</td>
<td>3</td>
<td>1.7</td>
</tr>
<tr>
<td>IB-B</td>
<td>9</td>
<td>5.0</td>
</tr>
<tr>
<td>IB-C</td>
<td>4</td>
<td>2.2</td>
</tr>
<tr>
<td>IB-D</td>
<td>19</td>
<td>10.5</td>
</tr>
<tr>
<td>IB-E</td>
<td>21</td>
<td>11.6</td>
</tr>
<tr>
<td>IB-F</td>
<td>37</td>
<td>20.4</td>
</tr>
<tr>
<td>DI-A</td>
<td>3</td>
<td>1.7</td>
</tr>
<tr>
<td>DI-B</td>
<td>5</td>
<td>2.8</td>
</tr>
<tr>
<td>DI-C</td>
<td>9</td>
<td>5.0</td>
</tr>
<tr>
<td>DI-D</td>
<td>7</td>
<td>3.9</td>
</tr>
<tr>
<td>DI-E</td>
<td>10</td>
<td>5.5</td>
</tr>
<tr>
<td>DI-F</td>
<td>39</td>
<td>21.5</td>
</tr>
<tr>
<td>DI-G</td>
<td>15</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Intact classrooms in six schools (IB-A, IB-B, IB-C, IB-D, IB-E, IB-F) were randomly assigned to the experimental group and received IBI as the treatment. Intact classrooms in seven schools (DI-A, DI-B, DI-C, DI-D, DI-E, DI-F, DI-G,) were randomly assigned to the control group and received DI as the treatment. The number of students receiving IBI was 93 and the number of students receiving DI was 88. Table 4-5 displays student participation totals by group.
Table 4-5. Participation totals by group.

<table>
<thead>
<tr>
<th>Treatment</th>
<th># Intact Classrooms</th>
<th># of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inquiry-based Instruction</td>
<td>6</td>
<td>93</td>
</tr>
<tr>
<td>Direct Instruction</td>
<td>7</td>
<td>88</td>
</tr>
<tr>
<td>Total</td>
<td>13</td>
<td>181</td>
</tr>
</tbody>
</table>

**Student Demographics**

Students participating in this study were given the option to self-report demographic data. Demographic data collected for each student were gender, age, and ethnicity.

**Gender.** A total of 46.4% \((n = 84)\) of the students identified as male, and 33.7% \((n = 61)\) identified as female. Thirty-six students did not reveal gender. The experimental group contained 39 males (41.9%) and 34 females (36.6%). Twenty students (21.5%) in the experimental group did not indicate gender. Of the 88 students in the control group, a majority was male (51.1%, \(n = 45\)). Twenty-seven students (30.7%) in the control group indicated being female, however, 16 students (18.2%) did not reveal their gender. Table 4-6 displays student participation by gender.

Table 4-6. Student participation by gender \((n = 181)\).

<table>
<thead>
<tr>
<th>Gender</th>
<th>IBI ((n = 93))</th>
<th>DI ((n = 88))</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n)</td>
<td>%</td>
<td>(n)</td>
</tr>
<tr>
<td>Male</td>
<td>39</td>
<td>41.9</td>
<td>45</td>
</tr>
<tr>
<td>Female</td>
<td>34</td>
<td>36.6</td>
<td>27</td>
</tr>
<tr>
<td>Non-response</td>
<td>20</td>
<td>21.5</td>
<td>16</td>
</tr>
</tbody>
</table>

*Note: IBI = Inquiry-based Instruction; DI = Direct Instruction*

**Age.** Students were asked to share their birthdate in a month-day-year format. Student ages were calculated at the end of the first month of the study when all teachers were delivering the treatment. Students ranged from 14 to 19 years of age. The majority of students was 16 years of age (34.3%, \(n = 62\)), followed by 15 years of
age (24.3%, n = 24.3), 17 years of age (19.9%, n = 36), 18 years of age (13.3%, n = 24), 14 years of age (7.2%, n = 13), and 19 years of age (1.1%, n = 2). Overall, students in the control group were slightly younger in age. More students in the control group were 14 years of age (11.4%, n = 10) and 15 years of age (30.7%, n = 27), compared to the treatment group, which consisted of three (3.2%) 14 year-olds and 17 (18.3%) fifteen year-olds. The treatment group also had more students who were 18 years old (21.5%, n = 20) compared to the control group (4.5%, n = 4). Table 4-7 displays student participation by age.

Table 4-7. Student participation by age (n = 181).

<table>
<thead>
<tr>
<th>Age</th>
<th>IBI (n = 93)</th>
<th>DI (n = 88)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>14</td>
<td>3</td>
<td>3.2</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>17</td>
<td>18.3</td>
<td>27</td>
</tr>
<tr>
<td>16</td>
<td>30</td>
<td>32.3</td>
<td>32</td>
</tr>
<tr>
<td>17</td>
<td>22</td>
<td>23.7</td>
<td>14</td>
</tr>
<tr>
<td>18</td>
<td>20</td>
<td>21.5</td>
<td>4</td>
</tr>
<tr>
<td>19</td>
<td>1</td>
<td>1.1</td>
<td>1</td>
</tr>
</tbody>
</table>

*Note: IBI = Inquiry-based Instruction; DI = Direct Instruction*

**Ethnicity.** Students were given the option to self-report ethnicity. A total of 143 students (79%) reported ethnicity. A majority of students identified as White, non-Hispanic (58%, n = 105), followed by Hispanic or Latino (11%, n = 20), Black or African American (3.3%, n = 6), and Asian or Pacific Islander (2.2%, n = 4). Eight students (4.4%) identified as Other. Students’ ethnicities were somewhat similar across treatment groups. The experimental group contained a higher percentage of Hispanic or Latino students (15.1%, n = 14) compared to the control group (6.8%, n = 6). Slightly more students in the control group (5.7%, n = 5) identified as Black or African American compared to the experimental group (1.1%, n = 1). Two students each in the
experimental group and control group identified as Asian or Pacific Islander. Table 4-8 displays student participation by their self-reported ethnicity.

Table 4-8. Participation by ethnicity (n = 181).

<table>
<thead>
<tr>
<th>Ethnicity</th>
<th>Treatment Group</th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IBI (n = 93)</td>
<td>DI (n = 88)</td>
<td></td>
<td>n %</td>
</tr>
<tr>
<td>Asian or Pacific Islander</td>
<td>2 2.2</td>
<td>2 2.3</td>
<td>4</td>
<td>2.2</td>
</tr>
<tr>
<td>Black or African American</td>
<td>1 1.1</td>
<td>5 5.7</td>
<td>6</td>
<td>3.3</td>
</tr>
<tr>
<td>Hispanic or Latino</td>
<td>14 15.1</td>
<td>6 6.8</td>
<td>20</td>
<td>11.0</td>
</tr>
<tr>
<td>White, non-Hispanic</td>
<td>50 53.8</td>
<td>55 62.5</td>
<td>105</td>
<td>58.0</td>
</tr>
<tr>
<td>Other</td>
<td>5 5.4</td>
<td>3 3.4</td>
<td>8</td>
<td>4.4</td>
</tr>
<tr>
<td>Non-response</td>
<td>21 22.6</td>
<td>17 19.3</td>
<td>38</td>
<td>21.0</td>
</tr>
</tbody>
</table>

Note: IBI = Inquiry-based Instruction; DI = Direct Instruction

Responses

A series of twelve instruments was used to collect data throughout the duration of this study. Although all teachers had the option to deliver instruments via hard copy or electronically, all teachers utilized the electronic option for student assessments. Students completed the electronic instruments through a link provided on a web page created by the researcher for the purpose of this study. Each student’s content knowledge achievement was measured through four pretests and posttests. Content knowledge pretests were administered before each module, and content knowledge posttests were administered after each module. Each student’s critical thinking ability was measured at the beginning of the study through the Critical Thinking Test in Environmental Education (CTTEE) (Cheak, 1999). The CTEE was again delivered as a posttest after students were exposed to the entire treatment. The Environmental Attitude Inventory (EAI) (Campbell, Walizcek, & Zajicek, 1999) was used to measure students’ attitudes toward the environment. The EAI was administered as a pretest at the start of the study and as a posttest after the entire treatment.
Response Rates

Data were received from all teachers who started the study. Teachers in 12 of the 13 intact classrooms completed the delivery of the entire treatment. One teacher was only able to complete one of the modules and cited a lack of time to complete the remaining modules. Compared to similar studies (Shoulders, 2012), this study had a low teacher mortality rate, however, completion rates for this study’s instruments varied considerably. Teachers cited forgetfulness, student test fatigue, student absences, and technological problems as reasons for students not completing instruments.

Instrument completion rates for the eight content knowledge assessments were, in general, above 70%. However, content knowledge completion rates for the control group were slightly lower and ranged from 59.1% \( (n = 52) \), as seen in the Module 3 posttest, to 92% \( (n = 81) \) as seen in the Module 1 posttest. The experimental group had higher instrument completion rates for Modules 2 through 4. Completion rates as high as 91.4% \( (n = 84) \) and 87.1% \( (n = 81) \) were recorded.

Completion rates for the CTTEE instrument were higher on the pretest (86.2%, \( n = 156 \)) compared to the posttest (61.9%, \( n = 112 \)). The completion rates for the control group’s pretest (84.1%, \( n = 74 \)) and posttest (63.6%, \( n = 56 \)) were similar to those of the experimental group’s pretest (88.2%, \( n = 82 \)) and posttest (60.2%, \( n = 56 \)). Teachers cited a conflict in time and test fatigue for lower CTTEE posttest completion.

A total of 80.1% \( (n = 145) \) of students completed the EAI pretest. Completion rates between the treatment and control groups were similar. Less students completed the EAI posttest (68%, \( n = 123 \)). Table 4-9 displays the completion rates for all 12 instruments used to collect data in this study.
The instrument completion rates shown in Table 4-9 only reflect the percentage of students completing each instrument. Due to the design of this study, data were only included for each student who completed a pretest and posttest for each instrument, creating a paired sample. In several instances, teachers forgot to administer pretests and only administered posttests (or vice versa). These students’ posttest scores were, therefore, not utilized in the analysis of data for the study’s objectives. Furthermore, students were prompted to enter their student ID at the beginning of each instrument. In several instances, students entered incorrect ID numbers on assessments, preventing the pretest and posttest scores to be paired.

Completion rates for paired samples were calculated to properly reflect the data available for analysis in this study. As expected, completion rates for students successfully completing both the pretests and posttests for instruments were lower than completion rates for individual instruments. Instruments measuring content knowledge

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Treatment Group</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IBI (n = 93)</td>
<td>DI (n = 88)</td>
<td>Total (n = 181)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module 1 Pretest</td>
<td>75  80.6%</td>
<td>78  88.6%</td>
<td>153  84.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module 1 Posttest</td>
<td>85  91.4%</td>
<td>81  92.0%</td>
<td>166  91.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module 2 Pretest</td>
<td>75  80.6%</td>
<td>53  60.2%</td>
<td>128  70.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module 2 Posttest</td>
<td>53  60.2%</td>
<td>69  78.4%</td>
<td>150  82.9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module 3 Pretest</td>
<td>74  79.6%</td>
<td>60  68.2%</td>
<td>134  74.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module 3 Posttest</td>
<td>75  80.6%</td>
<td>52  59.1%</td>
<td>127  70.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module 4 Pretest</td>
<td>63  71.6%</td>
<td>71  76.3%</td>
<td>134  74.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module 4 Posttest</td>
<td>60  68.2%</td>
<td>76  81.7%</td>
<td>136  75.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EAI Pretest</td>
<td>73  78.5%</td>
<td>72  81.8%</td>
<td>145  80.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EAI Posttest</td>
<td>60  64.5%</td>
<td>63  71.6%</td>
<td>123  68.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTTEE Pretest</td>
<td>65  60.2%</td>
<td>74  84.1%</td>
<td>156  86.2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTTEE Posttest</td>
<td>56  63.6%</td>
<td>75  80.6%</td>
<td>112  61.9%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: IBI = Inquiry-based Instruction; DI = Direct Instruction; CTTEE = Critical Thinking Test in Environmental Education; EAI = Environmental Attitude Inventory
had paired sample completion rates between 59.1% \((n = 111)\), as seen in Module 3, to 79.0% \((n = 143)\), as seen in Module 1. The paired sample completion rates were higher, in general, for the experimental group compared to the control group. Paired sample completion rates for the control group were as low as 47.1% \((n = 42)\) and 48.9% \((n = 43)\).

The paired sample completion rate for the EAI was 55.8% \((n = 101)\). Scores for both the pretest and posttest for EAI were recorded from 53.8% \((n = 50)\) of students in the experimental group and 58.0% \((n = 51)\) in the control group. The paired sample completion rate for the CTTEE was 54.7% \((n = 99)\). The control group had a completion rate of 52.3% \((n = 46)\) and the experimental group had a completion rate of 57.0% \((n = 53)\). Table 4-10 displays completion rates for students who completed both the pretest and posttest for each instrument.

**Table 4-10. Instrument completion rates for paired samples.**

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Treatment Group</th>
<th>IBI ((n = 93))</th>
<th>DI ((n = 88))</th>
<th>Total ((n = 181))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(n)</td>
<td>(%)</td>
<td>(n)</td>
<td>(%)</td>
</tr>
<tr>
<td>Module 1 Paired Pre-Post</td>
<td>69</td>
<td>74.2</td>
<td>74</td>
<td>84.1</td>
</tr>
<tr>
<td>Module 2 Paired Pre-Post</td>
<td>69</td>
<td>74.2</td>
<td>42</td>
<td>47.7</td>
</tr>
<tr>
<td>Module 3 Paired Pre-Post</td>
<td>64</td>
<td>68.8</td>
<td>43</td>
<td>48.9</td>
</tr>
<tr>
<td>Module 4 Paired Pre-Post</td>
<td>67</td>
<td>72.0</td>
<td>54</td>
<td>61.4</td>
</tr>
<tr>
<td>EAI Paired Pre-Post</td>
<td>50</td>
<td>53.8</td>
<td>51</td>
<td>58.0</td>
</tr>
<tr>
<td>CTTEE Paired Pre-Post</td>
<td>53</td>
<td>57.0</td>
<td>46</td>
<td>52.3</td>
</tr>
</tbody>
</table>

*Note:* IBI = Inquiry-based Instruction; DI = Direct Instruction; CTTEE = Critical Thinking Test in Environmental Education; EAI = Environmental Attitude Inventory

**Result of Objectives**

**Objective 1.** Compare the content knowledge achievement of high school agriscience students taught using an IBI approach to a DI approach.
Students’ knowledge of environmental concepts and principles was measured through a series of four pretests and four posttests developed by the researcher. A content knowledge pretest was administered before each learning module, followed by a two-week treatment. After each treatment, students were administered a content knowledge posttest. Each module’s pretest and posttest included 20 multiple-choice questions that aligned to the learning objectives for each module. The ordering of questions was randomized during the posttest. A maximum score of 100 was possible for each pretest and posttest. Reliability for each instrument was calculated using the Kuder-Richardson (KR20) score (Huck, 2008). KR20 scores for each content knowledge instrument indicated acceptable reliability. Table 4-11 displays KR20 scores for each of the four instruments used to measure student content knowledge.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>KR20 Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module 1 Content Knowledge</td>
<td>.80</td>
</tr>
<tr>
<td>Module 2 Content Knowledge</td>
<td>.85</td>
</tr>
<tr>
<td>Module 3 Content Knowledge</td>
<td>.75</td>
</tr>
<tr>
<td>Module 4 Content Knowledge</td>
<td>.82</td>
</tr>
</tbody>
</table>

A content knowledge pretest was administered prior to the start of each module. Pretest scores were utilized to establish a baseline level of knowledge and were used as covariates to adjust posttest means. The four learning modules utilized in this study were: (a) Module 1, The Energy of Life; (b) Module 2, Flourishing Fauna; (c) Module 3, All Natural Flora; and (d) Module 4, Agricultural Stewardship.

The overall pretest mean for Module 1 was 53.04 ($SD = 19.41, n = 143$). The experimental group reported a mean of 50.43 ($SD = 19.75, n = 69$), and the control group had a mean score of 55.47 ($SD = 18.89, n = 74$). The overall mean score for the
Module 2 pretest was 48.65 (SD = 21.33, n = 111), with the experimental group reporting a mean score of 50.65 (SD = 21.47, n = 69) and the control group reporting a slightly lower mean score of 45.36 (SD = 20.94, n = 42). The overall mean content knowledge pretest scores for Modules 3 and 4 were lower. Module 3 had an overall mean score of 38.13 (SD = 14.64, n = 107) and Module 4 had an overall mean score of 36.61 (SD = 17.09, n = 121). Module 3 pretest mean scores for the experimental group (M = 37.58, SD = 14.77, n = 64) and control group (M = 38.95, SD = 14.58, n = 43) were similar. Lastly, mean pretest scores for the Module 4 content knowledge instrument were 38.36 (SD = 18.76, n = 67) for the experimental group and 34.44 (SD = 14.66, n = 54) for the control group. Table 4-12 displays pretest mean scores for content knowledge instruments.

Table 4-12. Pretest mean scores for content knowledge instruments.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>IBI</th>
<th>DI</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Module 1 CK</td>
<td>69</td>
<td>50.43</td>
<td>19.75</td>
</tr>
<tr>
<td>Module 2 CK</td>
<td>69</td>
<td>50.65</td>
<td>21.47</td>
</tr>
<tr>
<td>Module 3 CK</td>
<td>64</td>
<td>37.58</td>
<td>14.77</td>
</tr>
<tr>
<td>Module 4 CK</td>
<td>67</td>
<td>38.36</td>
<td>18.76</td>
</tr>
</tbody>
</table>

Note: IBI = Inquiry-based Instruction; DI = Direct Instruction; CK = content knowledge

A content knowledge posttest was administered after the delivery of each module. Student scores for the content knowledge posttests were used to measure content knowledge achievement for the learning objectives identified in each module. The highest overall posttest mean score of 70.87 (SD = 20.16, n = 143) was calculated for Module 1. The experimental group scored an average of 70.51 (SD = 21.73, n = 69), and the control group scored an average of 71.22 (SD = 18.72, n = 74). Module 2 posttest scores were slightly lower, with a mean score of 68.33 (SD = 23.31, n = 111).
The experimental group reported a mean score of 67.83 \((SD = 25.97, n = 69)\), and the control group reported a mean score of 69.17 \((SD = 18.38, n = 42)\). Posttest scores were the lowest in Module 3, with students obtaining an overall mean score of 52.94 \((SD = 20.08, n = 107)\). The experimental group had a lower mean score \((M = 51.56, SD = 21.45, n = 64)\), compared to the control group \((M = 55.00, SD = 17.90, n = 43)\). Lastly, a total mean score of 57.48 \((SD = 23.25, n = 121)\) was found for the Module 4 content knowledge posttest. The experimental group had a mean score of 58.51 \((SD = 24.65, n = 67)\), and the control group had a mean score of 56.20 \((SD = 21.54, n = 54)\). Table 4-13 displays posttest mean scores for the four content knowledge instruments used to assess students’ content knowledge achievement.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>IBI</th>
<th>DI</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module 1 CK</td>
<td>69</td>
<td>70.51</td>
<td>21.73</td>
</tr>
<tr>
<td>Module 2 CK</td>
<td>69</td>
<td>67.83</td>
<td>25.97</td>
</tr>
<tr>
<td>Module 3 CK</td>
<td>64</td>
<td>51.56</td>
<td>21.45</td>
</tr>
<tr>
<td>Module 4 CK</td>
<td>67</td>
<td>58.51</td>
<td>24.65</td>
</tr>
</tbody>
</table>

Note: IBI = Inquiry-based Instruction; DI = Direct Instruction; CK = content knowledge

The difference between students’ content knowledge pretest and posttest scores for each module was calculated to observe if changes in students’ content knowledge existed. Mean scores for all modules were higher on posttests compared to pretests. The overall gain in content knowledge scores were 17.83 \((SD = 16.99, n = 143)\) for Module 1, 19.68 \((SD = 22.05, n = 111)\) for Module 2, 14.81 \((SD = 17.39, n = 107)\) for Module 3, and 20.87 \((SD = 21.12, n = 121)\) for Module 4. Students in the experimental group had an average gain of 20.07 \((SD = 18.24, n = 69)\) in Module 1, 17.17 \((SD = 23.13, n = 69)\) in Module 2, 13.98 \((SD = 18.56, n =64)\) in Module 3, and 20.15 \((SD = 23.13, n = 69)\) in Module 4.
Lastly, mean gains in content knowledge scores for the control group were 15.74 ($SD = 15.56, n = 74$) in Module 1, 23.81 ($SD = 19.72, n = 42$) in Module 2, 16.05 ($SD = 15.61, n = 43$) in Module 3, and 21.76 ($SD = 20.10, n = 54$) in Module 4. Table 4-14 displays students’ mean gain in content knowledge achievement for each instrument.

<table>
<thead>
<tr>
<th>Table 4-14. Mean gain for content knowledge achievement.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment Group</td>
</tr>
<tr>
<td>Instrument</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Module 1 CK</td>
</tr>
<tr>
<td>Module 2 CK</td>
</tr>
<tr>
<td>Module 3 CK</td>
</tr>
<tr>
<td>Module 4 CK</td>
</tr>
</tbody>
</table>

*Note: IBI = Inquiry-based Instruction; DI = Direct Instruction; CK = content knowledge*

**Objective 2.** Compare the critical thinking ability of high school agriscience students taught using an IBI approach to a DI approach.

The Critical Thinking Test in Environmental Education (CTTEE) (Cheak, 1999) was used to measure students’ critical thinking abilities. The instrument is designed for students in grades eight through college. The CTTEE includes three sections (inferences, conclusions, bias), with each section having a passage and a series of multiple-choice questions with only one correct answer. The CTTEE instrument includes 27 questions with a minimum possible score of 0 and maximum possible score of 27. Previous reliability estimates using the Kuder-Richardson 20 (KR-20) were reported at .87, .70 (Cheak, 1999), and .72 (Robinson, 2001). For this study, the CTTEE instrument was determined to have a Cronbach’s alpha of .78 using the KR-20 score. Prior to the delivery of the treatment, students were administered the CTTEE as a pretest.
Following the entire duration of the treatment, the CTTEE was administered as a posttest.

Pretest and posttest scores for the CTTEE instrument were similar. The overall mean score for the CTTEE pretest was 14.21 ($SD = 5.06, n = 99$). The overall mean score for the CTTEE posttest was slightly lower at 13.58 ($SD = 5.49, n = 99$). The experimental group achieved a mean pretest score of 13.87 ($SD = 5.45, n = 53$) and a mean posttest score of 13.15 ($SD = 5.30, n = 53$). The control group achieved a mean pretest score of 14.61 ($SD = 4.59, n = 53$) and a mean posttest score of 14.07 ($SD = 5.52, n = 46$). Table 4-15 displays students’ mean scores for the CTTEE instrument.

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Instrument</th>
<th>IBI</th>
<th>DI</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>M</td>
<td>SD</td>
<td>n</td>
</tr>
<tr>
<td>Pre CTTEE</td>
<td>53</td>
<td>13.87</td>
<td>5.45</td>
<td>46</td>
</tr>
<tr>
<td>Post CTTEE</td>
<td>53</td>
<td>13.15</td>
<td>5.30</td>
<td>46</td>
</tr>
</tbody>
</table>

*Note: IBI = Inquiry-based Instruction; DI = Direct Instruction; CTTEE = Critical Thinking Test in Environmental Education*

**Objective 3.** Compare the environmental attitude of high school agriscience students taught using an IBI approach to a DI approach.

Students attitudes toward the environment were assessed before and after the treatment. The Environmental Attitude Inventory (EAI) (Campbell, Walizcek, & Zajicek, 1999) was used as a scale to determine students’ attitudes toward protecting the environment. The EAI consisted of 15-items and used a Likert-type scale (1 = strongly disagree; 2 = disagree; 3 = neither agree or disagree; 4 = agree; 5 = strongly agree). The EAI was administered to students as a pretest prior to treatment delivery. Immediately after students completed all four learning modules, the EAI was given
again as a posttest. The EAI was validated for high school students and reported a
previous Cronbach’s alpha reliability coefficient of .64 (Campbell, Walizcek, & Zajicek,
1999). The Cronbach’s alpha reliability coefficient calculated for this study was .70.

Students’ pretest and posttest mean scores for the EAI were similar. Students
reported an overall mean score of 3.54 ($SD = 0.42, n = 101$) on the pretest and an
overall mean score of 3.51 ($SD = 0.45, n = 101$) on the posttest. The control group
reported the same mean score of 3.60 ($n = 51$) for both the pretest ($SD = 0.38$) and
posttest ($SD = 0.49$). The experimental group reported a mean score of 3.49 ($SD =
0.45, n = 50$) for the pretest and a mean score of 3.41 ($SD = 0.48, n = 50$) for the
posttest. Table 4-16 displays students’ pretest and posttest mean scores for the EAI
instrument.

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>IBI</th>
<th>DI</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrument</td>
<td>$n$</td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>Pre EAI</td>
<td>50</td>
<td>3.49</td>
<td>0.45</td>
</tr>
<tr>
<td>Post EAI</td>
<td>50</td>
<td>3.41</td>
<td>0.48</td>
</tr>
</tbody>
</table>

Note: IBI = Inquiry-based Instruction; DI = Direct Instruction; EAI = Environmental
Attitude Inventory

Frequencies of overall student responses for each item can be seen in Appendix
J. Frequencies for students exposed to the treatment group and frequencies for
students exposed to the control group are also displayed in Appendix J.

**Objective 4.** Examine the relationship between student content knowledge
achievement, critical thinking ability, environmental attitude, and demographic
characteristics.
Prior to conducting statistical analyses of the data, relationships were determined for all variables using Pearson product-moment and point biserial correlations. The magnitude of correlations was interpreted using the guidelines presented by Davis (1971). Davis described correlations between .01 and 0.09 as negligible, between .10 and .29 as low, between .30 and .49 as moderate, between .50 and .69 as substantial, between .70 and .99 as very high, and 1 as perfect. Fifteen variables were examined for correlations. Ethnicity was dummy coded as one for White and zero for all other ethnicities. Correlations were separately examined for the group receiving IBI and the group receiving DI. Appendix P displays correlations for variables within each group.

**Correlations in IBI group.** A low correlation \((r = .24)\) was observed between age and the Module 3 posttest and a moderate correlation \((r = .31)\) was seen between gender and the EAI posttest. A low correlation \((r = .28)\) was found between ethnicity and the Module 1 pretest and between ethnicity and the Module 4 posttest \((r = .26)\). A moderate correlation \((r = .34)\) was also observed between ethnicity and the Module 4 pretest.

Many significant correlations were observed between content knowledge instruments. All content knowledge instruments were observed to have moderate to very high correlations with each other. The highest correlations were observed between the Module 3 posttest and the Module 4 posttest \((r = .71)\) and between the Module 1 posttest and the Module 2 posttest \((r = .71)\). The lowest correlations were observed between the Module 2 pretest and the Module 3 posttest \((r = .33)\) and between the Module 1 posttest and Module 4 pretest \((r = .39)\).
A substantial correlation ($r = .67$) was observed between the CTTEE pretest and CTTEE posttests. The CTTEE pretest and CTTEE posttest were observed to have moderate to very high correlations with all content knowledge assessments. The highest correlations were seen between the CTTEE pretest and Module 1 pretest ($r = .72$), between the CTTEE posttest and Module 1 pretest ($r = .67$), and between the CTTEE pretest and the Module 1 posttest ($r = .67$).

A substantial correlation ($r = .58$) was observed between the EAI pretest and EAI posttest. Significant correlations were observed between the EAI posttest and all instruments. Correlations between the EAI posttest and content knowledge instruments ranged from moderate, as observed between the EAI posttest and the Module 4 pretest ($r = .33$), to substantial, as observed between the EAI posttest and the Module 3 pretest ($r = .60$).

**Correlations in DI group.** In the control group, no statistically significant correlations were observed between age and other variables. A moderate correlation was observed between gender and the Module 2 posttest ($r = .31$). Several significant correlations were observed between ethnicity and other variables. Moderate correlations were seen between ethnicity and the Module 1 posttest ($r = .33$), Module 2 pretest ($r = .37$), Module 3 posttest ($r = .37$), CTTEE pretest ($r = .31$), and CTTEE posttest ($r = .34$).

Significant correlations were observed between all but one content knowledge tests. The strongest correlations were seen between the Module 1 pretest and the Module 1 posttest ($r = .66$), the Module 2 pretest and the Module 3 pretest ($r = .65$), the
Module 2 posttest and Module 3 posttest ($r = .60$), and the Module 3 pretest and Module 4 pretest ($r = .60$).

Unlike the group receiving IBI as the treatment, a significant correlation between the CTTEE pretest and CTTEE posttest was not observed for the control group. However, significant correlations were observed between CTTEE tests and content knowledge tests. Low correlations were seen between the CTTEE pretest and the Module 3 pretest ($r = .27$) and the Module 4 posttest ($r = .28$). Moderate correlations were observed between the CTTEE pretest and the Module 1 posttest ($r = .45$), the Module 2 posttest ($r = .39$), the Module 3 posttest ($r = .37$), and the Module 4 pretest ($r = .34$). A substantial correlation was observed between the CTTEE pretest and Module 2 pretest ($r = .53$). Significant correlations were found between all content knowledge tests and the CTTEE posttest. The strongest correlation, classified as very high, was observed between the CTTEE posttest and the Module 2 pretest ($r = .72$). Substantial correlations were observed between the CTTEE posttest and the Module 3 posttest ($r = .55$), the Module 2 posttest ($r = .54$), and the Module 4 posttest ($r = .54$).

A substantial correlation was observed between the EAI pretest and the EAI posttest ($r = .52$) and a low correlation was observed between the EAI pretest and the Module 4 posttest ($r = .29$). Moderate correlations were observed between the EAI pretest and Module 3 pretest ($r = .32$) and between the EAI pretest and Module 4 pretest ($r = .34$). Lastly, a low correlation was observed between the EAI posttest and the Module 1 pretest ($r = .26$).

**Tests of Hypotheses**

Dependent variables in this study were students’ content knowledge achievement, critical thinking ability, and environmental attitude. Students’ content
knowledge achievement was measured through four content knowledge posttests. Students’ critical thinking ability was measured through the CTTEE posttest, and environmental attitude was measured through the EAI posttest. Pretests for each of these instruments were used to establish a baseline for students and were used as covariates to control posttest means. Pretest and posttest data for each instrument were considered interval data. The study’s independent variable was the teaching method utilized in CASE® Natural Resources and Ecology courses. The control group received DI as the treatment, and the experimental group received IBI as the treatment.

Hypotheses were formulated to guide this study. Hypotheses were related to the statistical significance of possible effects of the IBI teaching method on students’ content knowledge achievement, critical thinking ability, and environmental attitude. Non-directional hypotheses were used, and decisions to retain or reject the null hypotheses were made at the .05 level. Statistical procedures for analysis of covariance (ANCOVA) were used to analyze data. Levene’s test and normality checks were carried out to ensure assumptions were met for each analysis.

**Hypothesis Related to Content Knowledge Achievement**

**H₀₁.** There is no significant difference in students’ content knowledge achievement based upon the teaching method used.

Students’ content knowledge achievement was measured through four researcher-development content knowledge posttests. Each content knowledge posttest was administered after each module’s treatment. After completion of the first module, students taught through IBI reported a mean posttest score of 70.51 ($SD = 71.3$), and students taught through DI reported a mean posttest score of 71.22 ($SD = 18.72$). Students were administered the Module 2 posttest after completion of the second
module. Students taught using IBI reported a mean posttest score of 67.83 (SD = 25.97), and students taught through DI reported a mean posttest score of 69.17 (SD = 18.38). For the third module, students receiving IBI reported a mean posttest score of 51.56 (SD = 21.73), and students receiving DI reported mean posttest score of 55.00 (SD = 18.72). Lastly, after completion of Module 4, students were administered the Module 4 content knowledge posttest. A mean score of 58.51 (SD = 24.65) was observed in the treatment group, and a mean score of 56.20 (SD = 21.54) was observed in the control group. Table 4-17 displays student mean posttest scores for content knowledge by treatment type.

Table 4-17. Posttest mean scores for content knowledge by treatment.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>IBI</th>
<th>DI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module 1 CK</td>
<td>69</td>
<td>70.51</td>
</tr>
<tr>
<td>Module 2 CK</td>
<td>69</td>
<td>67.83</td>
</tr>
<tr>
<td>Module 3 CK</td>
<td>64</td>
<td>51.56</td>
</tr>
<tr>
<td>Module 4 CK</td>
<td>67</td>
<td>58.51</td>
</tr>
</tbody>
</table>

Note: IBI = Inquiry-based Instruction; DI = Direct Instruction; CK = content knowledge

To determine if significant differences existed in content knowledge achievement for students taught using IB and students taught using DI, analysis of covariance procedures were used. A one-way ANCOVA was conducted for each content knowledge posttest to determine if a statistically significance difference existed between IBI and DI on students' content knowledge achievement while controlling for students' prior content knowledge.

Results of the one-way ANCOVA for the Module 1 posttest indicated there was no significant effect of instruction type on content knowledge achievement after controlling for students' prior knowledge, F(1, 140) = .997, p = .32. Results of the
Module 2 posttest also indicated there was not a significant effect of instruction type on content knowledge achievement after controlling for students’ prior knowledge, $F(1, 108) = 1.231, p = .27$. Results of the Module 3 posttest further validated non-significance, $F(1, 104) = .521, p = .47$. Lastly, results of the Module 4 posttest concluded that no significant effect of instruction type on content knowledge achievement existed after controlling for students’ prior knowledge, $F(1, 118) = .006, p = .94$. Table 4-18 displays univariate analysis of treatment effects for content knowledge.

<table>
<thead>
<tr>
<th>Source</th>
<th>$df_{(between)}$</th>
<th>$df_{(within)}$</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Module 1 CK</td>
<td>1</td>
<td>140</td>
<td>.997</td>
<td>.32</td>
</tr>
<tr>
<td>Module 2 CK</td>
<td>1</td>
<td>108</td>
<td>1.231</td>
<td>.27</td>
</tr>
<tr>
<td>Module 3 CK</td>
<td>1</td>
<td>104</td>
<td>.521</td>
<td>.47</td>
</tr>
<tr>
<td>Module 4 CK</td>
<td>1</td>
<td>118</td>
<td>.006</td>
<td>.94</td>
</tr>
</tbody>
</table>

*Note: CK = content knowledge*

Based upon the results of this study, the null hypothesis failed to be rejected. Results indicated no significant difference in student content knowledge achievement based upon the teaching method used.

**Hypothesis Related to Critical Thinking**

$H_{02}$. There is no significant difference in students’ critical thinking ability based upon the teaching method used.

Students’ critical thinking ability after exposure to the study’s treatment was measured through the CTTEE posttest. A CTTEE pretest was administered prior to the treatment and served as a measure of students’ prior critical thinking ability. After exposure to the treatment for the entire duration of the study, students taught through IBI reported a mean CTTEE posttest score of 13.15 ($SD = 5.30$), and students taught through DI reported a mean CTTEE posttest score of 14.07 ($SD = 5.52$).
A one-way ANCOVA was conducted to determine if a statistically significant difference existed between the IBI and DI treatments for students' critical thinking ability after controlling for students' prior critical thinking ability. Results of the CTTEE posttest indicated no significant effect of instruction type on students' critical thinking ability after controlling for students' prior ability \( F(1, 96) = .333, p = .57 \). Table 4-19 displays univariate analysis of treatment effects for critical thinking ability.

<table>
<thead>
<tr>
<th>Source</th>
<th>( df_{\text{between}} )</th>
<th>( df_{\text{within}} )</th>
<th>( F )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTTEE</td>
<td>1</td>
<td>96</td>
<td>.333</td>
<td>.57</td>
</tr>
</tbody>
</table>

*Note: CTTEE = Critical Thinking Test in Environmental Education*

Based upon the results of this study, the null hypothesis failed to be rejected. Results indicated no significant difference in student critical thinking ability based upon teaching method used.

**Hypothesis Related to Environmental Attitude**

H\(_{03}\). There is no significant difference in student environmental attitude based upon the teaching method used.

Students’ environmental attitude after exposure to the study’s treatment was measured through the EAI posttest. A pretest using the EAI was administered prior to the treatment and served as a measure of students’ prior attitudes toward protecting the environment. After exposure to the treatment for the entire duration of the study, students taught through IBI reported a mean EAI posttest score of 3.41 (\( SD = .48 \)), and students taught through DI reported a mean EAI posttest score of 3.60 (\( SD = .40 \)).

A one-way ANCOVA was conducted to determine if a statistically significance difference existed between IBI and DI treatments for students’ environmental attitude
after controlling for students’ prior attitude toward environmental protection. Results of
the ANCOVA indicated no significant effect of instruction type on students’
environmental attitude after controlling for students’ prior environmental attitude $F(1, 98) = 3.01, p = .09$. Table 4-20 displays univariate analysis of treatment effects for students’
environmental attitude.

<table>
<thead>
<tr>
<th>Source</th>
<th>$df_{(between)}$</th>
<th>$df_{(within)}$</th>
<th>$F$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAI</td>
<td>1</td>
<td>98</td>
<td>3.01</td>
<td>.09</td>
</tr>
</tbody>
</table>

*Note: EAI = Environmental Attitude Inventory*

Based upon the results of this study, the null hypothesis failed to be rejected.
Results indicated no significant difference in students’ critical thinking ability based upon
the teaching method used.

**Chapter Summary**

This chapter presented the results of the study. The study’s objectives and
hypothesis guided the research. The objectives were: 1) compare the content
knowledge achievement of high school agriscience students taught using an IBI
approach to a DI approach; 2) compare the critical thinking ability of high school
agriscience students taught using an IBI approach to a DI approach; 3) compare the
environmental attitude of high school agriscience students taught using an IBI approach
to a DI approach; and 4) examine the relationship between students’ content knowledge
achievement, critical thinking ability, environmental attitude, and demographic makeup.
The null hypotheses tested in this study were: 1) there is no significant difference in
students’ content knowledge achievement based upon the teaching method used; 2)
there is no significant difference in students’ critical thinking ability based upon the
teaching method used; and 3) there is no significant difference in students’
environmental attitude based upon the teaching method used.

Chapter 5 will provide a more in-depth discussion of conclusions and
interpretations of the findings presented in this chapter. Furthermore, implications and
recommendations stemming from the findings will be discussed.
CHAPTER 5
SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This study was designed and conducted to determine the effects of IBI on students' content knowledge achievement, critical thinking ability, and environmental attitude in an environmentally focused agriscience curriculum.

In Chapter 1, factors that led to the development of this study were presented. The need for sustainable food production and use of natural resources to meet the demands of a growing global population (World Food Economic Forum, 2010) was identified. Furthermore, the urgent need for agricultural industries to have a renewed and vested interest in environmental stewardship was noted. The chapter concluded that in order to address future environmental challenges facing the agricultural industry, an agricultural workforce that possesses scientific knowledge, critical thinking ability, and a favorable environmental attitude is needed.

Chapter 1 further described that the United States education system has struggled to foster students' science content knowledge achievement and critical thinking ability (National Center for Education Statistics, 2015). Initiatives from the science education community were discussed that promote the use of IBI approaches in teaching science education (NRC, 2012).

In Chapter 2, a theoretical framework was presented that guided the development of this study. The theoretical framework included the theory of cognitive development (Piaget, 1952), sociocultural theory (Vygotsky, 1962), and constructivism. A review of literature was provided in areas related to science education, environmental education, agricultural education, content knowledge achievement, critical thinking ability, and environmental attitude. Lastly, Chapter 2 presented the conceptual model.
utilized for this study. The conceptual model adapted the Presage-Process-Product model (Biggs, 2003) for the implementation of IBI in an environmentally focused agriscience curriculum.

Chapter 3 defined the research methods that were used for this study. The study was quasi-experimental and used a nonrandomized control group, pretest-posttest design with intact agriscience classrooms. The study’s population and sample, research design and procedure, instructional design, instrumentation and data collection, and data analysis process were described.

Chapter 4 reported findings of the study. Demographic variables describing the characteristics of teachers who employed the treatment were presented. Characteristics of each school that participated in the study were described in terms of geographic location (United States Census Bureau, 2015) and locale boundary (Geverdt, 2015). Furthermore, the demographic variables of age, gender, and ethnicity were presented for students who participated in the study. Results pertaining to the study’s objectives and hypotheses were reported.

This chapter presents a brief review of the study’s design and further describes findings related to the study’s objectives and hypotheses. Conclusions and implications, based upon interpretation of results are presented. The chapter concludes by providing discussion and recommendations for practitioners and for further research.

Summary of Design

Purpose of the Study

The purpose of this study was to determine the effects of IBI in an environmentally focused agriscience curriculum on students’ content knowledge
achievement, critical thinking ability, and environmental attitude. The following objectives and hypotheses guided this study:

**Statement of Objectives**

1. Compare the content knowledge achievement of high school agriscience students taught using an IBI approach to a DI approach.
2. Compare the critical thinking ability of high school agriscience students taught using an IBI approach to a DI approach.
3. Compare the environmental attitude of high school agriscience students taught using an IBI approach to a DI approach.
4. Examine the relationship between students’ content knowledge achievement, critical thinking ability, environmental attitude, and demographic makeup.

**Statement of Hypotheses**

The research questions that this study investigated are presented as null hypotheses. During statistical analysis, the following null hypotheses were tested using a .05 level of significance.

- **H₀₁** There is no significant difference in students’ content knowledge achievement based upon the teaching method used.
- **Hₐ₁** Students taught using an IBI approach will have higher content knowledge achievement compared to students taught using a DI approach.
- **H₀₂** There is no significant difference in students’ critical thinking ability based upon the teaching method used.
- **Hₐ₂** Students taught using an IBI approach will have higher critical thinking ability compared to students taught using a DI approach.
- **H₀₃** There is no significant difference in students’ environmental attitude based upon the teaching method used.
- **Hₐ₃** Students taught using an IBI approach will have a more positive environmental attitude compared to students taught using a DI approach.
Methods

Population. The population of the study was all high school agriscience students in the United States. The accessible population was students of agriscience teachers who attended the CASE® Institute for NRE certification between the years 2013 and 2017, and who were currently teaching. The total number of agriscience teachers who completed the CASE® Institute for NRE certification between the years 2103 and 2017 was 167.

Sample. The sample size needed to meet statistical criteria identified in this study was determined using the Hay’s (1973) formula. A needed sample size of 60 subjects for each treatment was calculated. The estimated needed sample size was doubled to reflect high mortality rates seen in similar studies (Boone, 1998; Dyer, 1995; Flowers, 1986; Myers, 2004; Shoulders, 2012). A convenience sampling method using a combination of email and phone communication was used to recruit teachers to participate in the study. A total of 21 teachers indicated interest in participating met the criteria identified in the study. After follow-up communication, 13 teachers agreed to participate. Of the 13 teachers, 12 teachers started the study and 11 teachers completed the entire duration of the study. The sample consisted of 181 students.

Research Design. The study was quasi-experimental and used a nonequivalent control group, pretest-posttest design (Campbell & Stanley, 1963). The dependent variables under investigation were students’ content knowledge achievement, critical thinking ability, and environmental attitude. The independent variable that served as the treatment for this study was the teaching method used in agriscience classrooms. The treatment delivered to the experimental group was IBI, and the treatment delivered to the control group was DI. The duration of the study was designed to last approximately
eight weeks and included four learning modules. Prior to the start of the study, students were administered pretest instruments that measured environmental attitude (EAI) and critical thinking ability (CTTEE). Prior to each of the four two-week learning modules, students were administered a pretest that measured content knowledge achievement. After each module, students were administered a posttest that measured content knowledge. After students were exposed to the entire treatment, they were again administered an instrument measuring critical thinking ability (CTTEE) and an instrument measuring environmental attitude (EAI), which served as posttest scores.

Threats to internal validity were addressed. The study used random selection to assign intact classrooms to either the control group or experimental group. Pretest scores were used to adjust posttest mean scores to reduce interaction effects. Testing effects were reduced by randomizing the order of questions between pretest and posttests (Campbell & Stanley, 1963). Multiple schools were used to reduce the risk of interaction with subjects. Threats to the fidelity of treatment delivery were addressed by selecting teachers who had completed the CASE® Institute for NRE certification, which provided professional development to teachers on the use of IBI. Teachers were also provided detailed lesson plans to follow.

**Instructional Design.** The instructional content for the study aligned with the existing course design for the CASE® NRE course. Four modules were used (The Energy of Life, Flourishing Fauna, All Natural Flora, Agricultural Stewardship) that included environmental, agricultural, and science-based concepts. Each module was designed to last approximately two weeks and included four instructional plans. The content in each instructional plan for IBI and DI treatments was consistent, however, the
instructional approach for how the content was taught aligned with each treatment type. Instructional guides for DI were designed from recommendations provided by Eggen and Kauchak (2012), and instructional guides for IBI followed the BSCS 5E instructional model (Bybee et al., 2006) and the recommendations provided by Contant, Bass, and Carin (2014).

**Instrumentation and Data Collection.** All data were collected electronically using a researcher-development webpage and Qualtrics software. All instruments measuring content knowledge achievement were researcher created. Each content knowledge pretest and posttest consisted of 20 multiple-choice questions that aligned to learning objectives identified in each module. A minimum possible score was 0 and a maximum possible score was 100. Post-hoc reliability analysis using the KR20 (Gall, Borg, & Gall, 1996) was determined to be .80, .85, .75, and .82, respectively.

Critical thinking ability was measured using the CTTEE (Cheak, 1999). The CTTEE consisted of 27 multiple-choice questions and was designed for students in grades six through college freshman in EE. The instrument reports students critical thinking scores on a range from 0 to 27. Previous reliability estimates were reported as .87 (Cheak, 1999) and .70 (Robinson, 2001). The reliability estimate using the KR20 (Gall, Borg, & Gall, 1996) was determined to be .72 in this study.

Environmental attitudes were measured using the EAI scale (Campbell, Walizcek, & Zajicek, 1999). The scale consisted of 15 statements designed to measure students’ attitudes toward protecting the environment, and was administered on a five-point, Likert-type scale. The scale had been previously used for students enrolled in agriscience courses and reported a reliability coefficient of .64 (Campbell, Walizcek, &
Zajicek, 1999). The Cronbach’s alpha reliability coefficient for this study was calculated to be .70.

**Data Analysis.** Data were analyzed using SPSS version 22. Means, frequencies, and standard deviations were used as a measure of central tendency. ANCOVA was used to analyze Objectives 1, 2, and 3. For the analysis of each objective, pretest scores for the instrument under investigation were used as a covariate to adjust posttest means. Correlational statistics were used to address Objective 4.

**Summary of Findings**

Data for this study were collected for teacher and student demographic data. The independent variable under investigation was the instructional approach to teaching an environmentally focused agriscience curriculum. Dependent variables were content knowledge achievement, critical thinking ability, and environmental attitude. A summary of results found in this study are presented according to demographics, response rate, objectives, and hypotheses.

**Demographics**

**Teacher and School Demographics.** In order to participate in this study, teachers must have completed the CASE® Institute for NRE certification between the years of 2013 and 2017. One teacher reported attending the institute in 2013, three attended the institute in 2014 and two attended in 2016. Six teachers completed the institute in 2017. Eight teacher participants were male and four were female.

Schools were classified to region and division characteristics according to the United States Census Bureau (2015) classification system. A majority of schools participating in this study were located in the Midwest \((n = 10)\) and were in a rural area or small town. One school, which had a large number of student participants, was
located in the Pacific division in the western region. This school was located in a
midsized city. The number of students enrolled in each agriculture course ranged from
three to 37. Rural schools had smaller class sizes in the NRE course in comparison to
schools located in towns or cities.

**Student Demographics.** Students self-reported gender. Thirty-six students
failed to report gender (19.9%). Eighty-four (46.4%) students identified as male, and 61
(33.7%) identified as female. The number of males and females in each treatment group
was similar. The largest age range of students fell between 15 and 17 years of age. A
majority \((n = 62, 34.3\% )\) of students was 16 years of age, and 44 \((24.3\% )\) students were
15 years of age. Students in the IBI treatment group were slightly older compared to the
DI group.

Students self-reported ethnicity. Thirty-eight \((21.0\% )\) students did not identify
their ethnicity. A majority \((n = 105, 58\% )\) of students identified as being White, non-
Hispanic, followed by Hispanic or Latino \((n = 20, 11\% )\), Other \((n = 8, 4.4\% )\), Black or
African American \((n = 6, 3.3\% )\), and Asian or Pacific Islander \((n = 4, 2.2\% )\). Ethnicities
identified by students for each treatment were similar.

**Response Rate**

Students’ response rate varied by instrument. Response rates were affected by
one teacher who could not complete the study in its entire duration, student absences,
teacher-reported technology issues, and teacher forgetfulness. The average response
rate for the completion of individual instruments was 76.6\%, with a 79.1% average
instrument response rate for the experimental group and a 74.0% average instrument
response rate for the control group being observed. For the purpose of pretest and
posttest paired samples used for the analysis of data in this study, the response rates
were adjusted accordingly. The observed average paired samples response rate was 62.8%, with the experimental group completing 66.7% and the control group completing 58.7% of paired sample instruments. Paired sample completion rates were the highest (79%) for the Module 1 pretest and posttest and the lowest (54.7%) for the CTTEE pretest and posttest.

**Objective One**

Objective 1 sought to compare the content knowledge achievement of high school agriscience students taught using an IBI approach to a DI approach. A series of four module posttest instruments were used to measure students' content knowledge achievement for the content identified in the four modules presented in this study. A maximum possible score on each of the instruments was 100. The overall mean scores for posttest instruments measuring student content knowledge achievement was 70.87 (SD = 20.16) for Module 1; 68.33 (SD = 23.31) for Module 2; 52.94 (SD = 20.08) for Module 3; and 57.48 (SD = 23.25) for Module 4. Students in the control group achieved slightly higher mean scores for Module 1, Module 2, and Module 3. Students in the experimental group achieved a slightly higher mean score for Module 4.

**Objective Two**

Objective 2 sought to compare the critical thinking ability of high school agriscience students taught using an IBI approach to a DI approach. The CTTEE (Cheak, 1999) was used as a posttest to measure students critical thinking ability after being exposed to the treatment. A maximum possible score on the CTTEE was 27. The overall mean score for the CTTEE posttest was 13.58 (SD = 5.39). Students exposed to DI had a slightly higher mean posttest score (M = 14.07, SD = 5.52) compared to students exposed to IBI (M = 13.15, SD = 5.30).
Objective Three

Objective 3 sought to compare the environmental attitude of high school agriscience students taught using an IBI approach to a DI approach. The EAI scale (Campbell, Walizcek, & Zajicek, 1999) was administered as a posttest to assess students’ attitudes toward environmental protection after being exposed to the treatment. The instrument used a 5-point, Likert-type scale (1 = strongly disagree; 2 = disagree; 3 = neither agree or disagree; 4 = agree; 5 = strongly agree) for 15-items. The overall mean score for the scale was 3.51 (SD = 0.45). Students exposed to DI had a higher posttest score (M = 3.60, SD = 0.49) compared to students exposed to IBI (M = 3.41, SD = 0.48).

Objective Four

Objective 4 sought to examine the relationship between students’ content knowledge achievement, critical thinking ability, environmental attitude, and demographic makeup. Pearson product-moment and point biserial correlations were used to examine correlations between all variables in this study and presented the magnitude of correlations, as recommended by Davis (1971).

Fifteen variables were examined for correlations within the group that received IBI and within the group that received DI. For the group that received IBI, low correlations were observed between ethnicity and the Module 1 pretest (r = .28) and between ethnicity and the Module 4 posttest (r = .26). A moderate correlation was observed between ethnicity and the Module 4 pretest (r = .34). For the group that received DI, moderate correlations were observed between ethnicity and the Module 1 posttest (r = .33), Module 2 pretest (r = .37), Module 3 posttest (r = .37), CTTEE pretest (r = .31), and CTTEE posttest (r = .34). No significant correlations were observed
between age and other variables in the control group, while age was observed to have a low correlation with the Module 3 posttest \( r = .24 \) in the experimental group. Gender was only found to have a significant correlation with the Module 2 posttest \( r = .31 \) in the control group.

Many significant correlations were found between content knowledge instruments within both groups. Correlations ranged from .33 to .71 within the group receiving IBI and from .39 to .65 within the group receiving DI. In the experimental group, a substantial correlation \( r = .67 \) was observed between the CTTEE pretest and posttest, while the control group did not have a significant correlation between these variables. Both groups had substantial correlations between the EAI pretest and EAI posttest. A correlation of .52 was observed in the group receiving DI and a correlation of .58 was seen within the group receiving IBI. Fewer significant correlations were seen between the EAI posttest and content knowledge instruments in the control group compared to the group receiving IBI.

**Null Hypothesis One**

Null Hypothesis 1 stated that there is no significant difference in students’ content knowledge achievement based upon the teaching method used. A one-way ANCOVA was used to determine if a statistically significant difference existed between IBI and DI on students’ content knowledge achievement, while controlling for students’ prior content knowledge. A one-way ANCOVA was used to examine posttest scores between groups for each of the four content knowledge modules. Results of the ANCOVA for Module 1 indicated an insignificant effect of instruction type on content knowledge achievement after controlling for students’ prior knowledge, \( F(1, 140) = .997, p > .05 \). Results of the ANCOVA for the Module 2 content knowledge posttest indicated an
insignificant difference, as well, $F(1, 108) = 1.231, p > .05$. ANCOVA results for the Module 3 content knowledge posttest, $F(1, 104) = .521, p > .05$, and Module 4 content knowledge posttest, $F(1, 118) = .006, p > .05$, further validated an insignificant difference between treatment type on student content knowledge achievement. Null Hypothesis 1 was failed to be rejected.

**Null Hypothesis Two**

Null Hypothesis 2 stated that there is no significant difference in students’ critical thinking ability based upon the teaching method used. A one-way ANCOVA was used to determine if a statistically significant difference existed between IBI and DI on students’ critical thinking ability, while controlling for students’ critical thinking ability prior to the treatment. A one-way ANCOVA was used to examine posttest scores between groups for the CTTEE. Results concluded there is not a significant effect of instruction type on students’ critical thinking ability after controlling for students’ prior ability, $F(1, 96) = .333, p > .05$. Null Hypothesis 2 was failed to be rejected.

**Null Hypothesis Three**

Null Hypothesis 3 stated that there is no significant difference in students’ environmental attitude based upon the teaching method used. A one-way ANCOVA was used to determine if a statistically significant difference existed between IBI and DI on students’ environmental attitude, while controlling for students’ environmental attitude prior to the treatment. A one-way ANCOVA was used to examine posttest scores between groups for the EAI. Results concluded there is not a significant effect of instruction type on students’ environmental attitude after controlling for students’ prior attitude, $F(1, 98) = 3.01, p > .05$. Null Hypothesis 3 was failed to be rejected.
Conclusions

The following conclusions of this quasi-experimental study are presented below:

1. IBI and DI are equally effective on students’ content knowledge achievement when used in a high school environmentally focused agriscience curriculum.

2. IBI and DI are equally effective on students’ critical thinking ability when used in a high school environmentally focused agriscience curriculum.

3. IBI and DI are equally effective on students’ environmental attitude when used in a high school environmentally focused agriscience curriculum.

4. A moderate to substantial relationship exists between students’ environmental attitude and content knowledge achievement when students are exposed to IBI.

5. Minimal relationships exist between students’ age or gender and content knowledge achievement, critical thinking ability, and environmental attitude when students are taught using IBI or DI.

6. Relationships exist between students’ ethnicity and content knowledge achievement, and between ethnicity and critical thinking, when students are taught using IBI or DI.

Implications from Findings

The findings from this study provided many implications. Implications for each conclusion are provided in sections according to Objectives 1, 2, 3, and 4, and corresponding hypotheses, used for this study.

Objective One

Objective 1 sought to compare the content knowledge achievement of high school agriscience students taught using an IBI approach to a DI approach. The null hypothesis that aligned with this objective was that there is no significant difference in students’ content knowledge achievement based upon the teaching method used.

Conclusion: IBI and DI are equally effective on students’ content knowledge achievement when used in a high school environmentally focused agriscience curriculum.
Results from this study indicated that students taught using IBI and DI had similar content knowledge achievement. The results were consistent in some instances of previous research that compared IBI to DI on content knowledge achievement in science education. Lawson, Abraham, and Renner (1989) found that students exposed to IBI, using the 5E learning cycle, and students exposed to DI, with employed learning activities, achieved similar gains in content knowledge achievement over a two-week treatment.

However, the results contradicted findings from (Hung, 2009), who observed that IBI in science had significant benefits in students’ science, math, and reading achievement over traditional methods of science instruction. Results of this study also contradicted previous research in agriscience comparing IBI to subject matter instruction (Thoron, 2010), which found that students exposed to IBI had higher content knowledge achievement compared to students exposed to the subject matter approach.

Although it was observed that a significant difference did not exist in students’ content knowledge achievement between IBI and DI, on average, students scored nearly 20% higher in content knowledge achievement (for each learning module) after being exposed to two weeks of instruction that used either IBI or DI.

This finding supports the use of IBI and DI as an instructional approaches to increase student content knowledge achievement. Previous studies have reported that students exposed to IBI demonstrate a positive change in content knowledge achievement (Amaral, Garrison, & Klentschy, 2002; Geier et al., 2008; Schroder, Scott, Tolson, & Lee, 2007). In one study, Valdez and Freve (2002) exposed an entire school
district to IBI, finding significant gains in students’ content knowledge achievement across the district.

**Objective Two**

Objective 2 sought to compare the critical thinking ability of high school agriscience students taught using an IBI approach to a DI approach. The null hypothesis that aligned with this objective was that there is no significant difference in students’ critical thinking ability based upon the teaching method used.

**Conclusion:** IBI and DI are equally effective on students’ critical thinking ability when used in a high school environmentally focused agriscience curriculum.

Results from this study indicated that students taught using IBI had no significant difference in critical thinking ability compared to students taught using DI. These results contradicted suggestions by the science education community (NSTA, 2003) which promote IBI over traditional types of instruction (e.g. DI) as a means to increase students’ ability to think critically about science. The nature of IBI is to expose students to a process in which they conduct scientific investigations, analyze information, and make informed decisions. Berman (1991) suggested that critical thinking skills can be increased by exposing students to authentic tasks and having students reflect on what they learn.

The results of this study also contradicted previous research in agriscience analyzing IBI and critical thinking. Thoron and Myers (2012a) conducted a quasi-experimental study comparing the impact of IBI and the subject matter approach on scientific reasoning. After a twelve-week treatment, students exposed to IBI scored
higher in scientific reasoning compared to students exposed to the subject matter approach.

Furthermore, changes in students’ critical thinking were not found after students were exposed to IBI or DI. The lack of improvement in students’ critical thinking abilities is concerning, especially since a majority of educators believe that improving students’ critical thinking skills should be a top priority in education (McTighe & Schollenberger, 1991; Sternberg & Baron, 1985; Pithers & Soden, 2000). However, the relatively short duration of this study may have impacted results, as changes in critical thinking ability have been described to take time (Foundation for Critical Thinking, 2015).

This study indicated that improving critical thinking skills, as opposed to content knowledge achievement, may take more time than eight weeks of instruction. However, a study by Robinson (2005) contradicted this assumption. Robinson (2005) found that middle school students exposed to eight-weeks of an environmentally focused curriculum, using active learning, improved critical thinking scores on the CTTEE instrument.

**Objective Three**

Objective 3 sought to compare environmental attitudes of high school agriscience students taught using an IBI approach to a DI approach. The null hypothesis that aligned with this objective was that there is no significant difference in students’ environmental attitude based upon the teaching method used.

**Conclusion:** IBI and DI are equally effective on students’ environmental attitude when used in a high school environmentally focused agriscience curriculum.
Results from this study indicated that neither students exposed to IBI or DI significantly changed their attitudes toward protecting the environment. However, it should be noted that students' environmental attitudes prior to the treatment were already fairly positive. Students' mean EAI pretest scores were 3.49 (IBI) and 3.60 (DI) on a five-point, Likert-type scale, respectively. For example, over 80% of students either agreed or strongly agreed with the statements: (a) it is important that each individual be aware of environmental concerns, and (b) special habitats should be set aside for endangered species.

Furthermore, it is likely that the CASE® NRE course was an elective course and students enrolled in the course out of their own interest in EE. Research suggests that attitudes may take time to form, the short duration of the curriculum may not have been long enough to change students' environmental attitude. Lastly, favorable environmental attitudes may have already been formed as a result of previous coursework in the NRE course.

Objective Four

Objective 4 sought to examine the relationship between students' content knowledge achievement, critical thinking ability, environmental attitude, and demographic makeup.

Conclusion: A moderate to substantial relationship exists between students' environmental attitude and content knowledge achievement when students are exposed to IBI.

Correlational results from this study indicated that a moderate to substantial relationship existed between environmental attitude scores and all content knowledge scores for students within the IBI group. Students who had higher environmental
attitude scores, on average, had higher content knowledge scores. However, a majority of correlations between environmental attitude scores and content knowledge scores were not significant for the group of students exposed to DI. This finding may support the use of IBI in environmentally focused curricula for students who have more favorable attitudes toward the environment. Students who have more favorable attitudes and interest toward the subject matter under investigation may be more likely to actively engage in discovery of the subject matter. Additionally, increasing students’ interest toward the subject matter may offer advantages for content knowledge achievement when using IBI as an instructional approach.

**Conclusion: Minimal relationships exist between students’ age or gender and content knowledge achievement, critical thinking ability, and environmental attitude when students are taught using IBI or DI.**

Students in this study had a considerable difference in age, ranging from 14 years of age to 19 years of age. However, correlational results indicated that age did not have a significant relationship with the dependent variables under investigation. The only exception was a low relationship being observed between the Module 3 posttest and age for the group of students exposed to IBI instruction. Overall, student age did not have a significant relationship between critical thinking ability, environmental attitude, nor content knowledge when students were taught using IBI or DI. Very few significant relationships were also observed between students’ gender and content knowledge achievement, environmental attitude, and critical thinking ability. A moderate relationship was observed between gender and the Module 2 posttest for student exposed to DI, and a moderate relationship was observed between gender and the
environmental attitude posttest for students taught using IBI. Overall, most correlations between gender and the dependent variables under investigation were not significant, and the few significant correlations that were observed were fairly weak, indicating, on average, that gender had a minimal relationship between content knowledge achievement, environmental attitude, and critical thinking ability when students are taught using IBI or DI.

**Conclusion:** Relationships exist between students’ ethnicity and content knowledge achievement, and between ethnicity and critical thinking, when students are taught using IBI or DI.

Correlational results from this study indicated several moderate relationships between ethnicity and dependent variables under investigation. For students exposed to DI, a moderate relationship was observed between ethnicity and two content knowledge posttests, between ethnicity and one content knowledge pretest, and between ethnicity and the CTTEE pretest and CTTEE posttest. However, for students exposed to IBI, ethnicity only had a moderate relationship between one content knowledge posttest, and a slight relationship between ethnicity and two content knowledge pretests. No identifiable relationship trends between ethnicity and dependent variables were observed when comparing the relationships for students exposed to IBI and for students exposed to DI, especially when taking note of pre-existing group differences (i.e. significant relationship between ethnicity and pretest scores).

Differences in student achievement by ethnicity have been well documented (Greenfield, 1996; Tate, 1997), and are linked to the many barriers that minority students face in the United States educational system (NCES, 2016).
Despite the finding of several low and moderate relationships between ethnicity and content knowledge achievement, and between ethnicity and critical thinking ability, no major differences could be established by treatment. This finding suggests that the use of IBI compared to DI had minimal impact on minority students’ achievement and support findings of similar studies (Burleson, 2013; Thoron, 2010). Lastly, ethnicity did not have a significant relationship with students’ environmental attitudes for students taught using IBI or DI.

**Discussion**

The results of this study indicated that IBI and DI are equally effective on students' content knowledge achievement, critical thinking ability, and environmental attitudes when employed in an eight-week, environmentally focused agriscience curriculum. The following section provides a discussion of the results seen within this study, and based upon the results, provides recommendations to agriscience teachers and for further research.

The demographics seen within this study were similar to previous studies in agriscience that used a quasi-experimental design and relatively large sample size (Burleson, 2013; Park, 2005; Shoulders, 2012; Thoron, 2010). Reports show that a majority of students enrolled in agricultural education are white (Pate, 2008). The majority (58%) of students participating in this study identified as white, demonstrating a commonality in agricultural education programs. In order for agricultural education to move forward, efforts are being made to recruit more diverse students. This study did include a higher percentage (11%) of students who identified as Hispanic or Latino than anticipated.
Although a convenient sampling method was used, specific geographical regions or locales were not targeted. A majority of CASE® NRE teachers who participated in this study taught in the Midwest, in a rural area or small town. Both the experimental group and control group had similar teacher and location demographics, as well as student demographics for ethnicity and gender.

It is critical to note that students in the control group were, on average, slightly younger in age. Students exposed to IBI had a mean age of 16.45 ($SD = 1.15$) and students exposed to DI had a mean age of 15.75 ($SD = 1.07$). The main difference in mean age can be explain by a higher percentage (21.5%) of students in the experimental group who were 18 year of age compared to the control group (4.5%). The difference in age could have impacted this study, as younger students who are forming new knowledge, may have benefited from DI over IBI (Eggen & Kauchak, 2012). However, age was only shown to have a significant correlation with one continuous variable, the Module 3 posttest, in which a low correlation was observed.

A clear definition of what constitutes IBI from other similar instructional approaches (i.e. problem-based learning) is not widely agreed upon (Minner et al., 2009). Although multiple perspectives of IBI exists (Llewellyn, 2002), scholars have agreed that IBI is a student-centered and teacher-guided approach to learning that places the responsibility of learning upon the student, and challenges students to investigate phenomenon. This study utilized the 5-E model of IBI (Bybee et al., 2006), which is easily explained as a step-by-step method to teaching through inquiry (Contant, Bass, & Carin, 2014). This approach to teaching through IBI was utilized in this study.
due to the ability for it to be easily described in a lesson plan, and therefore, ensuring the fidelity of the treatment by practicing teachers.

Although the 5-E model has been identified as an IBI approach (Bybee et al., 2006; Contant, Bass, & Carin, 2014), less structured approaches to implementing IBI may expose students to more authentic inquiry, which could have varying student outcomes. Authentic inquiry, has been especially promoted in EE, in which students are exposed to real world environmental problems and investigations (Ernst, 2009). Through authentic inquiry, students can become engaged in not only learning about environmental issues and their scientific dimensions, but can analyze, propose, and implement solutions for them (Forbes & Zint, 2010). Challenging students to address relevant environmental issues can provide meaningful experiences to students, fostering the construction of new scientific knowledge and thinking skills (Berman, 1991), while connecting students to the natural world. The approach to IBI seen within this study may have fallen short in providing authentic inquiry experiences that allow to students address local environmental issues. However, the national scope of this study as well as ensuring the fidelity of the treatment, would have provided challenges in doing so.

The control group in this study was exposed to DI. A more precise definition exists for DI. Direct instruction is a teacher-centered approach to learning, where the teacher provides information directly to students. The design of this study follows best practices in education using DI (Eggen & Kauchak, 2012). According to Eggen and Kauchak (2012), the four stages of DI are: 1) Introduction and Review; 2) Teacher Presentation; 3) Guided Practice; and 4) Independent Practice. In stage three and four
of the model, students are provided application activities through guided and independent practice.

This study found no significant differences between students’ content knowledge achievement using IBI and DI, however results indicate the students exposed to either IBI or DI, increased content knowledge by an average of 20% during a two-week period of instruction. Previous research has concluded IBI to be more effective compared to “traditional” teaching methods on students’ content knowledge achievement. In this study, DI was implemented using best practice, which can be described as giving students guided practice and individual practice after new content is first delivered to students. This study demonstrates that DI, when implemented properly, can be a useful instructional approach in meeting instructional objectives geared toward content knowledge achievement.

Another finding of this study was that neither IBI or DI improved the critical thinking ability of students. Previous literature provides empirical evidence to the contrary (McTighe & Schollenberger, 1991; Pithers & Soden, 2000; Sternberg & Baron, 1985), suggesting that IBI is a preferred instructional approach over traditional instruction to increase students’ critical thinking abilities. Although measures used in this study demonstrate statistical reliability, the assumption that students’ tried their best on assessments may not be valid. Students completed a total of twelve instruments during the eight-week duration of the study. The CTTEE posttest instrument was administered at the very end of the study. According to teachers, students began feeling test fatigue toward the end of the study, and therefore may have not tried their best at answering questions on the assessment. A follow-up analysis examining the amount of time
students took to complete the pretest and posttest, indicated that on average students spent less time on the CTTEE posttest compared to the CTTEE pretest.

Results of this study contradict a fair amount of literature that supports the use of IBI over DI. Several characteristics of this study may have contributed to this study’s results. Teachers participating in this study completed the CASE institute for NRE certification, and after receiving an invitation to participate in this research, voluntarily agreed to deliver instruction in their classrooms. All teachers participating in this study seemed to be ideal teachers and were very proactive toward expanding their knowledge and ability in teaching. Therefore, the teachers who participated in this study may have been well beyond the typical or average teacher. Exemplary teachers may be equally effective at teaching through a variety of methods due to their knowledge and ability, and therefore could have been very effective at delivering content through the use of DI, as well as IBI.

Additionally, the 5E model (Bybee et al., 2006) that was used to represent IBI and the 4-stage model (Eggen & Kauchak, 2012) that was used to represent DI may have had some overlap. The models used to represent IBI and DI both represented best practices in education and included a wide-range of student activities that promoted student learning. Application activities seen within the DI treatment had some components of student inquiry. However, the DI treatment used in this study, presented new content in a teacher-centered fashion, compared to the IBI method, which presented new content through student-centered investigation. Recommendations for practitioners and researchers resulting from this study are provided below.
Recommendations

Recommendations for Practice

1. Results of this study show that DI and IBI are both equally effective on students' content knowledge achievement when used in a high school environmentally focused agriscience curriculum. Although both methods can be effective, when using DI as a teaching approach, it is recommended to include all four steps as presented by Eggen and Kauchak (2012): 1) Introduction and Review; 2) Teacher Presentation; 3) Guided Practice; and, 4) Independent Practice.

2. There was a moderate relationship observed between students’ environmental attitude and content knowledge achievement for students taught through IBI. Students who have stronger environmental attitudes may benefit from being taught through IBI.

Recommendations for Further Research.

1. This study represented IBI through the 5E model (Bybee et al., 2006). There is a need to conduct experimental research on the effectiveness of other models and approaches to delivering IBI.

2. There were some similarities between the 5E model (Bybee et al., 2006) of IBI and the four step model of DI (Eggen & Kauchak, 2012). Future research comparing IBI to DI should include a larger distinction between teacher-centered and student-centered methods and activities.

3. This study did not indicate a significant change in students’ environmental attitude after being exposed to an eight-week environmentally focused agriscience curriculum. Due to the need to promote favorable environmental attitudes, especially among youth involved in agriculture, factors that influence students’ environmental attitudes and behaviors should be examined.

4. Individuals will need to be equipped with critical thinking skills to provide solutions to complex agricultural and environmental challenges. Results of this study did not indicate a significant change in students’ critical thinking ability after being exposed to an eight-week environmentally focused agriscience curriculum. Factors that influence students’ critical thinking ability within agricultural and environmental contexts should be examined.

5. Work with providers of nationally-recognized agriscience curricula to conduct experimental studies that may have significant impact on the design and delivery of curricula that is commonly used in SBAE across the nation.

6. This study examined the effect of teaching methods on content knowledge achievement. Future experimental studies on content knowledge should investigate students’ long-term knowledge retention as a result of the teaching method used.
7. This study employed a quantitative design to determine outcomes of IBI. Qualitative or mixed-methods studies involving IBI can provide an alternative lens on the outcomes of IBI. Qualitative data on teacher and student perceptions of IBI would expand the body of research on IBI in agriscience.

8. This study used a combination of twelve instruments in an eight-week period. Due to student test fatigue, caution should be taken when designing experimental studies that require students to complete a multitude of assessments over a relatively short duration.

9. This study did not gather data on students’ socioeconomic status or grade level. Future research investigating the effects of teaching methods in SBAE and EE should collect these variables to determine relationships between these variables and learning outcomes.
APPENDIX A
TEACHER RECRUITMENT LETTERS

September 27th, 2017

Dear Agriculture Teacher,

As a former participant of the Natural Resources and Ecology CASE training, you have been identified as a candidate to be a part of a nation-wide research study on teaching methods within agriscience education. The study is expected to start in early January, 2018.

In voluntary agreement to participate, students in your classroom will serve as participants in an eight-week research study that will expose them to CASE curriculum through the use of distinct teaching methods. As the teacher, you will receive detailed lesson plans and teaching resources for the duration of the study. At various points during the study, data will be collected on students’ content knowledge, environmental attitude, and critical thinking. All collected student data will remain anonymous and only aggregated student data will be shared.

Your participation in this study will be extremely valued. As the primary investigator of this study, I will utilize this research to complete my dissertation at the University of Florida. As a former high school agriscience teacher, I understand the complexity and demands of teaching and will strive to make this research a fun and meaningful experience to you and your students. Furthermore, I believe this research will provide important information that can lead to advancements in agriscience education.

If you are interested in learning more about this study, please complete this survey via the link provided in this email. The survey should take less than two minutes to complete.

Sincerely,

Blake Colclasure
PhD Candidate
Agricultural Education and Communication
University of Florida

The Foundation for The Gator Nation
An Equal Opportunity Institution
Invitation to Participate

What?
You and your students are invited to participate in a research project that will investigate the effects of an inquiry-enhanced curriculum that utilizes CASE Natural Resources and Ecology units as its foundation. You will be given detailed lesson plans and materials to teach the modified units, and student learning outcomes in critical thinking, content knowledge, and environmental attitude will be collected. The modified lesson plans are based on the following CASE units: The Energy of Life; All Natural Flora; Flourishing Fauna; and Agricultural Stewardship.

When?
The project will begin at the start of your school semester in January. The specific start date will vary according to your school schedule. The project will last approximately eight weeks, but can vary slightly due to the lesson delivery pace. Each unit will last approximately two weeks and in order to ensure fidelity of the study, teachers will need to teach all the units.

Where?
All lessons will be designed to be taught at your normal classroom location. Student access to classroom computers or a computer lab will be helpful. Material will be mailed to you in late-December/early-January.

How?
Lesson plans and other materials will be provided electronically and by hard copy. Teachers will receive a binder of detailed lesson plans, labs, assessments, etc., as well as a USB drive with digital copies of the material. You will be able to keep this material.

Why?
This project will serve as my dissertation for the completion of a PhD in Agricultural Education at the University of Florida. I have a passion for student learning in agricultural and environmental education, and for helping fellow agriculture teachers. I will be personally designing and financing a good portion of this study. Your contribution will be the key to successful research and I will be very appreciative of your time. I will be available to answer any questions and offer support throughout the duration of the project.

Sincerely,

[Signature]

Blake Colclasure
APPENDIX B
RESEARCHER BIOGRAPHIES

Blake Colclasure is a PhD candidate in Agricultural Education and Communication at the University of Florida. His primary research interests include teaching methods in agriscience and environmental education. Before attending the University of Florida, Blake received a Master's degree in Environmental Sciences and Natural Resources and a Bachelor's degree in Agriculture and Environmental Science Communication and Education from the University of Illinois. Blake had the opportunity to teach agriscience at Steeleville High School in southern Illinois for three years. This positive experience inspired him to pursue a PhD at the University of Florida which will allow him to become a teacher educator in agricultural education.

Dr. Andrew Thoron is an associate professor of agricultural education at the University of Florida. Andrew grew up in central Illinois and taught high school agriscience at Mt. Pulaski High School. He then took on a leadership role with the Illinois State Board of Education for agricultural education where his primary responsibility was to aid agriscience teachers, administrators, and community members in developing and maintaining agricultural education programs. Andrew's research interests are in the area of teaching and learning, focusing on argumentation skill development. Additional research interests are central to effective teaching, student achievement and scientific reasoning.
APPENDIX C
INFORMED ASSENT AND CONSENT FORMS

Informed Assent for Students

Protocol Title: Investigation of teaching methods effect on student content knowledge, critical thinking, and environmental attitude (IRB201703357)

Please read this document carefully before you decide to participate in this study.

Purpose of the research study: The purpose of this study is to investigate a teaching method and how it impacts students' knowledge, thinking, and attitude toward the environment.

What you will be asked to do in this study: You will be asked to participate in normal lessons in your agriscience course. In addition, you will be asked to complete a series of assessment instruments.

Time Required: Lesson plans have been developed to take 8 weeks of classroom instruction.

Risks and Benefits: There are no anticipated risks or benefits to your participation in this study.

Confidentiality: Your identity will be kept confidential to the extent allowed by law.

Voluntary participation: Your participation in this study is completely voluntary. There is no penalty for not participating.

Right to withdraw from study: You have the right to withdraw from the study at any time without consequence.

Whom to contact if you have questions about the study:
Blake Coleslasure, Graduate Student, Agricultural Education and Communication Department, 310 Rolfs Hall, P.O. Box 110540, Gainesville, FL 32611-0540; Phone: (217) 898-2036; Email: becoleslasure@ufl.edu
Andrew C. Thoron, PhD, Associate Professor, Agricultural Education and Communication Department, Rolfs Hall, P.O. Box 110540, Gainesville, FL 32611-0540; Phone: (352) 294-1992; Email: athoron@ufl.edu

Whom to contact about your rights as a research participant in the study: UFIRB Office, Box 112250, University of Florida, Gainesville, FL 32611-2250; Phone: (352) 392-0433

Agreement Requirements:
I have read the procedure described above. I voluntarily agree to participate in the procedure and have provided my parent or guardian’s signed consent form that allows me to participate in this study. I have received a copy of this description.
Informed Consent for Students (18 years of age or older)

Protocol Title: Investigation of teaching methods effect on student content knowledge, critical thinking, and environmental attitude (IRB201703357)

Please read this consent document carefully before you decide to participate in this study.

Purpose of the research study: The purpose of this study is to investigate a teaching method and how it impacts students’ knowledge, thinking, and attitude toward the environment.

What you will be asked to do in this study: You will be asked to participate in normal lessons in your Agriscience/Natural Resource & Ecology course. In addition, you will be asked to complete a series of assessment instruments.

Time Required: Lesson plans have been developed to take 8 weeks of classroom instruction.

Risks and Benefits: There are no anticipated risks or benefits to your participation in this study.

Confidentiality: Your identity will be kept confidential to the extent allowed by law.

Voluntary participation: Your participation in this study is completely voluntary. There is no penalty for not participating.

Right to withdraw from study: You have the right to withdraw from the study at any time without consequence.

Whom to contact if you have questions about the study:
Blake Colclasure, Graduate Student, Agricultural Education and Communication Department, 310 Rolfs Hall, P.O. Box 110540, Gainesville, FL 32611-0540; Phone: (217) 898-2036; Email: bcolclasure@ufl.edu

Andrew C. Thoron, PhD, Associate Professor, Agricultural Education and Communication Department, Rolfs Hall, P.O. Box 110540, Gainesville, FL 32611-0540; Phone: (352) 294-1992; Email: a thoron@ufl.edu

Whom to contact about your rights as a research participant in the study: UFIRB Office, Box 112250, University of Florida, Gainesville, FL 32611-2250; Phone: (352) 392-0433

Agreement:
I have read the procedure described above. I am 18 years of age or older and voluntarily agree to participate in the study. I have received a copy of this description.

Participant (Printed Name): ____________________________________________

Signature: ____________________________ Date: ___________
Dear Parent or Guardian,

Your child’s Agriscience/Natural Resource & Ecology class has been selected to participate in a research study (IRB201703357) to measure the effect of teaching methods. The results of this study will be used to improve the instruction received by students in agriscience programs. These results may not directly help your child today, but will benefit future students. With your permission, I would like to ask your child to volunteer to participate in this research.

In addition to the normal classroom lessons and assessments, your child will be asked to complete a critical thinking assessment and an environmental attitude assessment, taking approximately 40 minutes at the beginning and end of the study. Your child’s identity will be kept confidential to the extent allowed by law. Your child’s name will not be collected or recorded. Also, participation in this study will not affect their grades in the course.

You and your child have the right to withdraw consent of your child’s participation at any time without consequence. There are no known risks or immediate benefits to the participants. No compensation is offered for participation.

If you have any questions about this research protocol, please contact Blake Colclasure (bcolclasure@ufl.edu) or Dr. Andrew Thoron (athoron@ufl.edu). Questions or concerns about your child’s rights as a research participant may be directed to the UFIRB Office, University of Florida, Box 112250, Gainesville, FL 32611, (352) 392-0433.

I have read the procedure described above. I voluntarily give consent for my child, ________________________________, to participate in this study. I have received a copy of this description.

Parent/Guardian (Printed Name): ________________________________

Signature: ___________________________ Date: ________________
APPENDIX D
LESSON TITLES AND OBJECTIVES

Module: The Energy of Life
Lesson 1: Introduction to Energy in Ecosystems
1) Determine the sequence of energy flow of a group of organisms and sketch the food chain.
2) Calculate the percent of energy transfer through the trophic levels of a food chain.
Lesson 2: Exploring Food Chains and Food Webs
1) Research an ecosystem of choice and determine a food chain present in that ecosystem.
2) Use a graphic organizer to depict an energy pyramid and the relationships within the pyramid.
Lesson 3: Carrying Capacity
1) Simulate the carrying capacity of a deer population in relation to access to food, water, and shelter.
2) Determine the habitat requirements for a group of animals in an ecosystem and the overall area needed to sustain the ecosystem.
Lesson 4: Invasive Species
1) Investigate an invasive species and determine the impact invasive species have on local food webs.

Module: Flourishing Fauna
Lesson 1: Exploring Habitats
1) List the components of a habitat and be able to explain why distinct habitats are important for the survival of a population.
2) Explore the habitat requirements of a species.
Lesson 2: Managing Wildlife Populations
1) Conduct hypothetical wildlife management decisions and identify at least four factors that can affect the size of wildlife populations.
Lesson 3: Adaptations
1) Investigate the adaptive nature of an animal, such as the beak of a bird to its environment in order to acquire food for survival.
Lesson 4: Genetics
1) Predict the probability of the occurrence of qualitative traits within an animal species using Punnett Squares.

All Natural Flora
Lesson 1: Exploring Biodiversity
1) Determine the biodiversity of plants in a given area using a common sampling technique.
Lesson 2: Vegetative Observations
1) Conduct a Relevé or use internet resources to conduct a web survey of regional vegetative composition types.
Lesson 3: Vegetative Management
1) Investigate vegetative management to improve the habitat of an animal species.
Lesson 4: Ecological Succession
1) Simulate the process of vegetative succession by role playing in a game and/or using graphic analysis

Agricultural Stewardship
Lesson 1: Introduction to Agricultural Stewardship
1) Explore sustainable and non-sustainable practices in agricultural production.
Lesson 2: Nutrient Management
1) Use the “4R” nutrient stewardship approach to make fertilizer recommendations.
Lesson 3: Soil Conservation
1) Explore strategies for soil conservation in agricultural production.
Lesson 4: Agricultural Management Plan
1) Apply the skills and knowledge learned regarding stewardship and sustainable agriculture management decisions related to a fictitious property, determine a commodity to raise, apply for a stewardship program, and determine the best stewardship practices to implement.
Dear Teacher,

First and foremost, I cannot thank you enough for participating in this research project. This research will provide valuable information to stakeholders of agricultural and environmental education. Conclusions made from this research will be disseminated back to CASE, agricultural teacher educators across the nation, and yourselves. This project will also serve as my dissertation research at the University of Florida.

Below are some brief notes that will help you get started.

• The research design of this project separates all participating teachers into two groups. Each group of lesson plans has modifications and additions to the existing curriculum that I believe are improvements. Group A teachers will implement a more traditional teaching approach that includes interest approaches, direct instruction, application activities with inquiry, student evaluations, and lesson summaries. Group B teachers will implement the 5E model of inquiry-based instruction. Although the content is very similar for each group, the method of which it is taught is different. Please use the method of instruction identified in the lesson plans to the best of your ability. At the conclusion of the study, you will have access to each set of lesson plans that may be useful for you when you teach this content again!

• Enclosed you will find an audio recorder. When you are teaching lessons, please record yourself as often as you can. It is okay if you do not record everything. The audio recordings will allow me to check the fidelity of the treatment – don’t worry if you find yourself slipping up from time-to-time! You are able to keep the recorders if you would like. I will just need access to some of the audio recordings and you should be able to send the file electronically at the end of the study.

• Hard copies of each lesson plan and materials needed can be found within this binder. A checklist for completion can be found in the next few pages and will be useful to keep organized. Everything is also digital. It is preferred that students take assessments digitally. However, if you want to distribute hard copies of the assessments and send them back or scan them that is okay too (I will pay for any shipping costs!).

• This research project follows all laws required by the Institute Review Board. In order for the data to be used, signatures are needed by students who are over 18 and by parents of students who are under 18. These forms can also be found in the next few pages.

• If at any time you have questions or concerns, please don’t hesitate to contact me at bcolclasure@ufl.edu or by phone at 217-898-2036.

• You have been assigned to:

GROUP A

All lesson plans, materials, and student assessments can be found at:

https://bcolclasure3.wixsite.com/enved
Dear Teacher,

First and foremost, I cannot thank you enough for participating in this research project. This research will provide valuable information to stakeholders of agricultural and environmental education. Conclusions made from this research will be disseminated back to CASE, agricultural teacher educators across the nation, and yourselves. This project will also serve as my dissertation research at the University of Florida.

Below are some brief notes that will help you get started.

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• Enclosed you will find an audio recorder. When you are teaching lessons, please record yourself as often as you can. It is okay if you do not record everything. The audio recordings will allow me to check the fidelity of the treatment – don’t worry if you find yourself slipping up from time-to-time! You are able to keep the recorders if you would like. I will just need access to some of the audio recordings and you should be able to send the file electronically at the end of the study.

• Hard copies of each lesson plan and materials needed can be found within this binder. A checklist for completion can be found in the next few pages and will be useful to keep organized. Everything is also digital. It is preferred that students take assessments digitally. However, if you want to distribute hard copies of the assessments and send them back or scan them that is okay too (I will pay for any shipping costs!).

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• If at any time you have questions or concerns, please don’t hesitate to contact me at bcolclasure@ufl.edu or by phone at 217-898-2036.

• You have been assigned to:

GROUP B

All lesson plans, materials, and student assessments can be found at:

https://bcolclasure3.wixsite.com/enved-groupb
APPENDIX F
TEACHER CHECKLIST FOR COMPLETION

Checklist for Completion

This table may serve as a useful tool to make sure that all portions of the project are completed in the correct sequence. Placing a check in the left column of the table as the items are completed may be a useful strategy to keep organized.

<table>
<thead>
<tr>
<th></th>
<th>Estimated Time to Complete</th>
<th>To Complete</th>
</tr>
</thead>
<tbody>
<tr>
<td>(√)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 min</td>
<td>Students Take Environmental Attitude Survey 1</td>
<td></td>
</tr>
<tr>
<td>45 min</td>
<td>Students Take Critical Thinking Assessment 1</td>
<td></td>
</tr>
<tr>
<td>15 min</td>
<td>Students Take Test 1 (pre-test) for the Energy of Life Module</td>
<td></td>
</tr>
<tr>
<td>2 days</td>
<td>Teach Lesson 1</td>
<td></td>
</tr>
<tr>
<td>2 days</td>
<td>Teach Lesson 2</td>
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</tr>
<tr>
<td>2 days</td>
<td>Teach Lesson 3</td>
<td></td>
</tr>
<tr>
<td>2 days</td>
<td>Teach Lesson 4</td>
<td></td>
</tr>
<tr>
<td>15 min</td>
<td>Students Take Test 2 (post-test) for the Energy of Life Module</td>
<td></td>
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<tr>
<td>15 min</td>
<td>Students Take Test 1 (pre-test) for the Flourishing Fauna Module</td>
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<tr>
<td>2 days</td>
<td>Teach Lesson 1</td>
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<td>2 days</td>
<td>Teach Lesson 2</td>
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<tr>
<td>2 days</td>
<td>Teach Lesson 3</td>
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<td>2 days</td>
<td>Teach Lesson 4</td>
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</tr>
<tr>
<td>15 min</td>
<td>Students Take Test 2 (post-test) for the Flourishing Fauna Module</td>
<td></td>
</tr>
<tr>
<td>15 min</td>
<td>Students Take Test 1 (pre-test) for the All Natural Flora Module</td>
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<tr>
<td>2 days</td>
<td>Teach Lesson 1</td>
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<td>2 days</td>
<td>Teach Lesson 2</td>
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<td>2 days</td>
<td>Teach Lesson 3</td>
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<tr>
<td>2 days</td>
<td>Teach Lesson 4</td>
<td></td>
</tr>
<tr>
<td>15 min</td>
<td>Students Take Test 2 (post-test) for the All Natural Flora Module</td>
<td></td>
</tr>
<tr>
<td>15 min</td>
<td>Students Take Test 1 (pre-test) for the Agricultural Stewardship Module</td>
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<tr>
<td>2 days</td>
<td>Teach Lesson 1</td>
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<td>2 days</td>
<td>Teach Lesson 2</td>
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<td>2 days</td>
<td>Teach Lesson 3</td>
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<tr>
<td>2 days</td>
<td>Teach Lesson 4</td>
<td></td>
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<tr>
<td>15 min</td>
<td>Students Take Test 2 (post-test) for the Agricultural Stewardship Module</td>
<td></td>
</tr>
<tr>
<td>10 min</td>
<td>Students Take Environmental Attitude Survey 2</td>
<td></td>
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<tr>
<td>45 min</td>
<td>Students Take Critical Thinking Assessment 2</td>
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APPENDIX G
EXPERIMENTAL GROUP INSTRUCTIONAL PLANS

Inquiry-Based Instruction in
ENVIRONMENTAL SCIENCES
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<tr>
<th>INSTRUCTIONAL PLAN</th>
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</thead>
<tbody>
<tr>
<td><strong>Course:</strong></td>
<td>Natural Resources &amp; Ecology</td>
</tr>
<tr>
<td><strong>Unit:</strong></td>
<td>Module: The Energy of Life</td>
</tr>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Lesson 1: Introduction to Energy in Ecosystems</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>~ 2 Days</td>
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</tbody>
</table>

**Objectives:**
- Determine the sequence of energy flow of a group of organisms and sketch the food chain.
- Calculate the percent of energy transfer through the trophic levels of a food chain.

**Equipment, Supplies, References, and Other Resources:**
- Activity 5.1.1 Energy Transfer
- Picture Activity

<table>
<thead>
<tr>
<th>Teacher Directions – 5E Stages</th>
<th>Content Outline / Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Engage</strong></td>
<td>Ask: <em>What do organisms need to survive?</em> Write student responses on the board. Expected answers include food, water, shelter, warmth, etc. Asks: <em>How do you know / Why do you think that?</em> Lead the short discussion to focus on food.</td>
</tr>
<tr>
<td><strong>Explore</strong></td>
<td>Show the pictures of the organisms on the “picture activity”. You can project the images or provide printed copies. Have students work in small groups (~3) to discuss the prompt and to develop their group’s answers.</td>
</tr>
<tr>
<td><strong>Explain</strong></td>
<td>Have each group (or a couple of groups) briefly present their food chain and reasoning to the rest of the class. Introduce the formal definitions for the components of trophic levels: producer → primary consumers → secondary consumers → tertiary consumers → quaternary consumers. Have the groups go back to their diagram to add these labels to their flow chart, matching the correct trophic level to the correct species. After students have done this, have them share the answers to ensure that they are correct. Show students the picture of a fungi on the second page of “picture activity”. Ask students how this organism gets its food. Where would it fit into their food chain and their trophic level food chain? Lead students to the correct answer of a decomposer and that decomposers break down dead and decaying organic matter, and allow nutrients to be recycled.</td>
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<tr>
<td>Teacher Directions – SE Stages</td>
<td>Content Outline / Key Points</td>
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<tr>
<td>Elaborate</td>
<td>Next, challenge students to think about the types of organisms that are found in their local environment (e.g. area park, forest, prairie, etc.). Have each group construct their own food chain by using common names. If students have access to technology, also have them include scientific names. Challenge students to see which group can get the longest food chain. Make sure they use proper diagraming and organizational skills and labels. Have students identify which trophic level each of the organisms would be classified in.</td>
</tr>
<tr>
<td>Evaluate (1)</td>
<td>Have students share their food chains with another group or the rest of the class.</td>
</tr>
<tr>
<td>Engage</td>
<td>Have students look at the primary producer(s) that they have identified in their food chain. Ask and lead a discussion utilizing the following questions as a guide: <em>Where do plants get their food? How do we know this? What would happen if the sun went away or if heavy cloud cover blocked a large portion of sunlight for an extended period of time?</em></td>
</tr>
<tr>
<td>Explore</td>
<td>Write down these two statements on the board:</td>
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<tr>
<td></td>
<td>1) Energy cannot be created or destroyed. Energy is transferred.</td>
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<td></td>
<td>2) No transfer of energy is 100% complete.</td>
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<td></td>
<td>Have students justify if they agree or disagree with the two statements above. Each group should provide rationale to support their decision.</td>
</tr>
<tr>
<td>Explain</td>
<td>After a few minutes, have students pair up with another small group to compare and contrast their positions and justifications. Lead this into a class discussion, eventually telling them that these are the two laws of thermodynamics. Discuss ecological efficiency – the 10% rule – only 10% of energy will transfer from one trophic level to the next (energy can be measured in kilocalories (Kcal)). Provide the following question: If 1,000 Kcal of light energy are incorporated into producers how much energy is available to primary consumers, secondary consumers, and tertiary consumers? (answer: 100 Kcal, 10Kcal, 1Kcal).</td>
</tr>
<tr>
<td>Evaluate (2)</td>
<td>Pose the following question to elaborate on the above information: How does latitude and longitude determine the amount of energy and diversity of species in an ecosystem?</td>
</tr>
<tr>
<td>Lesson Summary</td>
<td>Students will complete Activity 5.1.1 Energy Transfer. Check the completion and accuracy of this assessment for student understanding.</td>
</tr>
<tr>
<td></td>
<td>Discussion of major concepts should include, but are not limited to:</td>
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<tr>
<td></td>
<td>• The role of the sun in providing initial energy for ecosystems</td>
</tr>
<tr>
<td></td>
<td>• Two laws of thermodynamics</td>
</tr>
<tr>
<td></td>
<td>• Trophic levels/food chain</td>
</tr>
<tr>
<td></td>
<td>• Ecological efficiency and energy loss (10% rule)</td>
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</tbody>
</table>
## INSTRUCTIONAL PLAN

<table>
<thead>
<tr>
<th>Course:</th>
<th>Natural Resources &amp; Ecology</th>
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</thead>
<tbody>
<tr>
<td>Unit:</td>
<td>Module: The Energy of Life</td>
</tr>
<tr>
<td>Lesson Title:</td>
<td>Lesson 2: Exploring Food Chains and Food Webs</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>~ 2 Days</td>
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</table>

### Objectives:
- Use a simulation to explore how organism in an ecosystem interact.
- Construct and conduct an experiment with a digital ecosystem comprising of grass, rabbits, and up to two predator species: hawks and foxes.

### Equipment, Supplies, References, and Other Resources:
- Computers with Java (can be downloaded free — if using OS X 10.9 or newer you will also need the launcher app, which is also free).
- Internet Access
- Handout: Exploring Ecosystems: Lab Report
- Grassland Habitat Picture

### Teacher Directions – 5E Stages

#### Engage

Project the picture of the grassland habitat.

Show students a picture of a grassland habitat. Ask "What type of species can be found here?". Record student responses in a trophic level pyramid having them identify both the species and the trophic level in which they would belong to. Ask "How do you think these species interact?" "How are the dependent on each other?" Responses should be what was learned from the previous lesson and can be expanded upon thinking about a "food web" as opposed to a "food chain". Tell students that they will be using grassland ecosystem simulation to explore how organisms interact and effect each other.

#### Explore

Have students work individual or in pairs, depending on the number of computers available. Hand out the lab report associated with this activity for students to complete.

Here is a direct link to the simulation: [https://learn.concord.org/resources/126/experiment-with-ecosystems](https://learn.concord.org/resources/126/experiment-with-ecosystems)

Alternatively, Students should go [http://www.concord.org/](http://www.concord.org/) Click on "Explore our free STEM resources" in the upper right-hand corner. Towards the bottom of the new page, you will find a search by keyword box. In the box type: "Experiment with Ecosystems". The simulation will appear below and you can

Students should go to the concord site and find the simulation for "Experiment with Ecosystems" (see teacher directions to the left for steps to access the simulation). Students or pairs of students should complete the simulation and answer the questions embedded in the activity via the lab report handout. Students should record their responses via the lab report as their digital responses are not saved.

If you have a projector, display the simulation Experiment with Ecosystems for the whole class to see while presenting basic instructions.

- Read carefully, since the simulation provides background information and has hyperlinks if you need to check the definition of any word appearing in blue (page 1)
- Use the arrows near the compass at the bottom of the screen to navigate through the pages.
- Complete questions for Balancing in Ecosystems (page 2)
- Read think like a scientist (page 3)
- Run the missing grass experiment (page 4 & 5)
<table>
<thead>
<tr>
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</table>
| click on it to open up the window. Click “preview” to complete the simulation. Note: students may or may not have to create an account – if they do it is worth it as several of these simulations will be used going forward! Java may also need to be downloaded. It is free also worth it. I've tried using several computers with this digital platform and they all have worked. | • Run the fox experiment (page 6, 7, and 8)  
• Have students stop once they complete page 8 |
| **Explain**  
Lead a meaning-making discussion on each of the two simulations to ensure that students correctly completed the simulations and understand the phenomenon | Bring the class together to talk about their findings. If you are able to project the simulation on a screen, do so as you get input from the students about questions they answered, hypotheses they made, and observation and results they obtained. |
| **Elaborate**  
Students will expand what they have learned into the development and analysis of a new experiment using the software. | Give students the opportunity to design their own experiment using the simulation software. Discuss with students what is expected of their design. Have them be involved in the conversation of what needs to be included when designing an experiment?  
Student should fully explain their design on the back of their lab report sheet. Students will conduct their experiment, record results, graph their data, and write a conclusion. |
| **Evaluate** | Depending on time, students can present their experimental design and results to the rest of the class. Lab reports can also be turned in so student learning can be evaluated. |
| **Lesson Summary**  
3-2-1 Activity | Students should write down 3 things they learned, 2 things they have a question about, and 1 thing they want the instructor to know. Depending on time, these can be discussed in class. |
<table>
<thead>
<tr>
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<tbody>
<tr>
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<tr>
<td><strong>Unit:</strong> Module: The Energy of Life</td>
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<tr>
<td><strong>Lesson Title:</strong> Lesson 3: Carrying Capacity</td>
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<td><strong>Estimated Time:</strong> ~ 2 Days</td>
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**Objectives:**
- Simulate the carrying capacity of a deer population in relation to access to food, water, and shelter.
- Determine the habitat area requirements for a group of animals in an ecosystem and the overall area needed to sustain the ecosystem.

**Equipment, Supplies, References, and Other Resources:**
- Activity 5.1.3 Carrying Capacity (or) Acorn Carrying Capacity Lab – depending on your class size
- 2 Island Royale Readings
- Island Royale Case Study Socratic Seminar Guide
- Science Issue Discourse Rubric

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<tr>
<th>Teacher Directions – 5E Stages</th>
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<tbody>
<tr>
<td><strong>Engage</strong> Engage students on a conversation about animal populations (e.g. carrying capacity). Don’t tell students if they are wrong or right, but build an interest on exploring these population dynamics in regards to carrying capacity.</td>
<td>Ask students if they like to hunt or fish and if they have heard of bag limits (# of animals that you are allowed to kill and keep). “Why do you think there are limits on the number of animals that humans can harvest?” (expected answers could be that too many of one species could reduce the population). “What are some natural ways that animal populations are kept in check?” (food, shelter, water, habitat, etc.).</td>
</tr>
<tr>
<td><strong>Explore</strong> Have students complete the lab activity 5.1.3 if your class size is large enough. If your class size is too small to complete the activity use the acorn carrying capacity lab in its place.</td>
<td>If using activity 5.1.3, conduct the simulation as a class. Then complete tables 1 and 2. Have students work individually or in small groups to complete the three analysis questions. Students should then complete part II – managing space requirements.</td>
</tr>
<tr>
<td><strong>Explain</strong> Lead a class discussion with student responses. Introduce the terms associated with the two labs by using questioning and guiding students to the correct answers.</td>
<td>Either have groups pair up with each other, or as a class, compare and contrast student responses on their lab reports. Use guiding questions to make sure that students have a firm understanding of carrying capacity (the number of animals that an ecosystem consistently supports), density dependent limiting factors (factors such as food, water, and shelter), and density independent factors (factors such as fire, temperature, and human activity).</td>
</tr>
<tr>
<td><strong>Elaborate</strong> Students will investigate the Island Royale Case Study via the readings provided or an online search in preparation for a Socratic Seminar on this case.</td>
<td>Have students investigate the Island Royale Phenomena – a historical analysis of predator-prey and carrying capacity study. Students can either use the internet to investigate this case study, or can use the readings provided in this lesson plan. Students will record their thoughts on this case study in preparation for a Socratic Seminar, which will be a graded class discussion on this issue. Students should</td>
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<td>Teacher Directions – 5E Stages</td>
<td>Content Outline / Key Points</td>
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<tr>
<td>study.</td>
<td>record sources for their thoughts and observations and be prepared to discuss. They can use the rubric provided to understand what is expected in the Socratic Seminar.</td>
</tr>
<tr>
<td>Evaluate</td>
<td>Students should form desks in a manner in which they can clearly see each other. Students should take turns (with no formal order) discussing this case study. If students are “silent”, use the questions provided in the Socratic Seminar handout to foster good communication.</td>
</tr>
<tr>
<td>Exit Pass</td>
<td>Without using notes, students should complete an Exit Pass answering the three questions: 1) What is carrying capacity? 2) What are density dependent limiting factors? 3) What are density independent limiting factors?</td>
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</table>
## INSTRUCTIONAL PLAN

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<tbody>
<tr>
<td>Unit:</td>
<td>Module: The Energy of Life</td>
</tr>
<tr>
<td>Lesson Title:</td>
<td>Lesson 4: Invasive Species</td>
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<tr>
<td>Estimated Time:</td>
<td>~2 Days</td>
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</table>

### Objectives:
- Students will design and analyze experiments to determine the threat of a potentially invasive species.
- Investigate an invasive species and determine the impact invasive species have on local food webs.

### Equipment, Supplies, References, and Other Resources:
- Computer and projector
- I’m a Scientist Series – Invasive Species – Part I
- I’m a Scientist Series – Invasive Species – Part II

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<tr>
<th>Teacher Directions – SE Stages</th>
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</thead>
</table>
| **Engage**  
Have students write down thoughts on the brief video clip.  
Ask students questions to engage them in this lesson. | Create student interest in the lesson by showing the YouTube video clip of the invasive species Asian Silver Carp:  
[http://www.youtube.com/watch?v=rPeg1tbBt0A&t=59s](http://www.youtube.com/watch?v=rPeg1tbBt0A&t=59s)  
Ask students questions such as “Why do you think there are so many of this fish?” “How do you think they were introduced?” “What do you think makes a species invasive?”, etc. |
| **Explore**  
Give pairs or small groups of students the sheet “I’m a Scientist Series – Invasive Species – Part I”. | Have students read the passage in the “I’m a Scientist Series – Invasive Species – Part I”.  
Have students work in small teams to record observations, identify the problem, and design an experiment to test the problem. |
| **Explain**  
Ask questions to guide students to think critically about their observations, problem, and experimental design. | Using the “I’m a Scientist Series – Invasive Species – Part I” have students discuss their responses to the first two questions as a class. Students should say what they observed and their evidence of the observation. Students should also discuss what the problem is and their evidence of that problem. Class discussion should lead into the following information:  
- What an invasive species is? (a species that has been introduced to a new area and can: reproduce and spread rapidly, have little to no natural predators, have an abundant food source and habitat, outcompete native species for local food sources)  
- Ways that invasive species can be introduced to new areas. (the obvious example here is via pet trade, but what about alternatives such as commodity trade, boat travel, etc.)  
- What are exotic species? (a species that is not natural to an area, however all exotic species are not necessarily invasive)  
- What are the impact of invasive species? (negatively impact natural food chains and food webs, reduce habitat for native species, can lead to dramatic changes in ecosystems) |
| **Elaborate**  
Give the same pairs or small groups of students the “I’m a |

Students should use the sheet “I’m a Scientist Series – Invasive Species – Part II” to answer the questions.  
Students should work in their groups to compare and contrast their
<table>
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<tbody>
<tr>
<td>Scientist Series – Invasive Species – Part II”. Have students work to answer the questions. Use the questions provided in the sheet and come up with new questions that challenge students to think critically as you walk around to each of the groups.</td>
<td>design from the one that the scientist decided upon. Students should critically examine their own design and the design provided. What are the strengths and weakness of each design? Do the designs adequately answer the research question? Next, students should analyze the data provided in the table. What conclusions can be made from this data? What management recommendations should be made and why?</td>
</tr>
<tr>
<td><strong>Evaluate</strong></td>
<td>Provide students the opportunity to explore an invasive species interested to them. Students should write a brief report that includes: the specie’s common and scientific name, native location, introduced location, and impact upon the environment in which it was introduced.</td>
</tr>
<tr>
<td><strong>Lesson Summary</strong></td>
<td>Students should create a “tweet” in 50 characters or less to summarize the content that was learned in this lesson. Have several students share their “tweet” and discuss major concepts in this lesson.</td>
</tr>
<tr>
<td><strong>Summary Tweet</strong></td>
<td></td>
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<tr>
<th><strong>INSTRUCTIONAL PLAN</strong></th>
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</tr>
<tr>
<td><strong>Unit:</strong> Module: Flourishing Fauna</td>
<td></td>
</tr>
<tr>
<td><strong>Lesson Title:</strong> Lesson 1: Exploring Habitats</td>
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<tr>
<td><strong>Estimated Time:</strong> ~ 2 Days</td>
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**Objectives:**
- List the components of a habitat and be able to explain why distinct habitats are important for the survival of a population.
- Explore the habitat requirements of a local species.

**Equipment, Supplies, References, and Other Resources:**
- Habitat Picture Activity
- Local Habitat Exploration Activity

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<tbody>
<tr>
<td><strong>Engage</strong></td>
<td>On the board write the word “survival”. Ask students what they need to survive. Record responses on the board. (expected answers include food, water, shelter, etc.). Ask students if any of these are more important than the other? Ask students if wildlife have the same requirements and how they differ from what we need to survive? (example, we have the luxury of living pretty much wherever we want because we can control our living environment – shipping in food, pumping water from a well, etc.). Tell students that they are going to explore different classifications of living environments for organism.</td>
</tr>
<tr>
<td><strong>Explore</strong></td>
<td>Each group of students should construct a graphic organizer (e.g. table) that distinguishes these habitat classifications from each other. Let students work through this. Guide students to look for things such as predicted soil types, vegetation, climate, animal species, and any other thoughts they may have towards each picture.</td>
</tr>
</tbody>
</table>
| **Explain** | On the overhead, go through each picture. At first have students guess what type of habitat classification each picture is. Lead students to the correct answer. Have students compare and contrast the components on their graphic organizers verbally with each picture. Spend a small amount of time on each habitat classification, but also be careful to not be too over exhausting and redundant. During the discussion, generate the consensus that habitat is the surroundings in which animals live and include
  - Food
  - Water
  - Shelter
  - Space
  Each of the habitat pictures provided certainly have variations in these components. |
**Teacher Directions – SE Stages**

| Ask students if they are able to distinguish between the biotic (living factors) and abiotic (non-living factors). Ask questions to make sure they understand the difference between these two terms. Lastly, introduce the term community – all the plants and animals living together in a specific area.  
Have students go back into their groups and select their favorite habitat picture. Then ask students to discuss how the living community is interconnected in that habitat. Furthermore, provide students the following definitions and have them brainstorm specific ways in which their habitat could experience each of these types of habitat loss.  
  - Habitat Destruction – natural habitats are no longer able to support the species present due to interference (e.g. deforestation, filling in wetlands, urbanization, etc.)  
  - Habitat Degradation – natural habitats remain intact but at a degraded state leading to the loss of a functioning ecosystem (e.g. pollutants, invasive species, destructive fishing practice, etc.)  
  - Habitat Fragmentation – natural habitats become spatial separation from a previous state of great continuity (agricultural conversion, urbanization, dam building)  
During the activity walk around to each group to facilitate and guide the process. Lastly, have each group briefly share if time allows.  

| Elaborate  
Have students complete the activity: Local Habitat Exploration. Encourage students in your class to select a variety of species. | Students should use resources to complete the “Local Habitat Exploration Activity” and should follow directions on the activity sheet.  

| Evaluate  
Students should turn in their final product for the Local Habitat Exploration Activity. Evaluation in student performance can be noted on the completeness of their work and if they critically thought about habitat loss for their chosen species. Put students’ final products on display or complete a quick gallery walk with your students.  

| Lesson Summary  
3 Quick Things  
Have students write down “3 Quick Things” they learned in this lesson regarding habitat and habitat loss. Lead this into a brief discussion to cover the main objectives of this lesson. |
INSTRUCTIONAL PLAN

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<tbody>
<tr>
<td>Unit:</td>
<td>Module: Flourishing Fauna</td>
</tr>
<tr>
<td>Lesson Title:</td>
<td>Lesson 2: Managing Wildlife Populations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>~ 2 Days</td>
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</table>

Objectives:

- Conduct hypothetical wildlife management decisions and identify at least four factors that can affect the size of wildlife populations.

Equipment, Supplies, References, and Other Resources:

- Passenger Pigeon Reading
- Passenger Pigeon Debate – Pro Protection
- Passenger Pigeon Debate – Anti Protection
- Activity 6.2.4 – Managing Populations
- Activity 6.2.4 – Moose Management Cards (per group of 4)
- One die (per group of 4)

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</table>
| **Engage**
Pass out reading “Passenger Pigeon” | Give students the reading “Passenger Pigeon”. Have the students read the true story about the extinction of the passenger pigeon. |
| **Explore**
Break students into two groups that will prepare for a debate. | In order to prepare for a brief debate, each group of students will receive the sheet “passenger pigeon – pro protection” or “passenger pigeon – anti protection”. Each group should discuss amongst themselves and come up with a list of arguments for their position that utilizes environmental, legal, social, ethnocentric, and economic values. Each group can prepare for around 10 minutes (more if needed). |
| **Explain**
Student Debate | The two groups should debate their position in an organized fashion led by the teacher. After the debate, ask the questions such as “why do you think it is important to understand the policies of wildlife management?”. Pick out student positions and have them follow up with justification (e.g. “Why did you use that as an argument?”). Ask why populations change? (answers include food sources, habitat changes, direction human intervention, density independent factors – forest fires, climate change). |
| **Explore (2)** | Have students partner up and give them 5 minutes to develop and revisit the follow scenario of the passenger pigeon still being alive, but in the process of going extinct. Have them jot down a few ideas of how they would manage the passenger pigeon population. |
| **Explain (2)** | Write the following on the board:  
  • Managing Habitat (e.g. removing invasive species) |
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<thead>
<tr>
<th>Teacher Directions – 5E Stages</th>
<th>Content Outline / Key Points</th>
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<tbody>
<tr>
<td></td>
<td>• Creating Habitat (e.g. planting a native butterfly garden)</td>
</tr>
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<td></td>
<td>• Managing Populations (e.g. hunting and fishing regulations)</td>
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<td></td>
<td>• Habitat Protection (e.g. protecting special areas from human intervention)</td>
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<td></td>
<td>• Population Protection (e.g. protecting specific animals from any human possession/interference (bad eagle)).</td>
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<td></td>
<td>Have students share their results. Place a checkmark next to each of these when a student shares a component of their management plan that aligns a management technique written on the board.</td>
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<thead>
<tr>
<th>Elaborate</th>
<th>Each group of students will complete Activity 6.2.4 Managing Populations. In groups, students should complete Part 1 – Determining Events; Part 2 – Managing Moose; Part 3 – Observations.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students should be grouped into</td>
<td>Each student should complete the conclusion questions to activity 6.2.4 in their own words.</td>
</tr>
<tr>
<td>groups of four. Each group should</td>
<td>1. What did you learn about the management of a wildlife population that you did not realize or understand prior to conducting this project?</td>
</tr>
<tr>
<td>complete Activity 6.2.4. Each</td>
<td>2. As a steward of natural resources, why is it important to understand the principles and policies of wildlife management?</td>
</tr>
<tr>
<td>student should complete their</td>
<td>3. Identify four factors that can affect the size of a wildlife population</td>
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<tr>
<td>own conclusion questions.</td>
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<tr>
<th>Evaluate</th>
<th>Word Splash – students are given a “splash” of the key words from the lesson. They must write a few meaningful sentences (summarize the lesson) using these words. The words are: population, wildlife management, habitat, carrying capacity.</th>
</tr>
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<tbody>
<tr>
<td>Conclusion Questions in activity</td>
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<td>6.2.4</td>
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<th>Lesson Summary</th>
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<tr>
<td>Word Splash</td>
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</table>
# INSTRUCTIONAL PLAN

**Course:** Natural Resources & Ecology  
**Unit:** Module: Flourishing Fauna  
**Lesson Title:** Lesson 3: Adaptations  
**Estimated Time:** ~ 2 Days  

**Objectives:**  
- Investigate the adaptive nature of an animal, such as the beak of a bird to its environment in order to acquire food for survival.

**Equipment, Supplies, References, and Other Resources:**  
- Dog Breed Pictures  
- The Case of Darwin’s Finches Activity Sheet  
- The Case of Darwin’s Finches Station Papers  
- The Case of Darwin’s Teacher Guide (ignore time frames – skip parts 1 or 2 or briefly cover)  
- Metric Ruler(s)  
- Common tools for picking things up (e.g. salad tongs, grill tongs, large pliers, tweezers, needle-nose pliers)  
- Food/candy/ beads of various sizes and shapes  
- Colored pencils (optional)

## Teacher Directions – 5E Stages | Content Outline / Key Points
--- | ---

**Engage**  
Show students the picture of the two dog breeds  
Show a picture of two breeds of dogs. Have students compare and contrast the two dog breeds. **Ask** students “How do you think these two types of dog breeds came to be?” **Ask** students if humans played a part in determining which traits are desired for a certain breed? **Ask** students to brainstorm how non-domesticated species can also develop specific traits (e.g. camouflage)

**Explore / Explain**  
Set up the 5 stations identified in the Darwin’s Finches lab. You can briefly discuss parts 1 and 2 of the procedure, but it is okay to jump into procedure 4 to save time.  
Have students break up into five groups (if you have enough students). It is okay if you do not have enough students (pairs of 2 would suffice). Each group of students will visit stations 1-5. If you have enough resources for each group to complete the stations in order that is best. However, having students rotate through the stations also work well.

**Elaborate / Evaluate**  
Give each group 5-10 minutes to develop their conclusions from the lab.  
Have teams present their conclusions and rationale. Discuss differences and come to a consensus that Darwin’s Finches are actually Tanagers.

Conduct class discussion that covers the following points: importance of making conclusion based on evidence, the validity of DNA evidence versus observational data in classifications, this project’s relationship to system biology (molecular, cellular, organism, population, community levels, changes in habitat, etc.), this project’s relationship to aspects of
<table>
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<th><strong>Teacher Directions – SE Stages</strong></th>
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<td>the nature of science (tentativeness, observation and inference, empirically based evidence).</td>
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<tr>
<td><strong>Lesson Summary</strong></td>
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<tr>
<td><strong>Journal Entry &amp; Discussion</strong></td>
<td>Have students write a brief journal entry about their experience with this lesson. What were the major concepts that they learned? After students write their entry, ask for volunteers to share their entry and discuss major themes associated with this lesson. (how species can adapt and evolve to environmental stimuli, how DNA sequencing is the most valid evidence for making conclusions on the relatedness of organisms)</td>
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### INSTRUCTIONAL PLAN

<table>
<thead>
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<th>Course</th>
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<tbody>
<tr>
<td>Unit</td>
<td>Module: Flourishing Fauna</td>
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<tr>
<td>Lesson Title</td>
<td>Lesson 4: Genetics</td>
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<tr>
<td>Estimated Time</td>
<td>~ 2 Days</td>
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#### Objectives:
- Predict the probability of the occurrence of qualitative traits within an animal species using Punnett Squares.

#### Equipment, Supplies, References, and Other Resources:
- Bear Cubs Picture (digital)
- Bear Coat Phenotypes and Genotypes
- Paper bag (or something to put slips of paper in)
- Activity 6.2.3 Population Pressures

#### Teacher Directions – 5E Stages

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<tr>
<td>Show students the “Bear Cubs Picture” on a projector.</td>
<td>Have students look at the bear cubs picture. Ask “What do you notice about this picture?” Eventually, students should come to the conclusion that the bear on the left has a lighter colored fur coat. <em>Ask</em> “Why do you think that this bear’s coat is lighter?” “Why do you think that is?” Continue to ask probing questions to see what students know about phenotypes and genotypes. (<em>e.g.</em> <em>Ask</em> has anyone heard of Gregor Mendel’s Pea Experiment?” etc.)</td>
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<th>Explore</th>
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<tr>
<td>Break students into groups. Give each group cutouts of the example Genotypes and Phenotypes of a bear’s color coat: “Bear Coat Phenotypes and Genotypes”.</td>
<td>Give each group of students cutouts of the genotype and phenotype examples of coat bears coat colors. Have each group investigate the cutouts and see what observations they can make from the symbols (genotypes) and (phenotypes). Let them work in teams to make observations and analysis. Try not to tell students answers. Let them observe and try to figure out conclusions on their own.</td>
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<th>Explain</th>
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| Have students take notes of key terminology that is seen from the student discussion via questioning. | Have each group explain their reasoning using their own terminology. Guide students’ thoughts to using the correct terminology by asking questions and eventually getting to the conclusion that the symbols are genes. *Ask* “What are genes?”
  - Gene – the simplest unit of inheritance that influences genetic traits in living things, carried in the chromosomes, passed from parent to offspring through meiosis and mitoses during sexual reproduction.
  - Genotype – the genetic make-up of living things. *Ask* “Does anyone know of a similar term only this term describes the observed characteristics of an individual without reference to its genetic make-up?”
  - Phenotype – the observed characteristic of an individual |
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<tr>
<td><strong>Explore (2)</strong></td>
<td>Collect all slips of paper from the cutouts in “Bear Coat Genotypes and Phenotypes” sheet.</td>
</tr>
<tr>
<td>Collect all slips of paper and let students draw 2 to represent a male and female bear to complete the challenge question.</td>
<td>Put all slips of paper in a bag or hat. Let each student (or pair of students) draw 2 slips of paper out of the bag. Challenge each group to figure out what the genotypes and phenotypes would look like for each offspring if the two bears had 4 offspring. They may or may not know how to do Punnett Squares and that is okay – don’t tell them yet. Let students try to figure it out.</td>
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<tr>
<td><strong>Explain (2)</strong></td>
<td>Have students explain how they completed the challenge above. What observations and analyses led them to this prediction? See if any students used a Punnett square to complete their predictions.</td>
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<tr>
<td>Let students explain their rationale to the challenge question. Provide correct terminology and Punnett Square calculations.</td>
<td>Provide several examples of using a Punnett Square from students’ bear slips. Make sure students understand how to calculate frequency of Genotypes (e.g. RR, Rr, rr) from the pairings and how to calculate the probability of phenotype (also expressed as a percentage).</td>
</tr>
<tr>
<td><strong>Elaborate</strong></td>
<td>Give each group the question: “What would happen if the bear’s environment changed to favor bears that have lighter fur color? (e.g. bear’s habitat became lighter allowing bears with lighter fur coat to blend in better in order capture prey)”</td>
</tr>
<tr>
<td>Challenge Question 2</td>
<td>Challenge students to use both the terms described in this lesson (phenotype, genotype) and terms used so far in this module and the last module. Discuss student responses.</td>
</tr>
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<td>Walk around to each group of students to guide their thinking.</td>
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</tr>
<tr>
<td><strong>Evaluate</strong></td>
<td>Students should complete the worksheet Activity 6.2.3 for a summative evaluation of this lesson.</td>
</tr>
<tr>
<td>Students should complete the worksheet Activity 6.2.3</td>
<td>Have students individually complete Activity 6.2.3 for a summative evaluation of this lesson.</td>
</tr>
<tr>
<td><strong>Lesson Summary</strong></td>
<td>Have students write down 2-3 things that they deem as key points from the lesson. Have them share their points with a neighbor. Briefly discuss student’s key points as a class.</td>
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<tr>
<td>Think/Pair/Share</td>
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<td>INSTRUCTIONAL PLAN</td>
<td>Group: B</td>
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<tr>
<td><strong>Course:</strong> Natural Resources &amp; Ecology</td>
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<tr>
<td><strong>Unit:</strong> Module: All Natural Flora</td>
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<tr>
<td><strong>Lesson Title:</strong> Lesson 1: Exploring Biodiversity</td>
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<td><strong>Estimated Time:</strong> ~ 3-4 Days</td>
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**Objectives:**
- Determine the biodiversity of plants in a given area using a common sampling technique.

**Equipment, Supplies, References, and Other Resources:**
- Computer, Projector, Internet
- Prairie Plant Community Pictures
- Estimating Plant Biodiversity – Virtual Lab (B)
- Activity 6.1.1 Exploring Biodiversity (and equipment – weather permitting)
- I'm a Scientist Series Biodiversity – Part I
- I'm a Scientist Series Biodiversity – Part II

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<tr>
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</table>
| **Engage**
Show students the four pictures of the different prairie plants. | After showing students the four pictures, have them discuss what is similar and different in each habitat. Ask question until students see a difference in each prairie's plant richness (number of different types of plants) and abundance (amount of each species). Lead students into the explore phase. |
| **Explore**
Break students into groups of 3 to 4. Give each group a set of the prairie pictures or place them on the board for all groups to see. | Have each group design a system in which to account for the plant biodiversity found in each prairie. Let students try to design procedures in which they can systematically collect biodiversity data in each of the four prairies. |
| **Explain**
Allow students explain in their own words the steps their group designed in the explore phase above. Follow this up with guided directions and formal definitions. | Let volunteers share the procedures they designed to compare and contrast the four prairies. As the teacher, expand and elaborate on their designs by describing ways in which to analyze the diversity in plant communities.
- Quadrats – plots of standard size (e.g. 1m x 1m) that can restrict the area to be sampled (common approach!)
- Relevé – the surveyor walks through each stand recording all the species encountered and describing the habitat and soil profile. Creates an organized list of plant diversity by canopy height, plant coverage, and habitat.
- Plot-less sampling – involves the use of sampling using points within a certain distance
- Distance methods – measures the distance from a sampling point or plant to the nearest plant
- Sampling with aerial photographs – using large scale (1:200) color or infra-red photographs are useful for mapping and recording |
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<tbody>
<tr>
<td><strong>Elaborate</strong></td>
<td>individual plant species in a range of vegetation types.</td>
</tr>
<tr>
<td>Have pairs of students complete Activity 6.1.1 Exploring Biodiversity (time &amp; weather permitting) AND/OR Estimating Plant Biodiversity – Virtual Lab B.</td>
<td>Have students complete Activity 6.1.1 if the weather is permitting. Students should follow directions associated with the laboratory exercise and should complete Activity 6.1.1 Student Worksheet. Students can work in small groups to complete this exercise. If a quadrat is unavailable a tape measure and string can be used. AND/OR (time and weather permitting) Have students complete the Estimating Plant Biodiversity – Virtual Lab. Students can work individually or in-pairs at teacher’s discretion. Students should complete the tables and lab questions associated with this virtual lab.</td>
</tr>
<tr>
<td><strong>Evaluate</strong></td>
<td>Give several minutes for students to individually work through part I of the activity. Discuss student responses. Have students complete I’m a Scientist Series Part II to be turned in for a summative evaluation of student growth in this lesson.</td>
</tr>
<tr>
<td>Have students complete I’m a Scientist Series - Biodiversity Part I Have students complete I’m a Scientist Series – Biodiversity Part II</td>
<td></td>
</tr>
<tr>
<td><strong>Lesson Summary</strong></td>
<td>Have each student write a central question that they believe to be important to this lesson. Collect students’ questions and redistribute them. Have students try to answer central question and share as a class.</td>
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## INSTRUCTIONAL PLAN

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<th>Group:</th>
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<tr>
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<tr>
<td>Unit:</td>
<td>Module: All Natural Flora</td>
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<tr>
<td>Lesson Title:</td>
<td>Lesson 2: Vegetative Observations</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>~ 2-3 Days</td>
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### Objectives:
- Conduct a Relevé or use internet resources to conduct a web survey of regional vegetative composition types.

### Equipment, Supplies, References, and Other Resources:
- Satellite and Aerial Picture Activity
- Project 6.1.2. Vegetation Relevé
- Vegetation Relevé Key
- Aerial Analysis Worksheet (B)

### Teacher Directions – 5E Stages

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</table>
| **Engage**
Questioning      | Ask students to think about their local community. Ask if the landscape has changed over the years? (e.g. building new subdivisions, new agricultural areas crops, new park, etc.). Ask students how they know these changes have occurred. Ask students what effect these changes have on wildlife species. |
| **Explore**
Group students into pairs/groups and give each pair/group aerial pictures found in the “Satellite & Aerial Picture Activity”, or conduct picture observations as a class. | Each pair/group of students (or as a class) should make a graphic organizer (e.g. table) that includes their observations from the pictures. Students should compare and contrast like pictures. Make hypothesis and prediction of how land cover has changed (why the think this) and potential effects of these changes on wildlife populations. |
| **Explain**
As a class, go over student responses to the picture analysis activity. Guide students to understand the important concepts identified in the right hand column through questioning. | Satellite and aerial imagery can document (as well as predict) changes in land cover (e.g. urban sprawl, changes in farming practices, etc.)

The first two picture of San Diego demonstrates urban sprawl that occurred between 1950 and 1990. Pay special attention to the natural areas (green) that were replaced by residential development.

The next two pictures are of Cap Cod, MA. Students should discuss the key that is provided and how the land cover changed between the years 1951 and 1990. Ask students what effect they think these changes may have had and why they think that.

The next picture shows urban sprawl in the northeastern IL (Chicago region). As stated in the activity the black dots are of blackbird populations. Students should discuss the effects that urban sprawl
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<td>have had on blackbird populations. The black dots were added to the map were based on field surveys during the time each of the photos were taken.</td>
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<td></td>
<td>The last four pictures demonstrate how agricultural production used to be more fragmented (more fields of smaller sizes, and different crop types). The newer pictures of each location demonstrate how fields have become much larger. Ask students questions to led them to the conclusion that there are less field edges (e.g. tree lines and grassy) that area important to connect habitat. Larger agricultural fields and increased monoculture has created a high degree of habitat fragmentation.</td>
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<tr>
<td><strong>Elaborate</strong></td>
<td>Students should work individually or in pairs to complete a digital aerial analysis to investigate questions of interest about their local area.</td>
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<tr>
<td>Students should use the project sheet “Aerial Analysis” to guide them in their investigation of regional land cover.</td>
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<td>AND/OR (depending on weather and time availability)</td>
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<tr>
<td>Students should complete a Vegetative Relevé (a physical analysis of vegetative cover) through using activity 6.1.2. Even if students are not able to get to the activity, the concept of a Vegetative Relevé should be discussed (quiz questions pertain to the Vegetative Relevé!!)</td>
<td></td>
</tr>
<tr>
<td>Vegetative Relevé</td>
<td>o A list of all the plants in a delimited plot of vegetation, with information on species cover, substrate, and abiotic factors</td>
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<tr>
<td>o Typically, vegetation is stratified into height categories chosen to describe vertical structure, and in each stratum each plant is assigned a cover value based on its representation in that stratum</td>
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<td>Ask: How can a Vegetative Relevé be used in addition to aerial mapping? What are the pros and cons to each?</td>
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<tr>
<td><strong>Evaluate</strong></td>
<td>Students should complete a lab report to discuss their findings for the aerial analysis activity and/or the Vegetative Relevé.</td>
</tr>
<tr>
<td><strong>Lesson Summary</strong></td>
<td>Have each student create a question that they believe represents a good question for the information they learned in this lesson. Have students pass their question to another student in the class. Students should try to answer their peer’s question. Discuss students’ questions as a class after.</td>
</tr>
<tr>
<td><strong>Partner and Class Questioning</strong></td>
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<td><strong>Engage</strong></td>
<td>Ask students if they have ever saw a monarch butterfly. Ask “What do you think they need in order to survive?” “What type of vegetation would you find the Monarch in?”</td>
</tr>
<tr>
<td>Have students watch the video clip, taking note on things that found interesting and potential environmental problems threatening the monarch butterfly.</td>
<td>If students seem unfamiliar with the butterfly, show students the quick video clip on Monarch Butterflies: <a href="https://www.youtube.com/watch?v=LawHWslqa5s">https://www.youtube.com/watch?v=LawHWslqa5s</a></td>
</tr>
<tr>
<td><strong>Explore</strong></td>
<td>In groups, have students create a list of things that could be done to protect the Monarch butterfly.</td>
</tr>
<tr>
<td>Partner students up into groups of 2 or 3.</td>
<td>Let each group share their thoughts. Record students’ ideas on the board that would be beneficial. Examples could include:</td>
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<tr>
<td><strong>Explain</strong></td>
<td>Discuss with students, through student questioning and notes that vegetation is an essential component to the functioning of an ecosystem.</td>
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<td>Have each group share their thoughts on ways in which the Monarch butterfly population can be preserved.</td>
<td>• Vegetation:</td>
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<td>○ involved in regulation of biogeochemical cycles (water, carbon, nitrogen, etc.)</td>
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<td>○ effects soil development over time, generally contributing to more productive soil</td>
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<td>○ conserves soil through root system (e.g. reduces erosion)</td>
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<td>○ provides food for primary consumers</td>
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<td></td>
<td>○ provides shelter for many species</td>
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<td>Teacher Directions – 5E Stages</td>
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<tr>
<td><strong>Elaborate</strong></td>
<td>Students should complete a Vegetative Management Plan for a species of interest to them. Direction for this assignment can be found on the project description page “Vegetative Management Plan”. As a class, create a list of the components that each group will need to discuss in their plan that will serve as the evaluation of their management plans.</td>
</tr>
</tbody>
</table>
| **Evaluate**                   | An evaluation of students’ vegetative management plan should be conducted. Depending on time constraints and the components agreed upon by the class, projects can be evaluated by:  
  - Oral Presentation  
  - Visual Presentation  
  - Written Presentation |
<p>| <strong>Lesson Summary</strong>             | Lead a quick discussion on the important takeaways from this lesson. Discuss the role that proper vegetation plays in a healthy ecosystem and how vegetation can be managed to improve the population of a specific species. |
| <strong>Student presentations</strong>      | |
| <strong>Discussion</strong>                 | |</p>
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<tr>
<td><strong>Engage</strong>&lt;br&gt;Ask students questions to get them engaged in the unit. Do not give students answers, but have them justify their thoughts and positions.</td>
<td>Ask: “Does anyone know of the devastating wildfires that have spread across areas of the west this past summer and fall?” “How do you think these fires started?” “Do you think some fires start naturally?” “How do you think wildfires effect plant community in habitats that fires spread through?” etc.</td>
</tr>
<tr>
<td><strong>Explore</strong>&lt;br&gt;Have students complete a virtual succession simulation.</td>
<td>Have students go to <a href="http://www.mrphome.net/mrp/succession.swf">http://www.mrphome.net/mrp/succession.swf</a> From this activity, have students take notes and thoughts on this virtual simulation, including key terms and understandings.</td>
</tr>
<tr>
<td><strong>Explain</strong>&lt;br&gt;Have students explain their findings from the virtual succession simulation. Expand on students’ findings in a discussion with question to make sure students understand the information in the right-hand column. Try to make sure that each of these concepts are covered fully.</td>
<td>Ecological succession – natural, gradual change in the types of species that live in an area&lt;br&gt;Primary succession – begins in a place without any soil (e.g. sides of volcanoes, landslides, flooding).&lt;br&gt;• 1st lichens grow followed by mosses – these are known as pioneer species&lt;br&gt;• grasses, wildflowers, and other plants take over as soil layer thickens due to decomposition and added organic matter&lt;br&gt;• shrubs and trees grow&lt;br&gt;Secondary succession – begins at a place that already has soil and was once home to living things&lt;br&gt;• occurs faster and has different pioneer species than primary succession (e.g. forest fire)&lt;br&gt;Climax community – A stable group of plants and animals that is the end result of the succession process.</td>
</tr>
<tr>
<td><strong>Elaborate</strong>&lt;br&gt;Set up lab aids material and pass out Activity 6.1.3 Ecological Succession</td>
<td>Have students complete Activity 6.1.3 Ecology Succession if lab aids are available. Have students work in small groups to complete the laboratory.</td>
</tr>
<tr>
<td>Teacher Directions – 5E Stages</td>
<td>Content Outline / Key Points</td>
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</tr>
<tr>
<td>AND/OR (depending on time and lab aid resources)</td>
<td>AND/OR (depending on time and lab aid resources)</td>
</tr>
<tr>
<td>Lab Case Study: Forest Succession</td>
<td>Have students work in small group to the Lab Case Study: Forest Succession</td>
</tr>
<tr>
<td><strong>Evaluate</strong></td>
<td></td>
</tr>
<tr>
<td>Pass out “Shaped by Fire” Reading</td>
<td>Have students individually read “Shaped by Fire”. Have students write a paragraph or two explaining how the fires at Yellowstone National Park demonstrate concepts learned in this lesson.</td>
</tr>
<tr>
<td><strong>Lesson Summary</strong></td>
<td></td>
</tr>
<tr>
<td>Catch-Phrase</td>
<td>Have students partner up. Have one student from each pair come up and record the following words, while keeping them a secret: Moss, Primary Succession, Climax Community, Pioneer Species. The student has one minute to try to get their partner to say the vocabulary words without saying the word. They can describe the word and use examples, but cannot draw or act.</td>
</tr>
<tr>
<td></td>
<td>Have students switch roles. The other student should record the following words while keeping them a secret: Secondary Succession; Yellowstone National Park; Forest Fire; Soil. Follow the same catch-phrase procedures.</td>
</tr>
<tr>
<td></td>
<td>After Catch-Phrase, discuss which words were easy and hard to describe and get partners to guess.</td>
</tr>
<tr>
<td>INSTRUCTIONAL PLAN</td>
<td>Group: B</td>
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<td>--------------------</td>
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</tr>
<tr>
<td><strong>Course:</strong></td>
<td>Natural Resources &amp; Ecology</td>
</tr>
<tr>
<td><strong>Unit:</strong></td>
<td>Module: Agricultural Stewardship</td>
</tr>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Lesson 1: Introduction to Agricultural Stewardship</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>~ 2 Days</td>
</tr>
</tbody>
</table>

**Objectives:**
- Explore sustainable and non-sustainable practices in agricultural production.

**Equipment, Supplies, References, and Other Resources:**
- Agricultural Stewardship Photos

<table>
<thead>
<tr>
<th>Teacher Directions – 5E Stages</th>
<th>Content Outline / Key Points</th>
</tr>
</thead>
</table>
| **Engage**
  Ask students questions to spark conversation about agricultural stewardship through the lens of the Dustbowl that occurred in the 1930’s. | Ask students if they have heard of the Dust Bowl that occurred in the United States during the early 1930’s. Ask questions to lead a short discussion to see what they know about this event and why it occurred. Ask students if the issue has been fixed and how it was fixed. (e.g. more sustainable tilling practices) |
| **Explore**
  Picture Exploration | Ask students what they think the term sustainability means. Lead a conversation that allow students to understand the concept of sustainability.  
  - Sustainability – the capacity of an ecosystem to endure. In ecology the word describes how biological systems remain diverse and productive overtime. Achieving sustainability will enable the Earth to continue to support life. Sustainable development meets the needs of all the present generation without compromising the ability of future generations to meet their own needs.  
  Group students into pairs or small groups. Show students the six pictures seen in the document “Agricultural Stewardship Photos”. In their groups, have students write down their observations. Have them record what agricultural practices are sustainable or unsustainable in each photo. If environmental issues are occurring, what can be done to limit the negative environmental impact. Students should organize their observations in a graphic organizer (e.g. table) |
| **Explain**
  Picture Explanations | As a class, go through each of the pictures. Ask students to describe their observations and predictions from the photos. Here are some thoughts on the pictures...  
  Picture 1: Poor management of water runoff, leading to soil erosion and potential nutrient runoff. The farmer could plant a riparian buffer zone in this area consisting of grasses.  
  Picture 2: Dustbowl. Carry on the conversation from the engage category. |
<table>
<thead>
<tr>
<th>Teacher Directions – 5E Stages</th>
<th>Content Outline / Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picture 3: Irrigation of lettuce. This could be a sustainable practice depending on water resources. Drip or strip irrigation could reduce the use of water.</td>
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<tr>
<td>Picture 4: A riparian buffer zone in corn field. Good management decision to reduce soil erosion and nutrient runoff.</td>
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</tr>
<tr>
<td>Picture 5: No-till farming practice. Beans are planted directly on top of corn stubble, leading to a reduction of soil erosion and use of fossil fuels (tractor use) to till soil. It is also evident that a crop rotation is being used (corn then soybeans). Since beans are a legume they add nitrogen to the soil naturally, reducing the use of adding nitrogen when corn is planted the following year.</td>
<td></td>
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<tr>
<td>Picture 6: Agroforestry – a sustainable land use management system in which trees or shrubs are grown around or among crops or pastureland.</td>
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<tr>
<td>Introduce students to the three pillars of sustainable development.</td>
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<tr>
<td>• Economic Growth – long term profitability for the farmer or rancher</td>
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<tr>
<td>• Environmental Protection – sustainable land use</td>
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<tr>
<td>• Social Equality – good quality life for the farmer and community</td>
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</tbody>
</table>

| Elaborate | Have students read/watch The Lorax and have students construct a graphic organizer that examines the pros and cons of the story in relation to each of the three pillars of sustainable development: economic growth, environmental protection, and social equity. |
| Students should read the book “The Lorax” if you have copies already. If not, feel free to use the full movie, movie clips, or the earlier produced and shortened animation at [https://www.youtube.com/watch?v=AEh2hkXOQB8](https://www.youtube.com/watch?v=AEh2hkXOQB8) |

| Evaluate | Students can be evaluated by their performance on the graphic organizer. Furthermore, the following questions can be given as a quiz to the material. |
| Graphic Organizer | 1) What is sustainable use? |
| Quiz | 2) What practices are used to make agriculture more sustainable? |
| | 3) Why must both production and consumption of food, fiber, and fuel on earth become sustainable? |

<p>| Lesson Summary | Discussion through questioning. |
| Discussion | • Review the three pillars to sustainable agriculture |
| | o Economic Growth |
| | o Environmental Protection |
| | o Social Equity |
| | • Review sustainable practices that farmers can implement. For example: |
| | o Planting Cover Crops |</p>
<table>
<thead>
<tr>
<th>Teacher Directions – 5E Stages</th>
<th>Content Outline / Key Points</th>
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<tbody>
<tr>
<td></td>
<td>o Crop Rotations</td>
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<td></td>
<td>o Agroforestry</td>
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<tr>
<td></td>
<td>o Utilizing Fertilizers &amp; Pesticides Responsibly</td>
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<tr>
<td></td>
<td>o Buffer Zones</td>
</tr>
<tr>
<td>Course:</td>
<td>Natural Resources &amp; Ecology</td>
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</tr>
<tr>
<td>Unit:</td>
<td>Module: Agricultural Stewardship</td>
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<tr>
<td>Lesson Title:</td>
<td>Lesson 2: Nutrient Management</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>~ 2 Days</td>
</tr>
</tbody>
</table>

**Objectives:**
- Use the “4R” nutrient stewardship approach to make fertilizer recommendations.

**Equipment, Supplies, References, and Other Resources:**
- Activity 7.1.2 Fertilizer Right
- Reading: Phytoremediation Article
- Reading: Pouring It On
- Computer, Projector, Internet

<table>
<thead>
<tr>
<th>Teacher Directions – 5E Stages</th>
<th>Content Outline / Key Points</th>
</tr>
</thead>
</table>
| **Engage**                     | Ask students if they have heard of “blue baby syndrome”. This illness occurs as infants consume too high levels of nitrates, decreasing oxygen carrying capacity of haemoglobin in babies, leading to a blue skin tint and the potential for death. Tell students that they are going to explore nitrogen accumulation in water supplies and that nutrient pollution is the top cause of water quality impairment, directly linked to 20% of impaired river and streams, and 22% of impaired lakes, also linked to:
  - low dissolved oxygen
  - impaired habitat
  - algal growth
  - noxious aquatic plants |
| **Explore**                    | After students have read the article, discuss the article with the class. Ask students what they know about nitrogen pollution and if they agree or disagree with the suggestions in the reading. Ask “Who should be blamed for excessive nitrate levels in water?” “What can farmers and homeowners do to limited nitrogen accumulation in water supply?” “How do you think excessive nitrogen in water effects ecosystems?” Challenge students to create a list of things that individuals can do (including farmers) to reduce the amount of nitrogen that escapes into the water supply. |
| **Explain**                    | Discuss students’ lists that they came up with. Make sure that students discuss the following examples
  - use less fertilizer (only when needed)
  - reduce fertilizer runoff through riparian buffers on agricultural land
  - create and protect areas that absorb excessive nutrients naturally (e.g. wetlands and phytoremediation)
<p>|                               | Use questioning and students lists to also discuss the following |</p>
<table>
<thead>
<tr>
<th>Teacher Directions – 5E Stages</th>
<th>Content Outline / Key Points</th>
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</thead>
<tbody>
<tr>
<td><strong>Elaborate</strong></td>
<td></td>
</tr>
<tr>
<td>Video, Article, &amp; Socratic Seminar</td>
<td>Students should read Phytoremediation and watch the video clip: <a href="https://www.youtube.com/watch?v=AJyshjzYGc">https://www.youtube.com/watch?v=AJyshjzYGc</a> Students should prepare to discuss the article and video clip via a non-graded Socratic Seminar. Students should record questions, observation, predictions, and conclusions. For example, can phytoremediation be used around agricultural fields to absorb nitrogen before it goes downstream? Students should recap the 4Rs discussed in the video.</td>
</tr>
<tr>
<td><strong>Evaluate</strong></td>
<td></td>
</tr>
<tr>
<td>Activity 7.1.2 Fertilizer Right</td>
<td>Students should complete Activity 7.1.2 Fertilizer Right and student responses should be used as the lesson’s summative evaluation.</td>
</tr>
<tr>
<td><strong>Lesson Summary</strong></td>
<td></td>
</tr>
<tr>
<td>Discussion Review</td>
<td>Review major problems that world is currently facing due to excessive nutrient pollution. Review what farmers can do to practice sustainable and efficient nutrient management. Review the 4 R’s The Right.... o Source o Time o Rate o Place</td>
</tr>
<tr>
<td>INSTRUCTIONAL PLAN</td>
<td>Group: B</td>
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<tr>
<td>Course:</td>
<td>Natural Resources &amp; Ecology</td>
</tr>
<tr>
<td>Unit:</td>
<td>Module: Agricultural Stewardship</td>
</tr>
<tr>
<td>Lesson Title:</td>
<td>Lesson 3: Soil Conservation</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>~ 1-2 Days</td>
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</tbody>
</table>

**Objectives:**
- Students will explore strategies for soil conservation in agricultural production.

**Equipment, Supplies, References, and Other Resources:**
- I’m a Scientist Series – Soil Runoff – Part I
- I’m a Scientist Series – Soil Runoff – Part II

<table>
<thead>
<tr>
<th>Teacher Directions – 5E Stages</th>
<th>Content Outline / Key Points</th>
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</thead>
<tbody>
<tr>
<td>Engage</td>
<td><strong>Ask:</strong> “Why is soil important to ecosystems?” (expected answers could include because it is the foundation of an ecosystem – soil type determine plant communities). <strong>Ask</strong> “What happens when soil is washed away?” <strong>Ask</strong> “Is it good or bad for farmers?” <strong>Why</strong> (expected answer is that good quality soil support agricultural production).</td>
</tr>
<tr>
<td>Explore</td>
<td>Students should work in pairs or small groups to read the situation, question observations and problems, and design an experiment to determine answers to the questions.</td>
</tr>
<tr>
<td>Explain</td>
<td>Allow each group to explain their observations, problems, and experimental design. Ask questions to lead students to the following types of tillage practice, which is important to understand in order to answer the research question.</td>
</tr>
<tr>
<td></td>
<td>What is the problem? Farmer wants to improve sustainability of his or her farm. Reducing soil runoff can:</td>
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<tr>
<td></td>
<td>1) improve soil quality / reduce soil loss – good for agriculture</td>
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<td></td>
<td>2) reduces potential fertilizer runoff</td>
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<tr>
<td></td>
<td>3) reduces other harmful effects in local waters such as Water Turbidity – the degree to which the water loses its transparency due to the presence of suspended particles. Clear water is considered a good measure for high quality and “healthy” water.</td>
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<tr>
<td></td>
<td>Practices the farmer is considering:</td>
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<td></td>
<td>No-Till – The farmer does not use tillage. Rather the farmer plants seeds directly in undisturbed soil.</td>
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<td></td>
<td>Conservation Tillage – minimizes the frequency or intensity of tillage (common to partially till the soil, leaving some residue from the crop that was grown the year prior)</td>
</tr>
<tr>
<td>Teacher Directions – SE Stages</td>
<td>Content Outline / Key Points</td>
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<tr>
<td>Conventional Tillage – 100% tillage of the soil (full-till)</td>
<td>Have students discuss, compare, and contrast their research design with others in the class.</td>
</tr>
<tr>
<td>Elaborate</td>
<td></td>
</tr>
<tr>
<td>I’m a Scientist Series – Soil Runoff – Part II</td>
<td>Students should go back into their pairs or groups. Students should receive “I’m a Scientist Series – Soil Runoff – Part II”. Students should compare and contrast their experimental design with the one that is provided.</td>
</tr>
<tr>
<td>Evaluate</td>
<td></td>
</tr>
<tr>
<td>I’m a Scientist Series – Soil Runoff – Part II continued</td>
<td>Students should work in their groups to create a brief research report discussing the conclusion section seen Part II of the assignment.</td>
</tr>
<tr>
<td>Lesson Summary</td>
<td></td>
</tr>
<tr>
<td>Word Splash</td>
<td>Given the words below, students should be able to a coherent paragraph that uses the terminology of the words correctly. The words are: No-Till, Conventional Tillage, Conservation Tillage, Soil Runoff, Non-Point Pollution, and Turbidity.</td>
</tr>
<tr>
<td>Teacher Directions – 5E Stages</td>
<td>Content Outline / Key Points</td>
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<tr>
<td><strong>Engage</strong>&lt;br&gt;Ask students the following questions and engage them in discussion without telling them right or wrong answers.</td>
<td><strong>Ask:</strong> “Do you think government regulation of agricultural production is good or bad? Why?” What can the government do besides make and enforce laws that promote sustainable agricultural practices?” etc.</td>
</tr>
<tr>
<td><strong>Explore</strong>&lt;br&gt;Give students a copy of the Conservation Stewardship Program – Conservation Activity List.</td>
<td>Have students pair up with a partner. Each pair of students should take five minutes to flip through the Conservation Stewardship Program. Students should look for enhancements that have been discussed in this class. Students should also be able to identify enhancements that have not been discussed. Students should record anything that surprised them or seems not to fit.</td>
</tr>
<tr>
<td><strong>Explain</strong>&lt;br&gt;Students should explain their thoughts after skimming through the Conservation Stewardship Program.</td>
<td>Have students explain their findings from the explore phase. <strong>Ask:</strong> What is an enhancement? What seemed appropriate? What seemed strange? Did anything unique standout? <strong>Ask:</strong> What do you think this program is? (Answer: The Conservation Stewardship Program (CSP) encourages agricultural producers to improve conservation systems by undertaking additional conservation activities and improving, maintaining, and managing existing conservation activities.</td>
</tr>
<tr>
<td><strong>Elaborate</strong>&lt;br&gt;Give each pair of students: Project 7.1.3 Stewards of the Land Conservation Program Application</td>
<td>Students will work in pairs to create a conservation program application for a fictitious 150 acres of land that they received. Students will use the conservation program application to complete: a property description; crop description; a description of five enhancements. Students should be shown the rubric for Project 7.1.3</td>
</tr>
<tr>
<td>Teacher Directions – 5E Stages</td>
<td>Content Outline / Key Points</td>
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<tr>
<td><strong>Evalute</strong></td>
<td>before they begin the project so they know how to be assessed.</td>
</tr>
<tr>
<td>Rubric 7.1.3</td>
<td>If time allows, have students share their plans with the class. Use the rubric 7.1.3 to assess student performance on the activity.</td>
</tr>
<tr>
<td><strong>Lesson Summary</strong></td>
<td>Have students individually complete the conclusion questions found in Activity 7.1.3. Then, discuss these questions as a class to serve as the lesson summary.</td>
</tr>
<tr>
<td>Questioning/Discussion</td>
<td>1) What challenges might a producer face when implementing conservation enhancements?</td>
</tr>
<tr>
<td></td>
<td>2) Why is it necessary for programs such as the Conservation Stewardship Program to exist?</td>
</tr>
<tr>
<td></td>
<td>3) Select two enhancements. Discuss how they benefit the environment or native species.</td>
</tr>
</tbody>
</table>
## APPENDIX H
### CONTROL GROUP INSTRUCTIONAL PLANS

<table>
<thead>
<tr>
<th>INSTRUCTIONAL PLAN</th>
<th>Group: A</th>
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</thead>
<tbody>
<tr>
<td><strong>Course:</strong></td>
<td>Natural Resources &amp; Ecology</td>
</tr>
<tr>
<td><strong>Unit:</strong></td>
<td>Module: The Energy of Life</td>
</tr>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Lesson 1: Introduction to Energy in Ecosystems</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>~ 2 Days</td>
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</tbody>
</table>

### Objective(s):
- Determine the sequence of energy flow of a group of organisms and sketch the food chain.
- Calculate the percent of energy transfer through the trophic levels of a food chain.

### Equipment, Supplies, References, and Other Resources:
- Presentation Note Pages
- PowerPoint: Energy in Ecosystems
- Activity 5.1.1

### Student Preparation
- Have students complete the bell ringer: Where does energy come from? Discuss student responses.
- Have students prepare to take notes to start the module.

### Teacher Directions / Methods
- Provide students presentation note pages.
- Present the PowerPoint "Energy in Ecosystems" using direct instruction.
- Have students take notes on the presentation and complete the reflections piece.

### Content Outline / Key Points
- Slide 1: Energy in Ecosystems
- Slide 2: Source of Energy
  - Nuclear reactions produce solar energy in the form of light and other radiation.
  - Autotrophic organisms capture light energy through photosynthesis.
- Slide 3: Light Energy Reaches Earth
  - Reflected back into space
  - Absorbed or transmitted by atmosphere
  - Absorbed and captured in photosynthesis
- Slide 4: What is energy?
  - Energy is the ability to do work.
  - Plants convert light energy into chemical energy, which animals can use to do the work of living.
- Slide 5: Thermodynamics
  - 1st Law – Energy cannot be created or destroyed. Energy is transferred.
  - 2nd Law – No transfer of energy is 100% complete
    - Incorporated into organism’s tissues.
    - Metabolized for heat and motion.
    - Remains in organism at death.
- Slide 6: Trophic Levels
  - An organism’s position in the sequence of energy transfers.
    - Producers – first level
    - Primary Consumers
    - Secondary Consumers
    - Tertiary Consumers
<table>
<thead>
<tr>
<th>Teacher Directions / Methods</th>
<th>Content Outline / Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>▪ Quaternary Consumers</td>
</tr>
<tr>
<td></td>
<td>▪ Slide 7: Decomposers and Detritivores</td>
</tr>
<tr>
<td></td>
<td>o Break down dead and decaying organic matter.</td>
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<td></td>
<td>o Allow nutrients to be recycled.</td>
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<td></td>
<td>▪ Slide 8: Productivity</td>
</tr>
<tr>
<td></td>
<td>o Gross primary production – the rate of total organic matter produced by plants.</td>
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<td></td>
<td>o Net primary production – the rate plants produce biomass beyond what is necessary to survive.</td>
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<tr>
<td></td>
<td>o Secondary production – the energy leaving one trophic level for the next.</td>
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<tr>
<td></td>
<td>▪ Slide 9: Ecological Efficiency</td>
</tr>
<tr>
<td></td>
<td>o 10% rule – only 10% of energy will transfer from one trophic level to the next.</td>
</tr>
<tr>
<td></td>
<td>o Energy measurement – kilocalories (Kcal)</td>
</tr>
<tr>
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<td>▪ Slide 10: Energy Loss</td>
</tr>
<tr>
<td></td>
<td>o Example:</td>
</tr>
<tr>
<td></td>
<td>▪ 1000Kcal of light energy incorporated into producers generates...</td>
</tr>
<tr>
<td></td>
<td>▪ 100Kcal of energy available to primary consumers which generates...</td>
</tr>
<tr>
<td></td>
<td>▪ 10Kcal energy available to secondary consumers generating...</td>
</tr>
<tr>
<td></td>
<td>▪ 1Kcal available to tertiary consumers</td>
</tr>
<tr>
<td></td>
<td>▪ Slide 11: Role of Light Energy in Ecosystems</td>
</tr>
<tr>
<td></td>
<td>o Light energy captured is dependent on latitude and longitude</td>
</tr>
<tr>
<td></td>
<td>o Tropical region – high input of light, greater biodiversity</td>
</tr>
<tr>
<td></td>
<td>o Polar region – low input of light, less biodiversity</td>
</tr>
<tr>
<td></td>
<td>▪ Slide 12: References</td>
</tr>
<tr>
<td>Application:</td>
<td>▪ Students will work in pairs to complete Activity 5.1.1 Energy Transfer</td>
</tr>
<tr>
<td></td>
<td>▪ Provide students with a copy of Activity 5.1.1 Energy Transfer. Students will work in pairs to complete the activity.</td>
</tr>
<tr>
<td></td>
<td>▪ Discussion of major concepts should include, but are not limited to:</td>
</tr>
<tr>
<td></td>
<td>o The role of the sun in providing initial energy for ecosystems</td>
</tr>
<tr>
<td></td>
<td>o Two Laws of Thermodynamics</td>
</tr>
<tr>
<td></td>
<td>o Trophic Levels</td>
</tr>
<tr>
<td></td>
<td>o Ecological Efficiency and Energy Loss</td>
</tr>
<tr>
<td>Evaluation:</td>
<td>▪ The teacher should collect and analyze student performance on</td>
</tr>
<tr>
<td>Teacher Directions / Methods</td>
<td>Content Outline / Key Points</td>
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<td></td>
<td>Activity 5.1.1.</td>
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</tbody>
</table>
## INSTRUCTIONAL PLAN

**Course:** Natural Resources & Ecology  
**Unit:** Module: The Energy of Life  
**Lesson Title:** Lesson 2: Exploring Food Chains and Food Webs  
**Estimated Time:** ~ 2 Days

### Objective(s):
- Research an ecosystem of choice and determine a food chain present in that ecosystem.  
- Use a graphic organizer to depict an energy pyramid and the relationships within that pyramid.

### Equipment, Supplies, References, and Other Resources:
- Student Note Sheet or Note’s Binder  
- Project 5.1.2 Ecosystem Study – Energy Pyramid  
- Project 5.1.2 Student Worksheet  
- Project 5.1.2 Evaluation Rubric  
- Computer with Internet access and graphic organizer software

### Student Preparation:
- Briefly review energy transfer material from lesson one and have students take out their student notes to add more content on food chains and food webs.

### Teacher Directions / Methods

<table>
<thead>
<tr>
<th>Teacher Directions / Methods</th>
<th>Content Outline / Key Points</th>
</tr>
</thead>
</table>
| • Write and discuss the following notes on the board using direct instruction. | • Food chain – A sequence of plants and animals that feed on each other.  
• Food web – A group of organisms that depend on each other for food in a given ecosystem. A food web typically consists of a series of interconnected food chains.  
• Biodiversity – the degree of different species found within an ecosystem.  
• An ecosystem with limited energy input from the sun (e.g. polar ecosystem) may have more of a straightforward flow of energy and less biodiversity compared to an ecosystem with high energy input (e.g. tropical ecosystem) |

### Application:

<table>
<thead>
<tr>
<th>Application</th>
<th>Content Outline / Key Points</th>
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</thead>
</table>
| • Have students work individually to complete Project 5.1.2 Ecosystem Study – Energy Pyramid | • Students will use project 5.1.2 Ecosystem Study – Energy Pyramid to select an ecosystem of choice and to determine the plants and animals that reside there.  
• Students will use a graphic organizer to develop a visual representation of the energy pyramid. The parameters of the pyramid include:  
  o The pyramid is titled and identifies the geographic area of the ecosystem.  
  o Must include 5 trophic levels.  
  o Must include a minimum of 5 plant organisms  
  o Must include a minimum of 5 animal organisms |
<table>
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<tr>
<th>Teacher Directions / Methods</th>
<th>Content Outline / Key Points</th>
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</thead>
</table>
| • Pass out project 5.1.2 Student Worksheet  
  • Gallery Walk | o Includes a picture or illustration, the common name, and the scientific name of each organism.  
  o Each organism is placed on the correct trophic level.  
  o Consumers may occupy more than one trophic level.  
  • Students should print and display their pyramid. During a gallery walk, students should fill in the worksheet 5.1.2 that requires them to note similarities and differences between the ecosystems. |
| **Closure/Summary:** | **Conclusion Questions**  
  o What producers are critical to the existence of your ecosystem?  
  o What consumers are critical to the existence of your ecosystem?  
  o What plant and animal interactions in your ecosystem were new to you?  
  o What differences between your ecosystem and others did you observe?  
  o What similarities between your ecosystem and others did you observe? |
| **Evaluation:** | • Use Project 5.1.2 Evaluation Rubric to assess student performance on their food pyramids. |
### INSTRUCTIONAL PLAN

<table>
<thead>
<tr>
<th>Course:</th>
<th>Natural Resources &amp; Ecology</th>
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<tbody>
<tr>
<td>Unit:</td>
<td>Module: The Energy of Life</td>
</tr>
<tr>
<td>Lesson Title:</td>
<td>Lesson 3: Carrying Capacity</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>~ 2 Days</td>
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</tbody>
</table>

**Objective(s):**
- Simulate the carrying capacity of a deer population in relation to access to food, water, and shelter.
- Determine the habitat are requirements for a group of animals in an ecosystem and the overall area needed to sustain the ecosystem.

**Equipment, Supplies, References, and Other Resources:**
- Activity 5.1.3 Carrying Capacity (or) Acorn Carrying Capacity Lab – depending on your class size
- 2 Island Royale Readings
- Island Royale Case Study Worksheet

**Student Preparation**
- To prepare students for the content in this module, have them watch the short video clip: [https://www.youtube.com/watch?v=Ol2ixl6iEUE](https://www.youtube.com/watch?v=Ol2ixl6iEUE)
- Lead a quick discussion on this video and introduce formal notes in the content outline below.

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<tr>
<th>Teacher Directions / Methods</th>
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</table>
| Teachers should use direct instruction to provide students with the following terminology and notes that will be useful for them to complete the application activity. Have students record these notes when they are written on the board. | Carrying Capacity – the number of animals that an ecosystem consistently supports.
  - Based on limiting factors
  - Density dependent limiting factors include food, water and shelter
- Populations that grow beyond the carrying capacity will be reduced by predation, disease, or starvation.
- Populations of organisms can also be affected by factors not associated with their population density
  - Density independent limiting factors include fire, temperature, and human activities. Density independent factors

**Application 1:**
- Have students complete the lab activity 5.1.3 if your class size is large enough. If your class size is too small to complete the activity use the acorn carrying capacity lab in its place.
- If using activity 5.1.3, conduct the simulation as a class. Then complete tables 1 and 2. Have students work individually or in small groups to complete the three analysis questions. Students should then complete part II – managing space requirements.
- If using the acorn carrying capacity lab, have students work in pairs or small groups to follow directions and complete the lab.

**Application 2:**
- Have students read the
- Students should work individually or in pairs to read the two articles
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<th>Teacher Directions / Methods</th>
<th>Content Outline / Key Points</th>
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<tr>
<td>two articles on Island Royale and answer the questions associated with the articles.</td>
<td>on population density in Island Royale. Students should complete the Case Study worksheet with the readings.</td>
</tr>
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</table>

**Closure/Summary:**

Exit Pass

- Without using notes, students should complete an Exit Pass answering the three questions: 1) What is carrying capacity? 2) What are density dependent limiting factors? 3) What are density independent limiting factors?

**Evaluation:**

- Student performance can be assessed by the completion and accuracy of the lab report and answers to the questions in the Island Royale Case Study.
### INSTRUCTIONAL PLAN

**Course:** Natural Resources & Ecology  
**Unit:** Module: The Energy of Life  
**Lesson Title:** Lesson 4: Invasive Species  
**Estimated Time:** ~2 Days

#### Objective(s):
- Investigate an invasive species and determine the impact invasive species have on local food webs.

#### Equipment, Supplies, References, and Other Resources:
- Computers with internet  
- Poster making materials (can be digital posters or hand-made)  
- Invasive Species Investigation Rubric

#### Student Preparation
- Create student interest in the lesson by showing the YouTube video clip of the invasive species Asian Silver Carp: [http://www.youtube.com/watch?v=rPeg1tbBt0A&t=59s](http://www.youtube.com/watch?v=rPeg1tbBt0A&t=59s)  
- Share learning objective with students.

#### Teacher Directions / Methods
- Record notes on the board. Have students keep notes in a notebook. Utilize direct instruction to give students a foundation on invasive species terminology.

#### Content Outline / Key Points
- **Invasive Species** – A species that has been introduced to a new area and:
  - can reproduce and spread rapidly (become invasive)  
  - have little to no natural predators  
  - have an abundant food source and habitat  
  - outcompete native species for local food source
- **Examples of Invasive Species**
  - Burmese python in Florida  
  - Asian lady beetle in Midwest  
  - Purpose Loosestrife in aquatic ecosystems  
  - Emerald Ash Borer in Midwest  
  - (other examples to region)
- **Ways that invasive species are introduced to new areas:**
  - Pet trade (people release pets e.g. amphibians/reptiles/fish)  
  - Commodity trade (invasive species can be “passengers” when commodities are shipped e.g. insects on crops)  
  - Boat travel (e.g. zebra mussels in boat live wells)
- **Exotic Species** – A species that is not natural to an area.
  - All exotic species are not invasive (e.g. someone releases a non-native turtle into an ecosystem, but the turtle does not find others to mate nor outcompetes native species for food shelter)  
  - Some exotic species can become invasive when criteria for invasive species are met
- **Impact of invasive species**
  - Negatively impact natural food chains/webs by outcompeting native species for food.
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<th>Teacher Directions / Methods</th>
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<td></td>
<td>o Reduce habitat for native species (e.g. invasive aquatic plant takes over native aquatic plants, changes habitat for organisms that rely on native aquatic plant for food source or habitat)</td>
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<td>o Can lead to total change in ecosystems (e.g. Emerald Ash borer kills ash trees leading to a complete change in forest ecosystems that were once highly established of ash tress)</td>
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**Application:**
- Invasive species investigation activity. Pass out sheet “Invasive Species Investigation Rubric” to students with directions and requirements.
- Invasive species presentations.

**Content Outline / Key Points**
- Students should investigate and select an invasive species of interest to them (encourage student selections to vary with little to no overlap of selected species). Each student should create a poster on their invasive species that includes the following components: picture; common name; scientific name; native habitat; area(s) of invasion; food source; predators; impact of invasive species on ecosystem’s natural food web.

**Closure/Summary:**
- Summary Tweet

**Content Outline / Key Points**
- Students should create a “tweet” in 50 characters or less to summarize the content that was learned in this lesson. Have several students share their “tweet” and discuss major concepts in this lesson.

**Evaluation:**
- Use the “Invasive Species Investigation Rubric” to grade students’ invasive species posters.
### INSTRUCTIONAL PLAN

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<tr>
<th>Course: Natural Resources &amp; Ecology</th>
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<tbody>
<tr>
<td>Unit: Module: Flourishing Fauna</td>
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<tr>
<td>Lesson Title: Lesson 1: Exploring Habitats</td>
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<td>Estimated Time: ~2 Days</td>
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**Objective(s):**

- List the components of a habitat and be able to explain why distinct habitats are important for the survival of a population.
- Explore the habitat requirements of a species.

**Equipment, Supplies, References, and Other Resources:**

- PowerPoint “Exploring Habitats”
- Activity 6.2.1 Habitat for Sale (modification described in lesson plan)

**Student Preparation**

- Ask students what they need to survive. Lead this discussion towards what animals need to survive. Have students get out their notebooks to take brief notes on the PowerPoint.

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<th>Teacher Directions / Methods</th>
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<tr>
<td>Use the PowerPoint “Exploring Habitats” and use direction instruction to present the information in the content outline to students in order to prepare students for the application activity. The amount of ‘notes’ students take is at your discretion. For each of the types of habitat discussed. Show the picture of the habitat and discuss the potential climate, soil, and organisms that live there.</td>
<td>Slide 3: Habitat – The surroundings in which an animal lives where all needs for life are found. This includes the right kind of: Food&lt;br&gt;Water&lt;br&gt;Shelter&lt;br&gt;Space&lt;br&gt;Slides 4-13: There are many different types of habitats and each type of habitat is home to a variety of species of plants and animals. For instance, general classifications of habitats could include: Coniferous forests (pine-based)&lt;br&gt;Deciduous forests (non-pine-based)&lt;br&gt;Mountain&lt;br&gt;Savanna&lt;br&gt;Temperate Grassland&lt;br&gt;Mediterranean&lt;br&gt;Tundra&lt;br&gt;Hot Desert&lt;br&gt;Tropical Rainforest&lt;br&gt;Polar Ice&lt;br&gt;Slide 14: Each type of habitat includes different biotic and abiotic factors Biotic – living organisms&lt;br&gt;Abiotic – non-living (soil, water, temperature, etc.)&lt;br&gt;Community – The plants and animals found living together</td>
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<td>Teacher Directions / Methods</td>
<td>Content Outline / Key Points</td>
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<td>in a specific area (habitat)</td>
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<td>• Slide 15: Organisms that live in a specific habitat (communities) depend upon biotic and abiotic factors of that habitat for survival</td>
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<td>o Example: A White-tailed Deer depends upon other biotic factors in that habitat such as trees that produce food (e.g. acorns) and grassy areas to bed (e.g. shelter). The deer depend upon abiotic factors such as adequate rainfall for water consumption and a specific range of temperature.</td>
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<td>o Think about how a habitat is interconnected. Small shifts in either abiotic or biotic factors can cause large changes to a habitat.</td>
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<td>• Slides 16-18: Main types of habitat loss</td>
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<td>o Habitat Destruction – natural habitats are no longer able to support the species present due to interference (e.g. deforestation, filling in wetlands, urbanization)</td>
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<td>o Habitat Degradation – natural habitats remain intact but at a degraded state leading to the loss of a functioning ecosystem (e.g. pollutants, invasive species, destructive fishing practice)</td>
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<td></td>
<td>o Habitat Fragmentation – natural habitats become spatial separation from a previous state of great continuity (agricultural conversion, urbanization, dam building)</td>
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<thead>
<tr>
<th>Application:</th>
<th>Due to time constraints, Activity 6.2.1 is modified. Give each student two organisms from the list on table 1. Have them use internet resources to fill in table 2.</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Use Activity 6.2.1 (table 1 and table 2) to have students complete the modification of the CASE activity.</td>
<td></td>
</tr>
<tr>
<td>Closure/Summary:</td>
<td>On an exit ticket, have students write down 1) the components of a habitat; 2) three types of general habitat classification; and, 4) two ways in which habitats are lost.</td>
</tr>
<tr>
<td>• Summary Quiz</td>
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<tr>
<td>Evaluation:</td>
<td>Use the application activity and summary quiz to assess student learning.</td>
</tr>
</tbody>
</table>
### INSTRUCTIONAL PLAN

**Course:** Natural Resources & Ecology  
**Unit:** Module: Flourishing Fauna  
**Lesson Title:** Lesson 2: Managing Wildlife Populations  
**Estimated Time:** ~ 2 Days

**Objective(s):**  
- Conduct hypothetical wildlife management decisions and identify at least four factors that can affect the size of wildlife populations.

**Equipment, Supplies, References, and Other Resources:**  
- The Passenger Pigeon Reading  
- Activity 6.2.4 Managing Populations  
- Activity 6.2.4 Moose Management Cards (per group of 4)  
- One die (per group of 4)

**Student Preparation**  
- As an interest approach, have students read the article “The Passenger Pigeon”. During the reading, students should record three things that they found interesting regarding the Passenger Pigeon and its extinction. Have students discuss their lists and why they identified them as important. Pose the question “Do you think humans could have better managed the Passenger Pigeon population?”. Discuss student responses.

### Teacher Directions / Methods

**Utilize direct instruction** to relay the following information to students. Students should take notes on this material.

- Populations of animals are changing in response to conditions within the group and external events.  
  - Populations can change due to:  
    - Food sources going up or down  
    - Habitat changes (destruction, degradation, fragmentation)  
    - Direct human intervention (e.g., hunting)  
    - Density independent factors (e.g., forest fires, climate change)  
- Wildlife Management – balancing the needs of wildlife and ecosystem resources with human use while using the best available science  
- Examples of wildlife management could include:  
  - Managing Habitat (e.g., removing invasive species)  
  - Creating Habitat (e.g., planting a native butterfly garden)  
  - Managing Populations (e.g., hunting and fishing regulations)  
  - Habitat Protection (e.g., protecting special areas from human intervention)  
  - Population Protection (e.g., protecting specific animals from any human possession/interference (bald eagle)).  
- Wildlife managers must consider the best way to manage wildlife populations.

**Application:**  
- Students should be

**Content Outline / Key Points**

- Each group of students will complete Activity 6.2.4 Managing
<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>grouped into groups of four. Each group should complete Activity 6.2.4. Each student should complete their own conclusion questions.</td>
<td>Populations. In groups, students should complete Part 1 – Determining Events; Part 2 – Managing Moose; Part 3 – Observations.</td>
</tr>
<tr>
<td><strong>Closure/Summary:</strong></td>
<td><strong>Evaluation:</strong></td>
</tr>
<tr>
<td>• Word Splash</td>
<td>• Each student should complete the conclusion questions to activity 6.2.4 in their own words.</td>
</tr>
<tr>
<td></td>
<td>1. What did you learn about the management of a wildlife population that you did not realize or understand prior to conducting this project?</td>
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<td></td>
<td>2. As a steward of natural resources, why is it important to understand the principles and policies of wildlife management?</td>
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<tr>
<td></td>
<td>3. Identify four factors that can affect the size of a wildlife population.</td>
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</table>
INSTRUCTIONAL PLAN

<table>
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<tr>
<th>COURSE:</th>
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<tbody>
<tr>
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<td>Module: Flourishing Fauna</td>
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<tr>
<td>LESSON TITLE:</td>
<td>Lesson 3: Adaptations</td>
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<tr>
<td>ESTIMATED TIME:</td>
<td>~ 2 Days</td>
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</table>

Objective(s):
- Investigate the adaptive nature of an animal, such as the beak of a bird to its environment in order to acquire food for survival.

Equipment, Supplies, References, and Other Resources:
- Computer and Projector with Internet Access
- Activity 6.2.2 Adaptive Avian
- Dog Breed Picture
- Materials needed for Activity 6.2.2 (eye dropper, long-handle tongs, pliers, short handled tongs, tweezers, two small containers, one small jar, different habitats – see activity 6.2.2 – you can adapt this for the materials that you have)

Student Preparation
- Show a picture of two breeds of dogs. Ask students “How do you think these two types of dog breeds came to be?” Explain that domestication and artificial selection (years of breeding for particular traits) created the different breeds of dogs. Ask students “Do you think the same process can occur naturally?” Introduce students to the term natural selection.
- Natural Selection – the process where organisms who are better adapted to their environment tend to survive and produce more offspring.

Teacher Directions / Methods
- Video
- Use direct instruction to prepare students for the application activity. Have students take notes. Discuss each of the adaptations mentioned and have students think of others.

Content Outline / Key Points
- Show students the Galapagos Finch Video (It is a little lengthy at 16 minutes, but really good!)
  [https://www.youtube.com/watch?v=mcM23M-CCog](https://www.youtube.com/watch?v=mcM23M-CCog)
- Adaptation – a genetically determined behavior, physical feature, or other characteristic that will help a living thing survive in its environment. Examples could include
  - Thicker fur in a cold climate
  - A pattern that helps an organism blend in with the environment (e.g. camouflage) and reduces predation
  - A bright color on an insect that warns predators that they could be poisonous (or mimics another species who is actually poisonous)
  - A streamlined body of a fish living in a fast moving stream that allows them to maneuver easier and quicker
- Organisms can be classified by physical appearance, structural morphology, and DNA sequence data
  - DNA analysis is the most valid evidence for making conclusions on the relatedness of organisms!
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<tr>
<th><strong>Teacher Directions / Methods</strong></th>
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<tbody>
<tr>
<td><strong>Application:</strong></td>
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<tr>
<td>• Set up lab requirements</td>
<td>• Students should work in teams to complete Activity 6.2.2 Adaptive</td>
</tr>
<tr>
<td>described in Activity 6.2.2</td>
<td>Avian. Have students follow the directions on the activity.</td>
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<tr>
<td>Adaptive Avian (if you do</td>
<td>• Part One – Predictions</td>
</tr>
<tr>
<td>not have all the items</td>
<td>• Part Two – Simulated Habitats</td>
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<tr>
<td>that is ok – use similar</td>
<td>• Part Three - Conclusions</td>
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<td>items!)</td>
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<tr>
<td>• Assign students to groups of</td>
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<td>four and give them</td>
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<tr>
<td>Activity 6.2.2 Adaptive</td>
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<tr>
<td>Avian</td>
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<tr>
<td><strong>Closure/Summary:</strong></td>
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<tr>
<td>• Laboratory Summary</td>
<td>• Discuss students’ results of the laboratory exercise. Relate results of</td>
</tr>
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<td>this activity to the key terms (natural selection, adaptation, etc.)</td>
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<td>that was taught in the lesson.</td>
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<tr>
<td><strong>Evaluation:</strong></td>
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<tr>
<td>• Collect the laboratory exercise to evaluate student performance. AND/OR Have students write a journal entry of at least one paragraph about what they learned in this lesson.</td>
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<td>INSTRUCTIONAL PLAN</td>
<td>Group: A</td>
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<tr>
<td>Course:</td>
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<td>Unit:</td>
<td>Module: Flourishing Fauna</td>
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<tr>
<td>Lesson Title:</td>
<td>Lesson 4: Genetics</td>
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<tr>
<td>Estimated Time:</td>
<td>~ 2 Days</td>
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</tbody>
</table>

**Objective(s):**
- Predict the probability of the occurrence of qualitative traits within an animal species using Punnett Squares.

**Equipment, Supplies, References, and Other Resources:**
- Activity 6.2.3 Population Pressures
- PowerPoint: Predicting Punnett Squares
- KWL Chart

**Student Preparation**
- Have students write down what they *Know* and *Want to Know* in a KWL chart regarding the following topics: Punnett Squares; Genotype; Phenotype; Recessive Genes; Dominant Genes

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<tr>
<th>Teacher Directions / Methods</th>
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<tbody>
<tr>
<td>Use the PowerPoint &quot;Predicting Punnett Squares&quot; using direct instruction to prepare students to complete activity 6.2.3</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Content Outline / Key Points</th>
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<tbody>
<tr>
<td>Slide 1: Title Page: Predicting with Punnett Squares</td>
</tr>
<tr>
<td>Slide 2: What are genes?</td>
</tr>
<tr>
<td>o A gene is the simplest unit of inheritance</td>
</tr>
<tr>
<td>o A gene influences certain genetic traits in living things</td>
</tr>
<tr>
<td>o The collection of similar genetic make-up of plants or animals is referred to as genotype</td>
</tr>
<tr>
<td>Slide 3: What do genes do?</td>
</tr>
<tr>
<td>o Genes are carried in the chromosomes in the gametes</td>
</tr>
<tr>
<td>o Genes are passed from parent to offspring through the process of meiosis and mitosis during sexual reproduction.</td>
</tr>
<tr>
<td>o The genetic transfer of traits from parent to offspring is called heredity or inheritance.</td>
</tr>
<tr>
<td>Slide 4: Defining traits of living things</td>
</tr>
<tr>
<td>o Genotype is the genetic make-up of living things</td>
</tr>
<tr>
<td>o Individual organisms of the same genotype breed alike</td>
</tr>
<tr>
<td>o These individuals are called purebred and produce offspring with similar characteristics</td>
</tr>
<tr>
<td>Slide 5: Defining traits of living things</td>
</tr>
<tr>
<td>o Phenoype is the observed characteristic of an individual organism without reference to its genetic make-up</td>
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<tr>
<td>o Individuals of the same phenotype look alike but may not breed alike</td>
</tr>
<tr>
<td>o These individuals are called hybrid and can produce offspring with varying characteristics</td>
</tr>
<tr>
<td>Slide 6: How heredity is affected by genes</td>
</tr>
<tr>
<td>o Each characteristic or trait has two genes — one derived from...</td>
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<td>Teacher Directions / Methods</td>
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|                              | - Calculate the probability of each phenotype. Express the
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<thead>
<tr>
<th>Teacher Directions / Methods</th>
<th>Content Outline / Key Points</th>
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<tbody>
<tr>
<td></td>
<td>probability as a percentage</td>
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<tr>
<td></td>
<td>o probability = (number in phenotype / 4)</td>
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<tr>
<td></td>
<td>o (probability) x 100 = percentage</td>
</tr>
<tr>
<td></td>
<td>• Slide 19: References</td>
</tr>
<tr>
<td><strong>Application:</strong></td>
<td>• Practice Example: A bear population has both shorthaired and longhaired individuals. Longhair is the dominant trait. The longhair genotype is LL or Ll. The shorthair genotype is ll.</td>
</tr>
<tr>
<td></td>
<td>o What is the % chance of shorthaired offspring when a Longhair (Ll) bear mates with a shorthaired bear (ll)?</td>
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<td></td>
<td>o What is the % chance of shorthaired offspring when a Longhair (Ll) bear mates with another Longhair (LL) bear?</td>
</tr>
<tr>
<td></td>
<td>o Keep doing similar problems until students catch on.</td>
</tr>
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<td></td>
<td>• Students should complete Activity 6.2.3 Population Pressure.</td>
</tr>
<tr>
<td><strong>Closure/Summary:</strong></td>
<td>• Have students complete the L in their KWL chart. Discuss student responses.</td>
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<td></td>
<td>• Use students’ Activity 6.2.3 lab report as a summative assessment for this lesson.</td>
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<td><strong>Evaluation:</strong></td>
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**INSTRUCTIONAL PLAN**

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<thead>
<tr>
<th>Group:</th>
<th>A</th>
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<tbody>
<tr>
<td><strong>Course:</strong></td>
<td>Natural Resources &amp; Ecology</td>
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<tr>
<td><strong>Unit:</strong></td>
<td>Module: All Natural Flora</td>
</tr>
<tr>
<td><strong>Lesson Title:</strong></td>
<td>Lesson 1: Exploring Biodiversity</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>~ 3-4 Days</td>
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</table>

**Objective(s):**
- Determine the biodiversity of plants in a given area using a common sampling technique.

**Equipment, Supplies, References, and Other Resources:**
- Computer, Projector, Internet
- Reading “New York Times Article”
- Estimating Plant Biodiversity – Virtual Lab (A)
- Activity 6.1.1 Exploring Biodiversity (and equipment – weather permitting)
- PowerPoint: Plant Communities

**Student Preparation**
- Show the short video clip on Biodiversity: [https://www.youtube.com/watch?v=kHlpfSIfdE](https://www.youtube.com/watch?v=kHlpfSIfdE)
- Ask students why plant biodiversity could be important and how biodiversity can be measured.

**Teacher Directions / Methods**
- Utilize direct instruction to present information to students in order to prepare them for the lab activity.

**Content Outline / Key Points**
- Slide 2: Plant Communities
- Slide 3: Plant Communities
  - A plant community is the group of plant populations that exist in a shared habitat or environment
- Slide 4: Purpose of Plants in Ecosystems
  - Provide energy by capturing light energy radiated from the sun and converting it to sugars and starches
  - Are autotrophic – make their own food
  - Provide habitat
  - Make oxygen
  - Protect water quality
- Slide 5: Biodiversity
  - Biodiversity is the degree of variation of life forms within a given ecosystem, biome, or planet
- Slide 6: The Need for Plant Sampling
  - To determine the composition and diversity of the plant community of interest
  - A plot size should be large enough to include significant numbers of individuals, but small enough so that plant can be separated, counted, and measured.
- Slide 7: Plant Sampling Techniques
  - Quadrats – plots of standard size that can restrict the area to be sampled
  - Releve – the surveyor walks through each stand recording all the species encountered and describing the habitat and soil profile

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<tr>
<th>Teacher Directions / Methods</th>
<th>Content Outline / Key Points</th>
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<tr>
<td>o Plot-less sampling – involves the use of sampling using points within a certain distance o Distance methods – measures the distance from a sampling point or plant to the nearest plant o Sampling with aerial photographs – using large scale (1:200) color or infra-red photographs are useful for mapping and recording individual plant species in a range of vegetation types.</td>
<td>Slide 8: Relevé o An organized list of plant diversity ▪ developed through a specific process of identifying plants ▪ categorize plants by canopy height ▪ categorize plants by coverage ▪ categorize by habitat</td>
</tr>
<tr>
<td>Slide 9: References</td>
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</table>

**Application:**
- Have students complete Activity 6.1.1 Exploring Biodiversity (weather permitting)
- AND/OR (time permitting) Have students complete Estimating Plant Biodiversity – Virtual Lab
- Have students complete Activity 6.1.1 if the weather is permitting. Students should follow directions associated with the laboratory exercise and should complete Activity 6.1.1 Student Worksheet. Students can work in small groups to complete this exercise. If a quadrat is unavailable a tape measure and string can be used.

  AND/OR (time and weather permitting)
  - Have students complete the Estimating Plant Biodiversity – Virtual Lab. Students can work individually or in-pairs at teacher’s discretion. Students should complete the tables and lab questions associated with this virtual lab.

**Closure/Summary:**
- Have students read the New York Times article • Headline Summary
- Students should summarize this reading with what they learned in this lesson to produce a Headline Summary. The Headline Summary is a newspaper headline that gives the main points of the lesson.

**Evaluation:**
- Collect lab reports for the lab 6.1.1 and/or the virtual lab, as well as students Headline Summaries to assess student learning of this lesson.
<table>
<thead>
<tr>
<th>Teacher Directions / Methods</th>
<th>Content Outline / Key Points</th>
</tr>
</thead>
</table>
| Use the PowerPoint “Vegetative Analysis” and use direct instruction to present information that will prepare students for the application activity. | Slide 1: Vegetative Analysis  
Slide 2: Objectives  
Slide 3: Satellite Imagery  
  o Satellite imagery can be used to assess vegetative cover in large areas.  
  o Models can be made that predict changes in future landscapes  
Slide 4: Satellite Imagery  
  o Satellite imagery can be used to assess the degree of urban sprawl of residential areas.  
  o Take the following pictures for example:  
  Slide 5: Photo with land classifications  
  Slide 6: Photo of change detection of urban sprawl  
  Slide 6: Photo of San Diego 1950  
  Slide 7: Photo of San Diego 1990  
  Slide 8: Photo of land cover of Cape Cod, MA  
  Slide 9: Satellite Imagery  
  o Maps of satellite imagery merged with the addition of physical sampling maps can tell researchers important information about wildlife populations  
  o For example, the next picture shows satellite imagery of urbanization in northeastern Illinois. The black dots represent active Yellow-headed Blackbird colonies at the years in which the photos were taken.  
Slide 10: Photo of Blackbird colonies in relation to urban sprawl in northeastern Illinois (Chicago area)
<table>
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<tr>
<th>Teacher Directions / Methods</th>
<th>Content Outline / Key Points</th>
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</thead>
<tbody>
<tr>
<td>• Slide 11: Satellite Imagery</td>
<td>o Satellite imagery and aerial photos can also show other changes in habitat beyond urbanization. o The following pictures show how the size of agricultural production fields changed, leading to habitat fragmentation.</td>
</tr>
<tr>
<td>• Slide 12: Photo of aerial imagery 1960’s agricultural area</td>
<td></td>
</tr>
<tr>
<td>• Slide 13: Photo of aerial imagery 1990’s agricultural area</td>
<td></td>
</tr>
<tr>
<td>• Slide 14: Photo of aerial imagery 1960 Clinton, IL</td>
<td></td>
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<tr>
<td>• Slide 15: Photo of aerial imagery 2007 Clinton, IL</td>
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<tr>
<td>• Slide 16: Drone Technology</td>
<td>o Modern drone technology is becoming more affordable and is heavily used in taking aerial photography</td>
</tr>
<tr>
<td>• Slide 17: Vegetative Relevé</td>
<td>o A list of all the plants in a delimited plot of vegetation, with information on species cover, substrate, and abiotic factors</td>
</tr>
<tr>
<td>• Slide 18: Vegetative Relevé</td>
<td>o Typically, vegetation is stratified into height categories chosen to describe vertical structure, and in each stratum each plant is assigned a cover value based on its representation in that stratum</td>
</tr>
<tr>
<td>• Slide 19: Vegetative Relevé</td>
<td>o Identify a plot that has correct criteria for the study o Mark the plot using stakes and flags o Identify site data ▪ General information ▪ Vegetation information ▪ Location information ▪ Plot information ▪ Soil information</td>
</tr>
<tr>
<td>• Slide 20: Site Data Sheet</td>
<td></td>
</tr>
<tr>
<td>• Slide 21: Vegetative Relevé</td>
<td>o Sketch the plot o Walk through entire plot to get a general sense of plant species, topography and habitat. o Next, walk the plot in the pattern described to survey the plants represented o Identify plants, starting with the tallest plants o Compare the identification of all plants located in the plot</td>
</tr>
<tr>
<td>• Slide 22: Vegetation Data Sheet</td>
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<tr>
<td>• Slide 23: Review of Objectives</td>
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**Application:**
- Have students complete Project 6.1.2 Vegetation Relevé. Also pass out Vegetation Relevé Key
- In small groups, students should conduct a Vegetative Relevé at a site around the school (or at location at home) – weather permitting. Students should use project 6.1.2 Vegetation Relevé and the Vegetation Relevé Key to assist them with this project.
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<tr>
<th>Teacher Directions / Methods</th>
<th>Content Outline / Key Points</th>
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</table>
| • AND/OR weather and time permitting  
  • Students can work individually or in pairs to complete the Aerial Analysis worksheet. | • AND/OR weather and time permitting  
  • Students should use the worksheet “Aerial Analysis” to investigate aerial imagery of the local area to assess local land cover and habitat. |

**Closure/Summary:**

- **Question Review**
  - Have each student create a question that they believe represents a good question for the information they learned in this lesson. Have students pass their question to another student in the class. Students should try to answer their peer’s question. Discuss students’ questions as a class after.

**Evaluation:**

- Use completed student worksheet/laboratory reports, “Project 6.1.2” and/or “Aerial Analysis” to evaluate student performance.
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<tr>
<th>INSTRUCTIONAL PLAN</th>
<th>Group: A</th>
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<tbody>
<tr>
<td><strong>Course:</strong></td>
<td>Natural Resources &amp; Ecology</td>
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<tr>
<td><strong>Unit:</strong></td>
<td>Module: All Natural Flora</td>
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<tr>
<td><strong>Lesson Title:</strong></td>
<td>Lesson 3: Vegetative Management</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>~ 2 Days</td>
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</tbody>
</table>

**Objective(s):**
- Investigate vegetative management to improve the habitat of an animal species.

**Equipment, Supplies, References, and Other Resources:**
- Vegetative Management Investigation worksheet
- Computer, Projector, Internet

**Student Preparation**
- Have students watch the quick video clip: [https://www.youtube.com/watch?v=LawHWsIqa5s](https://www.youtube.com/watch?v=LawHWsIqa5s)
- Have students take notes on the video and present the information below.
- As the video suggests, tell students that the vegetative plant Milk Weed is crucial to populations of Monarch Butterflies.

**Teacher Directions / Methods**
- Utilize direct instruction and have students take notes on the following in the right hand column. Write these notes on the board to prepare students for the application activity.

**Content Outline / Key Points**
- Vegetation is an essential component to the functioning of an ecosystem.
  - involved in regulation of biogeochemical cycles (water, carbon, nitrogen, etc.)
  - effects soil development over time, generally contributing to more productive soil
  - conserves soil through root system (e.g. reduces erosion)
  - provides food for primary consumers
  - provides shelter for many species
- Examples of how reduced vegetation have led to decline in species. Habitat loss is the greatest threat to the variety of life on this planet today!
  - Deforestation in rainforests have caused numerous declines in populations of animals in tropical regions
  - Large scale farming and the reduction of fence rows and tree rows in the agricultural landscape have reduced pheasant and prairie chicken populations (lack of shelter)

**Application:**
- Students should work individually to complete the worksheet "Vegetative Management Investigation".
- Have students use resources to investigate a vegetative management that can be used to improve the population of an animal species that interests them. Students should answer the questions posed in the worksheet to guide them through their analyses. Students cannot choose Monarch Butterfly as this has been discussed in the interest approach video and again in the summary.
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<td>• If time allows, have students share their investigations with the rest of the class.</td>
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<tr>
<td>Closure/Summary:</td>
<td>• Discuss what can be done locally to improve the habitat of the monarch butterfly (e.g. planting milkweed in a school-yard native habitat bed, providing money/subsidies to farmers who plant milkweed in riparian buffer zones, etc.). Discuss how the Milk Weed provides 1) regulation of biogeochemical cycles; 2) soil development; 3) soil conservation; 4) shelter; 5) food sources.</td>
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<tr>
<td>Evaluation:</td>
<td>• Use student responses on the worksheet “Vegetative Management Investigation” to evaluate student learning.</td>
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<td><strong>INSTRUCTIONAL PLAN</strong></td>
<td><strong>Group:</strong> A</td>
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<tr>
<td><strong>Course:</strong></td>
<td>Natural Resources &amp; Ecology</td>
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<td><strong>Unit:</strong></td>
<td>Module: Flourishing Fauna</td>
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<tr>
<td><strong>Lesson Title:</strong></td>
<td>Lesson 4: Ecological Succession</td>
</tr>
<tr>
<td><strong>Estimated Time:</strong></td>
<td>~ 2 Days</td>
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**Objective(s):**
- Simulate the process of vegetative succession by role playing in a game and/or using graphic analyses.

**Equipment, Supplies, References, and Other Resources:**
- Shaped by Fire Reading
- Activity 6.1.3 Ecological Succession (& Lab Aids Materials if you have them)
- Ecological Succession Lab

**Student Preparation**
- Have students read “Shaped by Fire”. During the reading, have student use a highlighter to highlight important passages of the reading to find important concepts of the article. Have student share their findings and have a quick class discussion about ecological succession and wildfires at Yellow Stone National Park.

**Teacher Directions / Methods**
- Use direct instruction while using the PowerPoint “Changes in Ecosystems: Ecological Succession” to prepare students to complete the application activity.
- Have students take notes on the material

**Content Outline / Key Points**
- **Slide 1: Changes in Ecosystems: Ecological Succession**
- **Slide 2: What is Ecological Succession?**
  - Natural, gradual change in the types of species that live in an area
  - Can be primary or secondary
  - The gradual replacement of one plant community by another though natural processes over time
- **Slide 3: Primary Succession**
  - Begins in a place without any soil:
    - Sides of volcanoes
    - Landslides
    - Flooding
  - First, lichens that do not need soil to survive grow on rocks
  - Next, mosses grow to hold newly made soil
  - Known as Pioneer Species
- **Slide 4: Pioneer Species**
  - Lichens photo
  - Moss photo
- **Slide 5: Primary Succession**
  - Soil starts to form as lichens and the forces of weather and erosion help break down rocks into smaller pieces
  - When lichens die, they decompose, adding small amounts of organic matter to the rocks to make soil
- **Slide 6: Photo**
- **Slide 7: Primary Succession**
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<tr>
<th>Teacher Directions / Methods</th>
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<tbody>
<tr>
<td></td>
<td>o Simple plants like mosses and ferns can grow in the new soil</td>
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<tr>
<td></td>
<td>• Slide 8: Primary Succession</td>
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<tr>
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<td>o The simple parts die, adding more organic material (nutrients to the soil)</td>
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<td>o The soil layer thickens, and grasses, wildflowers, and other plants begin to take over</td>
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<td>• Slide 9: Primary Succession</td>
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<td>o These plants die, and they add more nutrients to the soil</td>
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<td>o Shrubs and trees can now survive</td>
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<td>• Slide 10: Primary Succession</td>
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<td>o Insects, small birds, and mammals have begun to move into the area</td>
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<td>o What was once bare rock, now supports a variety of life</td>
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<td></td>
<td>• Slide 11: Secondary Succession</td>
</tr>
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<td></td>
<td>o Begins at a place that already has soil and was once the home of living organisms</td>
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<td></td>
<td>o Occurs faster and has different pioneer species than primary succession</td>
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<td></td>
<td>o Example: after forest fires</td>
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<td>• Slide 12: Photo</td>
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<td>• Slide 13: Photo</td>
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<td>• Slide 14: Photo</td>
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<td>• Slide 15: Photo</td>
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<td>• Slide 16: Climax Community</td>
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<td>o A stable group of plants and animals that is the end result of the succession process</td>
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<td></td>
<td>o Does not always mean big trees</td>
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<td></td>
<td>▪ Grasses in the prairies</td>
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<td>▪ Cacti in deserts</td>
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</table>

**Application:**
- Set up lab aides material and pass out Activity 6.1.3 Ecological Succession
- AND/OR (depending on time and lab aid resources)
- Ecological Succession Lab

- Have students complete Activity 6.1.3 Ecological Succession if lab aids are available. Have students work in small groups to complete the laboratory.
- AND/OR (depending on time and lab aid resources)
- Have students work in small groups to complete the Ecological Succession Lab. Students should complete the tables, construct graphs, and answer the conclusion questions.

**Closure/Summary:**
- Catch-Phrase

- Have students partner up. Have one student from each pair come up and record the following words, while keeping them a secret: Moss, Primary Succession, Climax Community, Pioneer Species. The student has one minute to try to get their partner to say the
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<td>vocabulary words without saying the word. They can describe the word and use examples, but cannot draw or act.</td>
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<td></td>
<td>▪ Have students switch roles. The other student should record the following words while keeping them a secret: Secondary Succession; Yellowstone National Park; Forest Fire; Soil. Follow the same catch-phrase procedures.</td>
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<td></td>
<td>▪ After Catch-Phrase, discuss which words were easy and hard to describe and get partners to guess.</td>
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<tr>
<td>Evaluation: Quiz</td>
<td>▪ Pop Quiz – Three Questions</td>
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<tr>
<td></td>
<td>1) Describe the process of primary succession.</td>
</tr>
<tr>
<td></td>
<td>2) Describe the process of secondary succession.</td>
</tr>
<tr>
<td></td>
<td>3) Compare and contrast a climax community to a community of pioneer species.</td>
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</table>
### INSTRUCTIONAL PLAN

| **Course:** | Natural Resources & Ecology |
| **Unit:** | Module: Agricultural Stewardship |
| **Lesson Title:** | Lesson 1: Introduction to Agricultural Stewardship |
| **Estimated Time:** | ~ 2 Days |

**Objective(s):**
- Explore sustainable and non-sustainable practices in agricultural production

**Equipment, Supplies, References, and Other Resources:**
- Sustainable Development PowerPoint
- Activity 7.1.1 Sustainable Use
- The Lorax book, movie, or video clip

### Student Preparation
- Ask students if they have heard of the Dust Bowl that occurred in the United States during the early 1930's. Have a short discussion to see what they know about this event and why it occurred. Lead this discussion into the objective for this lesson: explore sustainable and non-sustainable practices in agricultural production.

### Teacher Directions / Methods
- Deliver direction instruction via the PowerPoint “Sustainable Development”.

### Content Outline / Key Points
- **Slide 2: Sustainable Development**
- **Slide 3: Sustainability**
  - The capacity of an ecosystem to endure. In ecology the word describes how biological systems remain diverse and productive over time.
  - Achieving sustainability will enable the Earth to continue to support life.
- **Slide 4: Sustainable Development**
  - Development that meets the needs of all of the present generation without compromising the ability of future generations to meet their own needs.
- **Slide 5: Three Pillars**
  - The three pillars of sustainable development include
    - Economic growth
    - Environmental protection
    - Social equality
- **Slide 6: The Three Pillars and Sustainable Agriculture**
  - Economic Growth – means long term profitability for the farmer or rancher
  - Environmental Protection – means sustainable land use
  - Social Equity – means a good quality of life for the farmer and the community
- **Slide 7: Sustainable Use**
  - Use that can be sustained indefinitely with the resources provided, or which can be generated by such use.
- **Slide 8: Stewardship**
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<tr>
<td></td>
<td>o The responsible use and development of resources, providing for present needs and conserving for future demands.</td>
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<td>• Slide 9: Sustainable Agriculture Practices</td>
</tr>
<tr>
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<td>o Farming methods that do not deplete or damage the land. Providing safe sources of food and fiber for present and future generations. Examples of sustainable farm practices:</td>
</tr>
<tr>
<td></td>
<td>▪ Mixed farming</td>
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<td>▪ Multiple cropping</td>
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<td>▪ Crop rotation</td>
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<td>▪ Agroforestry</td>
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<td>• Slide 10: Principles of the Sustainable Farmer and Rancher</td>
</tr>
<tr>
<td></td>
<td>o A steward of productive agricultural land</td>
</tr>
<tr>
<td></td>
<td>o Environmental Health – preserves natural ecosystems</td>
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<td></td>
<td>o Economic Profitability – increase production and reduce costs</td>
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<td></td>
<td>o Economic Equity – support and improve the community health and economy</td>
</tr>
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<td></td>
<td>o Environmental Stewardship – careful management to maintain productivity</td>
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<td>• Slide 11: The Sustainable Consumer</td>
</tr>
<tr>
<td></td>
<td>o Chooses energy and resource reduced products</td>
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<td></td>
<td>o Chooses products produced locally</td>
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<td>o Chooses items produced sustainably</td>
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<td>o Chooses items produced under socially acceptable conditions</td>
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<td>o Where possible chooses communal use of resources (such as car-sharing)</td>
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<td>o Consumes less</td>
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<td>• Slide 12: References</td>
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**Application:**

- Students will complete “Activity 7.1.1 Sustainable Use”. If you do not have access to the book, feel free to use full movie, or the earlier produced shorted animation at [https://www.youtube.com/watch?v=AEh2hlcXDk8s](https://www.youtube.com/watch?v=AEh2hlcXDk8s)

- Part One – Reading (Directions)
  o With your partner, read the book provided (or film option). As you read, identify the natural resources discussed in the story. Record your observations on Activity 7.1.1 Student Worksheet.

- Part Two – Analyzing (Directions)
  o When you have finished reading, review your list of the natural resources discussed in the story. Record your observations on your worksheet in the column provided. Answer the analysis questions on the worksheet.

- Part Three – Comparing (Directions)
  o The history of the United States Dust Bowl is an example of unsustainable farming practices and the environmental, social, and economic effects. Working with your partner, use a computer to research the Dust Bowl. Find information on
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<tr>
<th>Teacher Directions / Methods</th>
<th>Content Outline / Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>each of the following questions presented in the worksheet and record your findings in Tables 2 and 3.</td>
</tr>
<tr>
<td><strong>Closure/Summary:</strong></td>
<td></td>
</tr>
<tr>
<td>• Class Review Questions</td>
<td>• Review the three pillars to sustainable agriculture</td>
</tr>
<tr>
<td></td>
<td>o Economic Growth</td>
</tr>
<tr>
<td></td>
<td>o Environmental Protection</td>
</tr>
<tr>
<td></td>
<td>o Social Equity</td>
</tr>
<tr>
<td>• Review sustainable practices that farmers can implement. For example:</td>
<td>• • Planting Cover Crops</td>
</tr>
<tr>
<td></td>
<td>o Crop Rotations</td>
</tr>
<tr>
<td></td>
<td>o Agroforestry</td>
</tr>
<tr>
<td></td>
<td>o Utilizing Fertilizers &amp; Pesticides Responsibly</td>
</tr>
<tr>
<td></td>
<td>o Buffer Zones</td>
</tr>
<tr>
<td><strong>Evaluation:</strong></td>
<td>• Use student responses from the summary for an informal evaluation. Utilize student responses from Activity 7.1.1. for a formal evaluation.</td>
</tr>
<tr>
<td>Use Activity 7.1.1.</td>
<td></td>
</tr>
</tbody>
</table>
## INSTRUCTIONAL PLAN

**Course:** Natural Resources & Ecology  
**Unit:** Module: Agricultural Stewardship  
**Lesson Title:** Lesson 2: Nutrient Management  
**Estimated Time:** ~ 2 Days  

### Objective(s):
- Use the “4R” nutrient stewardship approach to make fertilizer recommendations.

### Equipment, Supplies, References, and Other Resources:
- Activity 7.1.2 Fertilizing Right  
- Reading Phytoremediation Article  
- Phytoremediation Questions  
- Computer, Projector, Internet

### Student Preparation
- Have students watch the short video clip – The Mosaic Company: 4R Nutrient Stewardship  
- [https://www.youtube.com/watch?v=AlyshijYGC](https://www.youtube.com/watch?v=AlyshijYGC)  
- Students should take notes while watching the video.

### Teacher Directions / Methods

- Teachers should use direct instruction to relay information to students via writing out notes on the board. Students should take notes to the extent determined by the instructor.

### Content Outline / Key Points

- Plants need nutrients in order to grow. Farmers add nutrients to the soil to increase crop productivity. The most common fertilizers include the follow macronutrients
  - Nitrogen (N) – helps with rapid plant growth  
  - Phosphorus (P) – helps with transformation of solar energy into chemical energy  
  - Potassium (K) – helps in the building of protein
- Nutrients that are added to agricultural areas can leach out beyond the crop it was intended to serve, causing negative impacts on the environment.
- Nutrient pollution is the top cause of water quality impairment, directly linked to 20% of impaired river and streams, and 22% of impaired lakes, also linked to
  - low dissolved oxygen  
  - impaired habitat  
  - algal growth  
  - noxious aquatic plants
- Point source pollution – specific areas of nutrient pollution which can be heavily monitored (Clean Water Act) (e.g. factory)  
- Non-point source pollution – wide-spread use of fertilizers for agricultural and landscape (fertilizing lawns). Non-point sources are not really enforced.
- Together, non-point and point source nutrient pollution, are causing negative consequences to environmental habitats (especially habitats that are located “downstream” of watershed areas in agricultural and residential neighborhoods) Examples
<table>
<thead>
<tr>
<th>Teacher Directions / Methods</th>
<th>Content Outline / Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>include:</td>
</tr>
<tr>
<td></td>
<td>- Lake Okeechobee Watershed in the Everglades</td>
</tr>
<tr>
<td></td>
<td>- Dead Zone in the Gulf of Mexico</td>
</tr>
<tr>
<td></td>
<td>- What can be done to reduce non-point pollution?</td>
</tr>
<tr>
<td></td>
<td>- Use less fertilizer (only when needed)</td>
</tr>
<tr>
<td></td>
<td>- Reduce fertilizer runoff through riparian buffers on agricultural land</td>
</tr>
<tr>
<td></td>
<td>- Create areas that can absorb excessive nutrients naturally (e.g. wetlands = phytoremediation)</td>
</tr>
<tr>
<td>Application:</td>
<td>- Have students read the Phytoremediation Article and answer the questions in the provided worksheet.</td>
</tr>
<tr>
<td></td>
<td>- Have students work individually or in pairs to complete the Activity 7.1.2 Fertilizing Right.</td>
</tr>
<tr>
<td>Closure/Summary:</td>
<td>- Review major problems that are world is currently facing due to excessive nutrient pollution.</td>
</tr>
<tr>
<td></td>
<td>- Review what farmers can do to practice sustainable and efficient nutrient management. Review the 4 R’s</td>
</tr>
<tr>
<td></td>
<td>- The Right...</td>
</tr>
<tr>
<td></td>
<td>- Source</td>
</tr>
<tr>
<td></td>
<td>- Time</td>
</tr>
<tr>
<td></td>
<td>- Rate</td>
</tr>
<tr>
<td></td>
<td>- Place</td>
</tr>
<tr>
<td>Evaluation:</td>
<td>- Use student performance on the phytoremediation worksheet and Activity 7.1.2 Fertilizing Right to evaluate student performance.</td>
</tr>
</tbody>
</table>
### INSTRUCTIONAL PLAN

<table>
<thead>
<tr>
<th>Course:</th>
<th>Natural Resources &amp; Ecology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit:</td>
<td>Module: Agricultural Stewardship</td>
</tr>
<tr>
<td>Lesson Title:</td>
<td>Lesson 3: Soil Conservation</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>~ 1-2 Days</td>
</tr>
</tbody>
</table>

**Objective(s):**
- Students will explore strategies for soil conservation in agricultural production.

**Equipment, Supplies, References, and Other Resources:**
- Case Study Reading: Soil Erosion in Montacute Village

### Student Preparation
- Have students complete the bell ringer: Why is soil important to ecosystems? Discuss student responses and have them prepare to take a few notes on soil conservation in agriculture.

#### Teacher Directions / Methods

- Teachers should use direct instruction to relay information to students via writing out notes on the board. Students should take notes to the extent determined by the instructor.

#### Content Outline / Key Points

- Farmers can improve the sustainability of their farming operations and improve local ecosystems by reducing soil erosion.
  - Improves soil quality/reduces soil loss — good for agriculture
  - Reduces potential fertilizer runoff
  - Reduces sediment buildup in local watersheds, increasing the quality of water
    - Measured in Turbidity — the degree to which the water loses its transparency due to the presence of suspended particles
- Types of tillage
  - No-till — farmer does not use tillage, but plants seeds directly into undisturbed soil
  - Conservation tillage — minimizes the frequency or intensity of tillage (partially tilled soil, with previous crop residue)
  - Conventional tillage — 100% tillage of the soil

#### Application:
- Case Study Reading: Soil Erosion in Montacute Village

- Students should read the article noting what is seen within this case study that relates to the notes that were taken above. After students read and take notes on the article, students should discuss the article as a class. What were their observations and what do they believe caused the soil erosion?

#### Closure/Summary:
- Word Splash

- Given the words below, students should be able to a coherent paragraph that uses the terminology of the words correctly. The words are: No-Till, Conventional Tillage, Conservation Tillage, Soil Runoff, Non-Point Pollution, and Turbidity.

#### Evaluation:
- Collect the word splash to formatively evaluate student performance.
# INSTRUCTIONAL PLAN

<table>
<thead>
<tr>
<th>Group: A</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Course:</th>
<th>Natural Resources &amp; Ecology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit:</td>
<td>Module: Agricultural Stewardship</td>
</tr>
<tr>
<td>Lesson Title:</td>
<td>Lesson 4: Agricultural Management Plan</td>
</tr>
<tr>
<td>Estimated Time:</td>
<td>~ 2 Days</td>
</tr>
</tbody>
</table>

**Objectives:**
- Apply the skills and knowledge learned regarding stewardship and sustainable agriculture management decisions related to a fictitious property, determine a commodity to raise, apply for a stewardship program, and determine the best stewardship practices to implement.

**Equipment, Supplies, References, and Other Resources:**
- Project 7.1.3 Stewards of the Land
- Conservation Program Application
- Conservation Stewardship Program Conservation Activity List
- Project 7.1.3 Evaluation Rubric

**Student Preparation**
- Have students complete the bell ringer: "Without increasing laws for environmental protection, how can the government promote sustainable agriculture?".

## Teacher Directions / Methods | Content Outline / Key Points

<table>
<thead>
<tr>
<th>Teachers should use direct instruction to relay information to students via writing out notes on the board. Students should take notes to the extent determined by the instructor.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Resource Conservation Service (NRCS) – branch of the USDA that works with landowners providing conservation planning and assistant programs designed to benefit the soil, water, air, plants, and animals.</td>
</tr>
<tr>
<td>Conservation Stewardship Program (CSP) – encourages land stewards to improve conservation performance by installing and adopting sustainable activities.</td>
</tr>
</tbody>
</table>

**Application:**
- Activity 7.1.3 Stewards of the Land. Students can work in pairs. Show students the rubric that you will be using to assess student projects.
- Have students complete the project 7.1.3 Stewards of the Land. Students will complete the conservation program application by providing: property description; crop description; five enhancement descriptions. Students will turn in the project for evaluation.

**Closure/Summary:**
- Question/Answer
- Have students individually complete the conclusion questions found in Activity 7.1.3. Then, discuss these questions as a class to serve as the lesson summary.
  - 1) What challenges might a producer face when implementing conservation enhancements?
  - 2) Why is it necessary for programs such as the Conservation Stewardship Program to exist?
  - 3) Select two enhancements. Discuss how they benefit the...
<table>
<thead>
<tr>
<th>Teacher Directions / Methods</th>
<th>Content Outline / Key Points</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>environment or native species.</td>
</tr>
<tr>
<td>Evaluation:</td>
<td>• Use Project 7.1.3 Evaluation Rubric to assess student performance on Project 7.1.3 Stewards of the Land.</td>
</tr>
</tbody>
</table>
Environmental Attitude Instrument

(Pretest)

Developed by: J. C. Bradley, T. M. Waliczek, & J. M. Zajicek

General Directions: Welcome to the Environmental Attitude Survey. This is not a timed survey and there are no correct or incorrect answers. You should mark an answer for each question. If you are unsure, try to answer the best you can with the information given. Only mark one answer for each question.

To start the survey, please create and record your unique ID number in the box below. Your unique ID number is your school’s abbreviation and your six-digit birth date. For example, a student attending Saint Johns High School (SJHS) born on July 31st, 2003 (07/31/03) would have the ID number “SJHS073103”. Please record your ID number below.

Student ID: ________________________________
Please mark a check (✓) in the box (□) that best indicates your level of agreement or disagreement to each of the following 15 statements. There are not right or wrong answers pertaining to your level of agreement for each of the statements.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither Agree or Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Special habitats should be set aside for endangered species..........................</td>
<td></td>
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<tr>
<td>2. Laws regarding water quality should be stricter...........</td>
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<tr>
<td>3. Animals that provide meat for people are the most important to protect...............</td>
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<tr>
<td>4. Poisonous snakes and insects that pose a threat to people should be killed..........</td>
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<tr>
<td>5. Landowners should be allowed to drain wetlands/swamps for agricultural or industrial uses...</td>
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<tr>
<td>6. It is important that each individual be aware of environmental concerns..........</td>
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<tr>
<td>7. Hunting and fishing are important management activities.................................</td>
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<tr>
<td>8. Individuals should be allowed to use private land for any purpose........................</td>
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<tr>
<td>Statement</td>
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<td>Neither Agree or Disagree</td>
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<tr>
<td>9. Government should regulate the use of land to protect wildlife habitat</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>10. Farmers should be held responsible for any damages to the environment</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
<td>11. All plants and animals play an important role in the environment</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
<td>12. Government should pass laws to make recycling mandatory</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>13. Management of wildlife populations should be left to nature</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
<td>14. Some wilderness areas should be preserved from development no matter how much money it costs</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>15. Industries should be held financially responsible for any pollution they cause</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

16. Please indicate your gender.
☐ Male
☐ Female

17. How would you describe your ethnicity?
☐ Asian or Pacific Islander
☐ Black or African American
☐ Hispanic or Latino
☐ White
☐ Other
Environmental Attitude Instrument

(Posttest)

Developed by: J. C. Bradley, T. M. Waliczek, & J. M. Zajicek

**General Directions:** Welcome to the Environmental Attitude Survey. This is not a timed survey and there are no correct or incorrect answers. You should mark an answer for each question. If you are unsure, try to answer the best you can with the information given. Only mark one answer for each question.

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**Student ID:** ________________________________
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<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>1. It is important that each individual be aware of environmental concerns.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>2. Management of wildlife populations should be left to nature</td>
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<td>☐</td>
</tr>
<tr>
<td>3. Laws regarding water quality should be stricter.</td>
<td>☐</td>
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<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5. Special habitats should be set aside for endangered species</td>
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<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8. Animals that provide meat for people are the most important to protect.</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>Statement</td>
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<td>Disagree</td>
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</tr>
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<td>11. Landowners should be allowed to drain wetlands/swamps for agricultural or industrial uses...</td>
<td>☐</td>
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<td>☐</td>
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<td>☐</td>
</tr>
<tr>
<td>12. Government should pass laws to make recycling mandatory...</td>
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<td>☐</td>
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<td>13. All plants and animals play an important role in the environment...</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>14. Poisonous snakes and insects that pose a threat to people should be killed...</td>
<td>☐</td>
<td>☐</td>
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</tbody>
</table>
**APPENDIX J**

**ENVIRONMENTAL ATTITUDE INVENTORY RESPONSE FREQUENCIES**

<table>
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<tr>
<th>Item Number</th>
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<td>4</td>
<td>3</td>
<td>11</td>
<td>7</td>
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<tr>
<td></td>
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<td>5</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2. Laws regarding water quality should be stricter</td>
<td>Pretest: 6</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Posttest: 6</td>
<td>5</td>
<td>4</td>
<td>4</td>
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</tr>
<tr>
<td>3. Animals that provide meat for people are the most important to protect*</td>
<td>Pretest: 7</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>2</td>
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<tr>
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<tr>
<td>4. Poisonous snakes and insect that pose a threat to people should be killed*</td>
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<td>19</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Posttest: 23</td>
<td>22</td>
<td>8</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>5. Landowners should be allowed to drain wetlands/swamps for agricultural or industrial uses*</td>
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<td>10</td>
<td>9</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Posttest: 11</td>
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<td>8</td>
<td>7</td>
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Note: * Negative statements.
<table>
<thead>
<tr>
<th>Item Number</th>
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<tr>
<td>1. Special habitats should be set aside for endangered species</td>
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<td>-</td>
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</tr>
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<td>2. Laws regarding water quality should be stricter</td>
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<td>3. Animals that provide meat for people are the most important to protect</td>
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<tr>
<td>4. Poisonous snakes and insect that pose a threat to people should be killed</td>
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<td>32.0</td>
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<td>5. Landowners should be allowed to drain wetlands/swamps for agricultural or industrial uses</td>
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<td>22.0</td>
<td>20</td>
</tr>
<tr>
<td>6. It is important that each individual be aware of environmental concerns</td>
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<td>-</td>
<td>-</td>
<td>10</td>
<td>20.0</td>
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<tr>
<td>7. Hunting and fishing are important management activities</td>
<td>Pretest 1</td>
<td>2.0</td>
<td>3</td>
<td>6.0</td>
<td>15</td>
</tr>
<tr>
<td>8. Individuals should be allowed to use private land for any purpose</td>
<td>Pretest 3</td>
<td>6.0</td>
<td>11</td>
<td>22.0</td>
<td>14</td>
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<tr>
<td>9. Government should regulate the use of land to protect wildlife habitat</td>
<td>Pretest -</td>
<td>-</td>
<td>2</td>
<td>4.0</td>
<td>23</td>
</tr>
<tr>
<td>10. Farmers should be held responsible for any damages to the environment</td>
<td>Pretest 3</td>
<td>6.0</td>
<td>16</td>
<td>32.0</td>
<td>18</td>
</tr>
<tr>
<td>11. All plants and animals play an important role in the environment</td>
<td>Pretest -</td>
<td>-</td>
<td>1</td>
<td>2.0</td>
<td>5</td>
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<tr>
<td>12. Government should pass laws to make recycling mandatory</td>
<td>Pretest 1</td>
<td>2.0</td>
<td>5</td>
<td>10.0</td>
<td>22</td>
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<tr>
<td>13. Management of wildlife populations should be left to nature</td>
<td>Pretest 6</td>
<td>12.0</td>
<td>13</td>
<td>26.0</td>
<td>19</td>
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<tr>
<td>14. Some wilderness areas should be preserved from development no matter how much money it costs</td>
<td>Pretest 3</td>
<td>6.0</td>
<td>2</td>
<td>4.0</td>
<td>20</td>
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<tr>
<td>15. Industries should be held financially responsible for any pollution they cause</td>
<td>Pretest 1</td>
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<td>1</td>
<td>2.0</td>
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<td>Disagree</td>
<td>Neither Agree or Disagree</td>
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<tr>
<td>1.</td>
<td>Special habitats should be set aside for endangered species</td>
<td>Pretest: 2, 3.9</td>
<td>4, 3.9</td>
<td>3, 5.9</td>
<td>21, 5.9</td>
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<td>Posttest: 2, 3.9</td>
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<td>2.</td>
<td>Laws regarding water quality should be stricter</td>
<td>Pretest: -</td>
<td>-</td>
<td>2, 3.9</td>
<td>11, 21.6</td>
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<td>Posttest: 2, 3.9</td>
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<td>3.</td>
<td>Animals that provide meat for people are the most important to protect</td>
<td>Pretest: 1, 2.0</td>
<td>6, 12.0</td>
<td>16, 20.8</td>
<td>21, 42.0</td>
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<td>Posttest: 1, 2.0</td>
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<td>4.</td>
<td>Poisonous snakes and insect that pose a threat to people should be killed</td>
<td>Pretest: 9, 17.6</td>
<td>18, 35.3</td>
<td>16, 31.4</td>
<td>5, 9.8</td>
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<td>Posttest: 12, 23.5</td>
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<td>5.</td>
<td>Landowners should be allowed to drain wetlands/swamps for agricultural or</td>
<td>Pretest: 13, 25.5</td>
<td>8, 15.7</td>
<td>16, 31.4</td>
<td>12, 23.5</td>
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<td>industrial uses</td>
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<tr>
<td>6.</td>
<td>It is important that each individual be aware of environmental concerns</td>
<td>Pretest: 5, 9.8</td>
<td>11, 21.6</td>
<td>15, 20.8</td>
<td>15, 29.4</td>
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<td>7.</td>
<td>Hunting and fishing are important management activities</td>
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<td>5, 9.8</td>
<td>14, 27.5</td>
<td>23, 45.1</td>
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<td>8.</td>
<td>Individuals should be allowed to use private land for any purpose</td>
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<td>16, 31.4</td>
<td>17, 33.3</td>
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<td>Posttest: 4, 7.8</td>
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<td>9.</td>
<td>Government should regulate the use of land to protect wildlife habitat</td>
<td>Pretest: 3, 5.9</td>
<td>2, 3.9</td>
<td>6, 11.8</td>
<td>28, 54.9</td>
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<td>10.</td>
<td>Farmers should be held responsible for any damages to the environment</td>
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<td>10, 19.6</td>
<td>15, 29.4</td>
<td>24, 47.1</td>
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<td>Posttest: 9, 17.6</td>
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<td>11.</td>
<td>All plants and animals play an important role in the environment</td>
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<td>12.</td>
<td>Government should pass laws to make recycling mandatory</td>
<td>Pretest: 1, 2.0</td>
<td>5, 9.8</td>
<td>13, 25.5</td>
<td>21, 41.2</td>
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<td>Posttest: 4, 7.8</td>
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<td>13.</td>
<td>Management of wildlife populations should be left to nature</td>
<td>Pretest: 3, 5.9</td>
<td>21, 41.2</td>
<td>9, 17.6</td>
<td>23.5, 44</td>
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<td>Posttest: 5, 9.8</td>
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<td>14.</td>
<td>Some wilderness areas should be preserved from development no matter how</td>
<td>Pretest: 3, 5.9</td>
<td>5, 9.8</td>
<td>15, 29.4</td>
<td>20, 39.2</td>
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<td>much money it costs</td>
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<td>15.</td>
<td>Industries should be held financially responsible for any pollution they</td>
<td>Pretest: 1, 2.0</td>
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<td>14, 27.5</td>
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<td>Posttest: -</td>
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The Critical Thinking Test of Environmental Education

(Pretest)

Developed by: Marie Cheak, Ph.D.

General Directions: Welcome to the Critical Thinking Test of Environmental Education. This is not a timed test. You will not get a grade on this test, but it is important for you to give it your best effort. You should mark an answer for each question. If you are unsure, try to answer the best you can with the information given. Only mark one answer for each question.

To start the assessment, please record you unique ID number in the box below. Your unique ID number is your school’s abbreviation and your six-digit birth date. For example, a student attending Saint Johns High School (SJHS) born on July 31st, 2003 (07/31/03) would have the ID number “SJHS073103”. Please record your ID number below.

Student ID: ____________________________
SECTION 1 – CONCLUSIONS

Directions:

Assume that the information given in the following text is accurate. There will be a short text on a specific topic, followed by a set of questions. Use the information given in the text to answer the questions that follow it. Choose one best answer for each question. The question will ask you to choose the best conclusion. A conclusion is the end result of the facts or data given.

Example Passage:

Sea horses are small fish that live in warm ocean waters. The head of a sea horse is shaped like the head of a horse. Sea horses swim upright and live among the kelp and sea grasses. Scientists have found that there are far fewer sea horses living in the ocean today than in the past. The scientists estimate that about 20 million sea horses disappear from the oceans each year.

Fishermen kill them by mistake when they catch other fish in their nets. People take them from the ocean to sell in pet stores. The fisherman blame the drop in number of sea horses on polluted ocean waters. They claim that other fish, not caught in the nets, are also dropping in numbers.

The pet industry claims that they sell too few sea horses for the pet industry to have any effect on the numbers that live in the ocean. People in the pet industry claim that loss of habitat, such as kelp beds, is the reason there are fewer sea horses in the oceans.

Example Question:

A conclusion that follows from the information given above is:

a) Fishing nets are the main cause for the drop in number of sea horses living in the oceans.

b) There is a decline in the number of sea horses living in the ocean.

c) The water in the ocean is too polluted for sea horses to live there.

The correct response is item b).
A botanist observed new tree seedlings in a patch of forest that had recently been logged from the old growth forest. She noticed that the new seedlings in the patch were all beech trees. The two principal hardwood trees in the old growth forest are beech and maple. It was expected that there would be approximately equal number of maple trees and beech trees found there. She conducted a survey of both the ages of the trees and the number of each type of tree found per acre in the old growth forest. The following graph represents the data from this survey of the old growth forests.

1. From the information above, it can be concluded that the biggest difference in the number of the two types of trees is at:
   a) 10 years old.
   b) 20 years old.
   c) 30 years old.

2. From the information above, it can be concluded that:
   a) More beech trees are growing per acre than maple trees, when the trees are the oldest.
   b) More maple trees than beech trees are growing per acre, within the first 40 years.
   c) As the maple tree population increases, the beech tree population decreases.

3. From the information above, it can be concluded that beech trees and maple trees are present in approximately equal numbers at:
   a) 10 years old through 20 years old.
   b) 40 years through 75 years and older.
   c) 10 through 40 years old.
4. From the information above, the conclusion that can be made about maple trees is that:
   a) There is a sharp decline in their numbers, in trees younger than 40 years.
   b) As they get older, fewer beech trees are found growing with them.
   c) As they age, fewer of them are present per acre in the old growth forest.

5. From the information above, the conclusion that can be made about beech trees is that:
   a) As their numbers decrease, the number of maples increase.
   b) As their numbers increase, the number of maples increase.
   c) There is no relationship between the two types of trees at any given age.
A biologist discovered a sharp decline in the amphibian population in a wetland in southern Florida. An analysis of the water showed no sign of high levels of toxins. The biologist surveyed a random sample of fish in the wetland and found that many of them were infected with disease. He then studied other wetland habitats in southern Florida. All of these habitats contained a large percentage of non-native fish.

The biologist researched the species of fish that are sold in pet stores. He compared those data with the data of non-native species found in the wild. Of the non-native species found in the wetlands sampled in southern Florida, 70 percent were species marketed through the pet trade. Thirty percent of the non-native species found in the wetlands were not marketed through the pet trade. These data are shown in the two graphs below.

6. Which conclusion best follows from the information above:

a) The pet trade is the cause of the decline in the amphibians in the wetlands.
b) There is a sharp decline in the amphibian population in the wetlands.
c) Results of the water tests for toxins were improperly analyzed.
7. Which conclusion best follows from the information above?

   a) One hundred percent of the total fish population in the wetlands of southern Florida are introduced through the pet trade.
   b) Seventy percent of the total fish population in the wetlands of southern Florida are also marketed through the aquarium trade.
   c) Thirty percent of the non-native fish population in the wetlands of southern Florida are not marketed through the pet trade.

8. Which conclusion best follows from the information above?

   a) The non-native fish species and native fish species present in the wetlands of southern Florida are equal in number.
   b) There are fewer numbers of non-native species of fish in the wetlands of southern Florida than native species.
   c) There are more non-native species of fish in the wetlands of southern Florida than native species.
SECTION 2 – INFERENCES

Directions:
Assume that the information given in the following text is accurate. There will be a short text on a specific topic, followed by a set of questions. Use the information given in the text to answer the questions that follow it. Choose one best answer for each question. The question will ask you to choose the best inference. An inference goes beyond the information given. It is an implication or judgment that is made from the information.

Example Passage:
Some years ago Mrs. Otto noticed that birds were dying in her backyard. Mrs. Otto knew that the town where she lived sprayed a chemical called DDT to kill mosquitoes. She thought there was a connection between the spraying of the chemical and the dead birds. Mrs. Otto asked the town officials to stop spraying the DDT used to kill mosquitoes. The town official did not listen to her. Mrs. Otto asked scientists to visit her yard and talk to her about the problem. The scientist met at Mrs. Otto’s house. They helped Mrs. Otto get the town officials to agree to stop use of the DDT chemical.

Example Question:
A good inference that can be made from the information given above is:

a) DDT killed the birds.
b) Only scientist can solve environmental issues.
c) Town officials should not make decisions about environmental issues.

The correct response is item a).
The citizens of rural Grazeville have different views on the proposed building of a railway through the community. The railway is expected to bring new jobs to the community. It is also expected to bring noise and degradation of the landscape surrounding Grazeville. The local town officials conducted a random survey of the adult population to see how they lined up on the issue.

Of the adult sample surveyed, 46% were for the railway, 52% were against, and 2% were undecided. Of those who were for the railway, the majority were from households where at least one adult was unemployed. Of those who were against, the majority were cattle ranchers.

9. From the above data, it can be inferred:
   a) Unemployment has an impact on the adults’ positive attitudes toward the proposed railway.
   b) Of the adults surveyed, 2% are not concerned about the environmental or economic impact of the proposed railway.
   c) New jobs from the railway will cause many cattle ranchers to quit cattle ranching.

10. From the above data, it can be inferred:
    a) More cattle ranchers were against the railway, than adults from other occupations.
    b) More unemployed people in Grazeville were against the railway, than cattle ranchers.
    c) There are more residents of Grazeville who are for the railway, than those who were against it.

11. From the above data, it can be inferred:
    a) Many people in Grazeville do not want the railway because of the noise it will bring.
    b) Many people in Grazeville are concerned about the environment.
    c) Many people in Grazeville are affected by their economic values.
In 1989 a ship named the *Exxon Valdez* spilled 11 million gallons of oil into the water off the coast of Alaska. This was the second worst oil spill in American history. This spill contaminated 1300 miles of shoreline. This is equivalent to driving the distance from New York City to Miami, Florida.

One and a half years after the *Exxon Valdez* spill Congress passed a bill to regulate the shipment of oil. This is the Oil Pollution Act of 1990. The act required oil tankers in U.S. waters to have had double hulls by 2015.

Approximately 31.5 billion gallons of oil is shipped by sea worldwide each day. The average amount of oil spilled each year is estimated to be 100 million gallons.

The Exxon oil company considered the cleanup of Alaskan oil spill nearly complete only two years after it occurred. There continues to be disagreement about how long the oil spilled in the water will continue to have harmful effects on the wildlife that live there. One such form of wildlife is the duck population. Scientists who studied the long-term effects of the spill on the duck population, observed ducks seven years after the Alaskan spill. The scientist counted the number of ducks that survived in oil polluted water after the 1997 winter. They found that 77 percent of these ducks lived through the winter. The scientist counted the number of ducks that survived the same winter where no oil had been spilled. They found that 94 percent of these ducks lived through the winter.

12. A good inference that can be made from the information given is:

   a) There was no need for citizens in the U.S. to be concerned about oil spills, prior to the major spill occurrence in the U.S.
   b) When a large oil spill occurred closer to home, U.S. citizens became more active toward pursuit of a solution.
   c) Legislators in Congress should be more responsible in drafting bills to protect American coastlines.

13. A good inference that can be made from the information given above is:

   a) Oil spills can be harmful to living things in the water many years after the spill.
   b) Ducks are more likely than other living things in the water to be affected by oil spilled in water.
   c) Oil should not be moved by ships.
14. A good inference that can be made from the information given above is:

   a) Oil spills have an impact on duck populations only during the winter season.
   b) The ducks died because of the harsh winter.
   c) Oil spilled in water is harmful to the ducks that live there.

15. A good inference that can be made from the information given above is:

   a) Compared to the total amount of oil spilled worldwide, the Alaskan spill is relatively small.
   b) The Alaskan oil spill does not represent a serious threat to the environment.
   c) The amount of oil spilled on a global scale yearly is insignificant in terms of its environmental impact.
Methyl mercury is one of the most toxic substances on Earth. Human activity, such as the use of coal-fired power plants and waste incineration, has doubled or even tripled the amounts of this substance in the environment.

Fluorescent light bulbs contain mercury. If a fluorescent bulb is tossed into a waste incinerator mercury enters the atmosphere. Rain washes mercury out of the atmosphere and deposits it in rivers and lakes. Bacteria convert this form of mercury into methyl mercury which is more toxic to living things. This form of mercury is absorbable across cell membranes and is extremely toxic. Methyl mercury enters the food chain through bacteria or plankton, when they are eaten by fish. As this form of mercury moves up the food chain it accumulates in ever increasing concentrations.

Scientists have studied the loon, a waterfowl that lives in the Northeast, to find more about the effects of this dangerous substance. These waterfowl make good subjects to study about methyl mercury concentrations, because they feed on large fish. They also live a long time – as long as 20 years. Scientist have found large concentrations of methyl mercury in loons, but the adults do not seem to die from it. However, scientists have found that 30 percent of the loons’ eggs contained enough methyl mercury to kill or damage the embryos.

Scientists have also measured the concentrations of methyl mercury in freshwater fish across the United States. The least concentrations are found in fish in Alaska and on the west coast. The heaviest concentrations are found on the east coast. Scientists know the prevailing winds carry mercury fro the Midwest to the East where rain washes it into the rivers and lakes.

16. A good inference that can be made from the information given is:
   a) There is a relationship between methyl mercury and the number of loon eggs that hatch.
   b) There is a relationship between methyl mercury and the number of live adult loons.
   c) There is a relationship between methyl mercury and the number of fish living in eastern freshwater habitats.

17. A good inference that can be made from the information given above is:
   a) Methyl mercury has no effect on human health.
   b) Only people living on the east coast need to worry about methyl mercury in the food chain.
   c) Humans will store methyl mercury in their bodies, if they eat fish contaminated with methyl mercury.
18. A good inference that can be made from the information given above is:

a) The loon population is in no serious threat, due to the levels of methyl mercury in the fish they eat.
b) Human activity in the Midwest has an impact on the loon population in the East.
c) Fish are unaffected by high levels of methyl mercury in the water.

19. A good inference that can be made from the information given above is:

a) A bacterium will contain more methyl mercury than a fish.
b) A fish will contain more methyl mercury than a loon.
c) A human will contain more methyl mercury than a fish.
SECTION 3 – IDENTIFYING BIAS

Directions:

You are asked to identify the issue, the beliefs, and the values in the following paragraphs. First you are asked to read a short paragraph after which you are asked to identify the environmental issue. Next you are asked to read more paragraphs that give different views of the same issue. Some of the human players and their beliefs about the issue will be given. In each case you are asked to identify the value represented by the player.

Finally, you will be asked to identify your own position on the issue. There is no right or wrong answer pertaining to “your” position on the issue.

1 The coyote is the romantic symbol of the Wild West. 2 Some people think this predator keeps deer populations in check. 3 The facts do not support this however. 4 Although coyotes prey on fawns, they have limited impact on adult deer populations.

5 As wildlife habitat is lost, deer are forced into populated urban areas. 6 This results in every increasing threats to highway safety and crop damage caused by the shifting deer population.

7 In a small town in Wyoming a contest is held each year for the purpose of killing coyotes. 8 Folks are split on their views about such a contest. 9 Hunters from all over the U.S. come to the contest to hunt and kill coyotes. 10 Some think the hunting contest should be allowed. 11 Others think it is inhumane treatment of animals when the goal of the contest is prize money.

20. The environmental issue portrayed in the above paragraphs is:

   a) To what extent is the coyote a romantic symbol of the Wild West?
   b) To what extent are deer important links in the food chain?
   c) To what extent should hunters be allowed to kill coyote for sport?

21. My position on the issue I chose above, is that I agree:

   a) to no extent.
   b) unsure.
   c) to a large extent.
Hunters disagree - “We are not hunting for contest prize money,” said Jule Stuple. “It is a change for us to get together and enjoy friends, who share common interests.”

Maro Filey, another hunter, put it this way. “The coyote is smart and I respect him. I don’t hunt him because I hate the coyote, but we do need a system of checks and balances. There are too many of them”.

But Jaz Row, with the state park agency, has a different opinion. “Hunters killing coyotes only increases their numbers. They respond by producing bigger litters of young.”

Although only a small percentage of Americans are hunters, they are very vocal about their position on hunting. “It’s rooted in our culture,” said Fino Lawrie. “That’s important to us.”

Many ranchers agree with the hunters. “Nearly 70% of the sheep lost in this state are lost because of coyotes,” said Billie Ford. “That means I don’t produce as much wool for market.”

The governor, in a letter to the opponents of the contest stated: “the coyote is unregulated in this state and they are allowed to be hunted.”

Val Turner, an animal activist, holds yet another view. At a press conference he commented, “Shooting coyotes doesn’t solve predator problems. There are other predators on sheep besides coyotes – like dogs and eagles.”

Directions:

Use the following value definitions to answer the items below: You may use any of them more than once, but choose only one to answer each question.

Here are the value definitions to which you can refer:

<table>
<thead>
<tr>
<th>The Value</th>
<th>The Definition</th>
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<tbody>
<tr>
<td>Environmental...</td>
<td>Pertaining to human activities in terms of quality of natural resources, e.g., plant and animal species, air, water, soil, etc.</td>
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<tr>
<td>Legal............</td>
<td>Relating to national, state, or local laws: law enforcement; lawsuits.</td>
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<tr>
<td>Social...........</td>
<td>Pertaining to shared human empathy, feelings, and status.</td>
</tr>
<tr>
<td>Ethnocentric.....</td>
<td>Pertaining to a focus on the fulfillment of ethnic/cultural goals.</td>
</tr>
<tr>
<td>Economic.........</td>
<td>The use and exchange of money, materials, and/or services.</td>
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</tbody>
</table>
22. The value indicated by Jule Stuple (sentences 12 and 13) is:
   a) Environmental  b) Legal  c) Social  d) Ethnocentric  e) Economic
23. The value indicated by Maro Filey (sentences 14, 15, 16, and 17) is:
   a) Environmental  b) Legal  c) Social  d) Ethnocentric  e) Economic
24. The value indicated by Jaz Rowe (sentences 18, 19, and 20) is:
   a) Environmental  b) Legal  c) Social  d) Ethnocentric  e) Economic
25. The value indicated by Fino Lawrie (sentences 22 and 23) is:
   a) Environmental  b) Legal  c) Social  d) Ethnocentric  e) Economic
26. The value indicated by Billie Ford (sentences 25 and 26) is:
   a) Environmental  b) Legal  c) Social  d) Ethnocentric  e) Economic
27. The value indicated by the governor (sentence 27) is:
   a) Environmental  b) Legal  c) Social  d) Ethnocentric  e) Economic
28. The value indicated by Val Turner (sentences 28, 29, and 30) is:
   a) Environmental  b) Legal  c) Social  d) Ethnocentric  e) Economic
The Critical Thinking Test of Environmental Education

(Posttest)

Developed by: Marie Cheak, Ph.D.

General Directions: Welcome to the Critical Thinking Test of Environmental Education. This is not a timed test. You will not get a grade on this test, but it is important for you to give it your best effort. You should mark an answer for each question. If you are unsure, try to answer the best you can with the information given. Only mark one answer for each question.

To start the assessment, please record your unique ID number in the box below. Your unique ID number is your school’s abbreviation and your six-digit birth date. For example, a student attending Saint Johns High School (SJHS) born on July 31st, 2003 (07/31/03) would have the ID number “SJHS073103”. Please record your ID number below.

Student ID: ________________________________
SECTION 1 – INFERENCES

Directions:

Assume that the information given in the following text is accurate. There will be a short text on a specific topic, followed by a set of questions. Use the information given in the text to answer the questions that follow it. Choose one best answer for each question. The question will ask you to choose the best inference. An inference goes beyond the information given. It is an implication or judgment that is made from the information.

Example Passage:

Some years ago Mrs. Otto noticed that birds were dying in her backyard. Mrs. Otto knew that the town where she lived sprayed a chemical called DDT to kill mosquitoes. She thought there was a connection between the spraying of the chemical and the dead birds. Mrs. Otto asked the town officials to stop spraying the DDT used to kill mosquitoes. The town official did not listen to her. Mrs. Otto asked scientists to visit her yard and talk to her about the problem. The scientist met at Mrs. Otto’s house. They helped Mrs. Otto get the town officials to agree to stop use of the DDT chemical.

Example Question:

A good inference that can be made from the information given above is:

a) DDT killed the birds.
b) Only scientist can solve environmental issues.
c) Town officials should not make decisions about environmental issues.

The correct response is item a).
In 1989 a ship named the Exxon Valdez spilled 11 million gallons of oil into the water off the coast of Alaska. This was the second worst oil spill in American history. This spill contaminated 1300 miles of shoreline. This is equivalent to driving the distance from New York City to Miami, Florida.

One and a half years after the Exxon Valdez spill Congress passed a bill to regulate the shipment of oil. This is the Oil Pollution Act of 1990. The act required oil tankers in U.S. waters to have had double hulls by 2015.

Approximately 31.5 billion gallons of oil is shipped by sea worldwide each day. The average amount of oil spilled each year is estimated to be 100 million gallons.

The Exxon oil company considered the cleanup of Alaskan oil spill nearly complete only two years after it occurred. There continues to be disagreement about how long the oil spilled in the water will continue to have harmful effects on the wildlife that live there. One such form of wildlife is the duck population. Scientists who studied the long-term effects of the spill on the duck population, observed ducks seven years after the Alaskan spill. The scientist counted the number of ducks that survived in oil polluted water after the 1997 winter. They found that 77 percent of these ducks lived through the winter. The scientist counted the number of ducks that survived the same winter where no oil had been spilled. They found that 94 percent of these ducks lived through the winter.

1. A good inference that can be made from the information given above is:
   a) Ducks are more likely than other living things in the water to be affected by oil spilled in water.
   b) Oil spills can be harmful to living things in the water many years after the spill.
   c) Oil should not be moved by ships.

2. A good inference that can be made from the information given is:
   a) There was no need for citizens in the U.S. to be concerned about oil spills, prior to the major spill occurrence in the U.S.
   b) Legislators in Congress should be more responsible in drafting bills to protect American coastlines.
   c) When a large oil spill occurred closer to home, U.S. citizens became more active toward pursuit of a solution.
3. A good inference that can be made from the information given above is:
   a) The Alaskan oil spill does not represent a serious threat to the environment.
   b) Compared to the total amount of oil spilled worldwide, the Alaskan spill is relatively small.
   c) The amount of oil spilled on a global scale yearly is insignificant in terms of its environmental impact.

4. A good inference that can be made from the information given above is:
   a) Oil spilled in water is harmful to the ducks that live there.
   b) Oil spills have an impact on duck populations only during the winter season.
   c) The ducks died because of the harsh winter.
The citizens of rural Grazeville have different views on the proposed building of a railway through the community. The railway is expected to bring new jobs to the community. It is also expected to bring noise and degradation of the landscape surrounding Grazeville. The local town officials conducted a random survey of the adult population to see how they lined up on the issue.

Of the adult sample surveyed, 46% were for the railway, 52% were against, and 2% were undecided. Of those who were for the railway, the majority were from households where at least one adult was unemployed. Of those who were against, the majority were cattle ranchers.

5. From the above data, it can be inferred:
   a) Of the adults surveyed, 2% are not concerned about the environmental or economic impact of the proposed railway.
   b) New jobs from the railway will cause many cattle ranchers to quit cattle ranching.
   c) Unemployment has an impact on the adults’ positive attitudes toward the proposed railway.

6. From the above data, it can be inferred:
   a) Many people in Grazeville are concerned about the environment.
   b) Many people in Grazeville do not want the railway because of the noise it will bring.
   c) Many people in Grazeville are affected by their economic values.

7. From the above data, it can be inferred:
   a) More unemployed people in Grazeville were against the railway, than cattle ranchers.
   b) More cattle ranchers were against the railway, than adults from other occupations.
   c) There are more residents of Grazeville who are for the railway, than those who were against it.
Methyl mercury is one of the most toxic substances on Earth. Human activity, such as the use of coal-fired power plants and waste incineration, has doubled or even tripled the amounts of this substance in the environment.

Fluorescent light bulbs contain mercury. If a fluorescent bulb is tossed into a waste incinerator mercury enters the atmosphere. Rain washes mercury out of the atmosphere and deposits it in rivers and lakes. Bacteria convert this form of mercury into methyl mercury which is more toxic to living things. This form of mercury is absorbable across cell membranes and is extremely toxic. Methyl mercury enters the food chain through bacteria or plankton, when they are eaten by fish. As this form of mercury moves up the food chain it accumulates in ever increasing concentrations.

Scientists have studied the loon, a waterfowl that lives in the Northeast, to find more about the effects of this dangerous substance. These waterfowl make good subjects to study about methyl mercury concentrations, because they feed on large fish. They also live a long time – as long as 20 years. Scientist have found large concentrations of methyl mercury in loons, but the adults do not seem to die from it. However, scientists have found that 30 percent of the loons’ eggs contained enough methyl mercury to kill or damage the embryos.

Scientists have also measured the concentrations of methyl mercury in freshwater fish across the United States. The least concentrations are found in fish in Alaska and on the west coast. The heaviest concentrations are found on the east coast. Scientists know the prevailing winds carry mercury fro the Midwest to the East where rain washes it into the rivers and lakes.

8. A good inference that can be made from the information given above is:

   a) The loon population is in no serious threat, due to the levels of methyl mercury in the fish they eat.
   b) Fish are unaffected by high levels of methyl mercury in the water.
   c) Human activity in the Midwest has an impact on the loon population in the East.

9. A good inference that can be made from the information given above is:

   a) Methyl mercury has no effect on human health.
   b) Only people living on the east coast need to worry about methyl mercury in the food chain.
   c) Humans will store methyl mercury in their bodies, if they eat fish contaminated with methyl mercury.
10. A good inference that can be made from the information given is:
   a) There is a relationship between methyl mercury and the number of live adult loons.
   b) There is a relationship between methyl mercury and the number of loon eggs that hatch.
   c) There is a relationship between methyl mercury and the number of fish living in eastern freshwater habitats.

11. A good inference that can be made from the information given above is:
   a) A bacterium will contain more methyl mercury than a fish.
   b) A fish will contain more methyl mercury than a loon.
   c) A human will contain more methyl mercury than a fish.
SECTION 2 – IDENTIFYING BIAS

Directions:

You are asked to identify the issue, the beliefs, and the values in the following paragraphs. First you are asked to read a short paragraph after which you are asked to identify the environmental issue. Next you are asked to read more paragraphs that give different views of the same issue. Some of the human players and their beliefs about the issue will be given. In each case you are asked to identify the value represented by the player.

Finally, you will be asked to identify your own position on the issue. There is no right or wrong answer pertaining to “your” position on the issue.

The coyote is the romantic symbol of the Wild West. Some people think this predator keeps deer populations in check. The facts do not support this however. Although coyotes prey on fawns, they have limited impact on adult deer populations.

As wildlife habitat is lost, deer are forced into populated urban areas. This results in every increasing threats to highway safety and crop damage caused by the shifting deer population.

In a small town in Wyoming a contest is held each year for the purpose of killing coyotes. Folks are split on their views about such a contest. Hunters from all over the U.S. come to the contest to hunt and kill coyotes. Some think the hunting contest should be allowed. Others think it is inhumane treatment of animals when the goal of the contest is prize money.

12. The environmental issue portrayed in the above paragraphs is:
   a) To what extent should hunters be allowed to kill coyote for sport?
   b) To what extent is the coyote a romantic symbol of the Wild West?
   c) To what extent are deer important links in the food chain?

13. My position on the issue I chose above, is that I agree:
   a) to no extent.
   b) unsure.
   c) to a large extent.
Hunters disagree - "We are not hunting for contest prize money," said Jule Stuple. "It is a change for us to get together and enjoy friends, who share common interests."

Maro Filey, another hunter, put it this way. "The coyote is smart and I respect him. I don't hunt him because I hate the coyote, but we do need a system of checks and balances. There are too many of them."

But Jaz Row, with the state park agency, has a different opinion. "Hunters killing coyotes only increases their numbers. They respond by producing bigger litters of young."

Although only a small percentage of Americans are hunters, they are very vocal about their position on hunting. "It's rooted in our culture," said Fino Lawrie. "That's important to us." Many ranchers agree with the hunters. "Nearly 70% of the sheep lost in this state are lost because of coyotes," said Billie Ford. "That means I don't produce as much wool for market."

The governor, in a letter to the opponents of the contest stated: "the coyote is unregulated in this state and they are allowed to be hunted." Val Turner, an animal activist, holds yet another view. At a press conference he commented, "Shooting coyotes doesn't solve predator problems. There are other predators on sheep besides coyotes – like dogs and eagles."

Directions:

Use the following value definitions to answer the items below: You may use any of them more than once, but choose only one to answer each question.

Here are the value definitions to which you can refer:

<table>
<thead>
<tr>
<th>The Value</th>
<th>The Definition</th>
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<tbody>
<tr>
<td>Environmental...</td>
<td>Pertaining to human activities in terms of quality of natural resources, e.g., plant and animal species, air, water, soil, etc.</td>
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<tr>
<td>Legal.............</td>
<td>Relating to national, state, or local laws: law enforcement; lawsuits.</td>
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<tr>
<td>Social...............</td>
<td>Pertaining to shared human empathy, feelings, and status.</td>
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<tr>
<td>Ethnocentric.......</td>
<td>Pertaining to a focus on the fulfillment of ethnic/cultural goals.</td>
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<tr>
<td>Economic...........</td>
<td>The use and exchange of money, materials, and/or services.</td>
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14. The value indicated by Jule Stuple (sentences 12 and 13) is:
   a) Environmental  b) Legal  c) Social  d) Ethnocentric  e) Economic

15. The value indicated by Maro Filey (sentences 14, 15, 16, and 17) is:
   a) Environmental  b) Legal  c) Social  d) Ethnocentric  e) Economic

16. The value indicated by Jaz Rowe (sentences 18, 19, and 20) is:
   a) Environmental  b) Legal  c) Social  d) Ethnocentric  e) Economic

17. The value indicated by Fino Lawrie (sentences 22 and 23) is:
   a) Environmental  b) Legal  c) Social  d) Ethnocentric  e) Economic

18. The value indicated by Billie Ford (sentences 25 and 26) is:
   a) Environmental  b) Legal  c) Social  d) Ethnocentric  e) Economic

19. The value indicated by the governor (sentence 27) is:
   a) Environmental  b) Legal  c) Social  d) Ethnocentric  e) Economic

20. The value indicated by Val Turner (sentences 28, 29, and 30) is:
   a) Environmental  b) Legal  c) Social  d) Ethnocentric  e) Economic
SECTION 3 – CONCLUSIONS

Directions:
Assume that the information given in the following text is accurate. There will be a short text on a specific topic, followed by a set of questions. Use the information given in the text to answer the questions that follow it. Choose one best answer for each question. The question will ask you to choose the best conclusion. A conclusion is the end result of the facts or data given.

Example Passage:

Sea horses are small fish that live in warm ocean waters. The head of a sea horse is shaped like the head of a horse. Sea horses swim upright and live among the kelp and sea grasses. Scientists have found that there are far fewer sea horses living in the ocean today than in the past. The scientists estimate that about 20 million sea horses disappear from the oceans each year.

Fishermen kill them by mistake when they catch other fish in their nets. People take them from the ocean to sell in pet stores. The fisherman blame the drop in number of sea horses on polluted ocean waters. They claim that other fish, not caught in the nets, are also dropping in numbers.

The pet industry claims that they sell too few sea horses for the pet industry to have any effect on the numbers that live in the ocean. People in the pet industry claim that loss of habitat, such as kelp beds, is the reason there are fewer sea horses in the oceans.

Example Question:

A conclusion that follows from the information given above is:

a) Fishing nets are the main cause for the drop in number of sea horses living in the oceans.
b) There is a decline in the number of sea horses living in the ocean.
c) The water in the ocean is too polluted for sea horses to live there.

The correct response is item b).
A biologist discovered a sharp decline in the amphibian population in a wetland in southern Florida. An analysis of the water showed no sign of high levels of toxins. The biologist surveyed a random sample of fish in the wetland and found that many of them were infected with disease. He then studied other wetland habitats in southern Florida. All of these habitats contained a large percentage of non-native fish.

The biologist researched the species of fish that are sold in pet stores. He compared those data with the data of non-native species found in the wild. Of the non-native species found in the wetlands sampled in southern Florida, 70 percent were species marketed through the pet trade. Thirty percent of the non-native species found in the wetlands were not marketed through the pet trade. These data are shown in the two graphs below.

21. Which conclusion best follows from the information above?

   a) The non-native fish species and native fish species present in the wetlands of southern Florida are equal in number.
   b) There are more non-native species of fish in the wetlands of southern Florida than native species.
   c) There are fewer numbers of non-native species of fish in the wetlands of southern Florida than native species.
22. Which conclusion best follows from the information above?
   
   a) One hundred percent of the total fish population in the wetlands of southern Florida are introduced through the pet trade.
   b) Thirty percent of the non-native fish population in the wetlands of southern Florida are not marketed through the pet trade.
   c) Seventy percent of the total fish population in the wetlands of southern Florida are also marketed through the aquarium trade.

23. Which conclusion best follows from the information above?
   
   a) There is a sharp decline in the amphibian population in the wetlands.
   b) Results of the water tests for toxins were improperly analyzed.
   c) The pet trade is the cause of the decline in the amphibians in the wetlands.
A botanist observed new tree seedlings in a patch of forest that had recently been logged from the old growth forest. She noticed that the new seedlings in the patch were all beech trees. The two principal hardwood trees in the old growth forest are beech and maple. It was expected that there would be approximately equal number of maple trees and beech trees found there. She conducted a survey of both the ages of the trees and the number of each type of tree found per acre in the old growth forest. The following graph represents the data from this survey of the old growth forests.

![Graph of Data from the Old Growth Forest](image)

Data from the Old Growth Forest

24. From the information above, it can be concluded that:

   a) More beech trees are growing per acre than maple trees, when the trees are the oldest.
   b) As the maple tree population increases, the beech tree population decreases.
   c) More maple trees than beech trees are growing per acre, within the first 40 years.

25. From the information above, it can be concluded that the biggest difference in the number of the two types of trees is at:

   a) 10 years old.
   b) 20 years old.
   c) 30 years old.

26. From the information above, it can be concluded that beech trees and maple trees are present in approximately equal numbers at:

   a) 10 years old through 20 years old.
   b) 10 through 40 years old.
   c) 40 years through 75 years and older.
27. From the information above, the conclusion that can be made about beech trees is that:

   a) As their numbers increase, the number of maples increase.
   b) As their numbers decrease, the number of maples increase.
   c) There is no relationship between the two types of trees at any given age.

28. From the information above, the conclusion that can be made about maple trees is that:

   a) As they get older, fewer beech trees are found growing with them.
   b) As they age, fewer of them are present per acre in the old growth forest.
   c) There is a sharp decline in their numbers, in trees younger than 40 years.
The Critical Thinking Test of Environmental Education Assessment Key

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Questions

1. Suppose a field of grass stores 1500 kilocalories of solar energy. A goose consumes the grass. Approximately how much energy is available to the coyote that preys on the goose?
   a) 1.5 Kcal
   b) 150 Kcal
   c) 1350 Kcal
   d) 1500 Kcal

2. Which of the following organisms belongs to the lowest trophic level?
   a) Strawberries
   b) Hawk
   c) Mice
   d) Snake
3. Which of the following organisms belongs to the highest trophic level?

   a) Strawberries
   b) Hawk
   c) Mice
   d) Snake

4. Which of the following would be a primary consumer?

   a) Oak tree
   b) Cat
   c) Seaweed
   d) Rabbit

5. A raccoon could be in any of the following categories EXCEPT:

   a) Primary consumer
   b) Secondary consumer
   c) Omnivore
   d) Detritivore

6. The number of animals an ecosystem can sustainably support is known as the:

   a) Metabolism
   b) Food Chain
   c) Food Web
   d) Carrying Capacity

7. Which of the following is a density independent limiting factor?

   a) Fire
   b) Water
   c) Food
   d) Predation

8. Which of the following is a density dependent limiting factor?

   a) Fire
   b) Earthquake
   c) Shelter
   d) Temperature
9. True or False: The transfer of energy is usually around 90% for each trophic level.
   
   a) True  
   b) False

10. Which of the following regions would likely have the most energy stored in living organisms and would likely have the greatest biodiversity?

   a) Desert Regions  
   b) Polar Regions  
   c) Tropical Regions  
   d) Tundra Regions

11. True or False: The laws of energy and thermodynamics states that energy cannot be created or destroyed as energy can only be transferred.

   a) True  
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12. Which of the following terms describe a series of interconnected food chains found within a given ecosystem?

   a) Food Scatter Plot  
   b) Food Web  
   c) Trophic Level Pyramid  
   d) Linked Food Chain

13. The Case Study of the Island Royale studied the population dynamics of which two organisms?

   a) Rabbits and Field Grass  
   b) Deer and Acorns  
   c) Wolves and Moose  
   d) Native Species and Invasive Species

14. Populations of a species that goes beyond the carrying capacity will likely do what?

   a) Continue to grow rapidly  
   b) Continue to remain above the carrying capacity  
   c) Eventually be reduced back to the carrying capacity  
   d) Completely collapse
15. Populations that extend beyond the carrying capacity are susceptible to...
   a) Disease
   b) Starvation
   c) Predation
   d) All the above

16. A species that has been introduced into a new area and spreads rapidly can be considered a/an ________.
   a) Invasive Species
   b) Exotic-Non Invasive Species
   c) Native Species
   d) Terminal Species

17. Which of the following is a common characteristic of invasive species?
   a) Have lots of natural predators
   b) Reproduce slowly
   c) Spread slowly to new areas
   d) Outcompete native species for local food sources

18. Which of the following is an example of how invasive species spread?
   a) Pet trade
   b) Commodity trade
   c) Boat travel
   d) All the above

19. True or False: All exotic species are also invasive.
   a) True
   b) False

20. Which of the following organisms would be considered an invasive species to the Illinois River?
   a) Channel Catfish
   b) Silver Carp
   c) Bluegill
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APPENDIX M
MODULE TWO CONTENT KNOWLEDGE ASSESSMENT

Flourishing Fauna Module Assessment

(Pretest)

General Directions: Welcome to the Flourishing Fauna Pretest. This is not a timed assessment and you will not be graded on this assessment. You should mark an answer for each question. If you are unsure, try to answer the best you can with the information given. Only mark one answer for each question.

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Questions

1. If a black bear in Idaho cannot find a place to hibernate for the winter the habitat resource it lacks is:
   a) Food
   b) Shelter
   c) Water
   d) Space

2. Which of the following beaks is the best adaptation for scooping up fish in water?
   a) A sharp hooked beak
   b) A short strong beak
   c) A shovel-type beak
   d) A needle shaped beak
3. A black rat with the genotype BB mates with a white rat, with the genotype bb. The offspring will have the following genotype(s):

   a) BB, Bb, bb  
   b) BB and bb  
   c) BB only  
   d) Bb only

4. Which of the following terms describes the genetic constitution (gene makeup) of an organism usually in reference to an associated trait?

   a) Gamete  
   b) Gene  
   c) Genetics  
   d) Genotype

5. A black rat with the genotype BB mates with a white rat, with the genotype bb. The offspring will have the following phenotype:

   a) 25% white and 75% black  
   b) 100% white  
   c) 50% black and 50% white  
   d) 100% black

6. Which of the following management techniques would NOT be used to increase the population of a species?

   a) Reduce disease exposure  
   b) Increase habitat  
   c) Reduce predator populations  
   d) Increase hunting

7. Which of the following management techniques would be used to increase the population of a species?

   a) Increased hunting  
   b) Reduce habitat access  
   c) Increase predator populations  
   d) Reduce disease with vaccinations
8. Which of the following general classifications of habitat would include a large number of pine trees at the lowest trophic level?

   a) Savanna  
   b) Mediterranean  
   c) Coniferous Forest  
   d) Tundra

9. Which of the following describes the non-living factors associated with an ecosystem?

   a) Biotic Factors  
   b) Abiotic Factors  
   c) Community Factors  
   d) Dead-zone Factors

10. Which of the following describes the process when natural habitat is lost due to a high degree of interference, such as deforestation?

    a) Habitat Destruction  
    b) Habitat Degradation  
    c) Habitat Management  
    d) Habitat Fragmentation

11. Which of the following terms describe all the biotic factors that are found together in a specific ecosystem?

    a) Primary Producers  
    b) Community  
    c) Biome  
    d) Food Chain

12. Which of the following would describe loss of habitat continuity due to agricultural fields causing a lack of connection between forested areas?

    a) Habitat Destruction  
    b) Habitat Degradation  
    c) Habitat Management  
    d) Habitat Fragmentation
13. This bird was once probably the most numerous bird in North America, however, immense over-hunting and habitat disruption caused the bird to go extinct in 1914.

a) Dodo bird  
b) Mourning Dove  
c) Carolina Parakeet  
d) Passenger Pigeon

14. This type of wildlife management would include planting native plants in a new school-yard butterfly garden.

a) Managing Habitat  
b) Creating Habitat  
c) Habitat Protection  
d) Population Protection

15. If a deer population experiences a growth beyond their carrying capacity, which management decision would help manage the deer population for a healthy ecosystem?

a) Establish food stations with shelled corn  
b) Increase hunting permits for deer  
c) Reduce deer habitat  
d) Remove invasive species

16. These birds were studied by Charles Darwin in the Galapagos Islands.

a) Finch  
b) Toucan  
c) Passenger Pigeon  
d) Dodo bird

17. Which of the following adaptations would be most beneficial for a population of bears that are experiencing warmer climates?

a) A patterned fur coat  
b) A thicker fur coat  
c) A thinner fur coat  
d) A more water repellent fur coat
18. Which of the following is the most valid evidence for making conclusions on the relatedness of organisms?

   a) DNA analysis
   b) Physical appearance analysis
   c) Structural morphology analysis
   d) Offspring analysis

19. Which genotype would indicate a phenotype of a recessive trait?

   a) RRr
   b) Rr
   c) rr
   d) RR

20. True or False: The observed characteristic of an individual without reference to its genetic makeup is called a phenotype.

   a) True
   b) False
General Directions: Welcome to the Flourishing Fauna Posttest. This is not a timed assessment and you may be graded on this assessment. You should mark an answer for each question. If you are unsure, try to answer the best you can with the information given. Only mark one answer for each question.

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c) Structural morphology analysis  
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# Flourishing Fauna Module Assessment Key

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General Directions: Welcome to the All Natural Flora Module Pretest. This is not a timed assessment and you will not be graded on this assessment. You should mark an answer for each question. If you are unsure, try to answer the best you can with the information given. Only mark one answer for each question.

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Questions

1. Which of the following terms describe the degree of variation of life forms within a given ecosystem, biome, or planet?
   a) Biome
   b) Biodiversity
   c) Community
   d) Ecological Fluctuation

2. An organism that produces and stores chemical energy through chemosynthesis or photosynthesis.
   a) Allogenic
   b) Autogenic
   c) Autotrophic
   d) Heterotrophic
3. These are used in one method of sampling and consist of typically a 1-meter x 1-meter square in which plant biodiversity is measured.

   a) Relevé
   b) Column
   c) Quadrat
   d) Satellite Sampling

4. Four students conduct percent cover surveys. Each plot has four species within it. Which student’s plot shows the most diversity?

   a) Kate’s plot: Species A – 25%; Species B – 25%; Species C – 25%; Species D – 25%
   b) Janelle’s plot: Species A – 90%; Species B – 3%; Species C – 3%; Species D – 3%
   c) Frank’s plot: Species A – 25%; Species B – 25%; Species C – 5%; Species D – 45%
   d) Deshawn’s plot: Species A – 45%; Species B – 45%; Species C – 9%; Species D – 1%

5. Two plots have been sampled. Plot one has 15 plant species, with one of the species covering 95% of the plot. Plot two has 3 species, with each species covering 33% of the plot. Which statement is the correct comparison of the two plots?

   a) They have the same diversity.
   b) Plot one is more diverse.
   c) Plot two is more diverse.
   d) They are diverse in different ways.

6. Which of the following terms describe the study of the relationship between organisms and their environment?

   a) Ecologist
   b) Ecology
   c) Ecosystem
   d) Ecodependent

7. Which of the following terms describe all the biotic and abiotic components of an environment?

   a) Ecologist
   b) Ecology
   c) Ecosystem
   d) Ecodependent
8. Which of the following terms describe plant migration on newly formed soils or upon soils that have never borne vegetation, such as a sand bar in a river?

a) Primary succession  
b) Secondary succession  
c) Transition  
d) Climax

9. When Mount St. Helens volcano erupted, it scorched tens of thousands of acres of forest with hot gases, and covered the land with hot ash, burning and burying the vegetation. One year later, surviving plants were growing up through the ash from the soil below. This is an example of:

a) Primary succession  
b) Secondary succession  
c) Climax  
d) Vegetative replacement

10. Which of the following terms describe the invasion by plants on land that was previously vegetated?

a) Primary succession  
b) Secondary succession  
c) Transition  
d) Climax

11. Which of the following terms describe the ultimate or final vegetative community in an ecosystem?

a) Primary succession  
b) Secondary succession  
c) Transition  
d) Climax

12. This is an organized list of plant diversity that is developed through a specific process of identifying plants and categorizing them according to their height and coverage.

a) Column  
b) Satellite Sampling  
c) Relevé  
d) Quadrat
13. Satellite imagery and aerial photographs can be most useful to identify which of the following?

   a) Conducting a Relevé
   b) Tracking Deer Populations
   c) Observing Urban Sprawl
   d) Measuring Biodiversity

14. Milk Weed is a critical vegetative plant to which of the species below?

   a) Prairie Chicken
   b) Lady Bug
   c) Pheasant
   d) Monarch Butterfly

15. Which of the following is NOT a function of vegetation in a habitat?

   a) Regulation of biogeochemical cycles (water, carbon, nitrogen)
   b) Providing food for secondary consumers
   c) Reducing soil erosion
   d) Providing shelter for animal species

16. Which of the following can be considered the greatest threat to biodiversity on the planet today?

   a) Habitat loss
   b) Pesticide use
   c) Water pollution
   d) Resource depletion

17. Which of the following vegetation types is the first to grow in primary succession?

   a) Shrubs
   b) Tree seedlings
   c) Weeds and grasses
   d) Lichens and moss

18. What are the first types of plants to grow in a newly formed area called?

   a) Primary species
   b) Angiosperms
   c) Pioneer species
   d) Invasive species
19. True or False: Yellowstone National Park has experienced secondary succession due to massive fires that burned through the area.

   a) True
   b) False

20. Which of the following terms describes the number of different plant species in a given plot?

   a) Species Richness
   b) Plant Abundance
   c) Shannon-Weiner Index
   d) Biodiversity Index
All Natural Flora Assessment

(Posttest)

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Agricultural Stewardship Module Assessment

(Pretest)

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1. Which of the following sustainability practices would have the most impact on conserving soil?
   a) Managing weeds with insects
   b) Using cover crops
   c) Converting manure to methane
   d) Removing invasive species

2. Which of the following is NOT a component of sustainable agriculture?
   a) Increasing profitability
   b) Increasing soil erosion
   c) Increasing productivity
   d) Conservation of natural resources
3. Which of the following is NOT one of three pillars to sustainable development?
   a) Economic growth
   b) Social equality
   c) Urban development
   d) Environmental protection

4. Which pillar of sustainable development refers to a good quality of life for the farmer and the community?
   a) Economic growth
   b) Social equality
   c) Urban development
   d) Environmental protection

5. Which of the following terms describe the capacity of an ecosystem to endure? In ecology the word describes how biological systems remain diverse and productive over time.
   a) Environmental Enhancement
   b) Conservation
   c) Sustainability
   d) Stewardship

6. This unsustainable farming practice occurred in the 1930’s and had negative environmental, social, and economic effects.
   a) Poor fertilizing use
   b) Poor irrigation use
   c) Poor tillage use
   d) Poor pesticide use

7. Using this along waterways can prevent soil erosion, fertilizer runoff, and can offer habitat for wildlife in agricultural areas.
   a) Buffer zone
   b) Conservation tillage
   c) Organic practices
   d) Integrated pest management
8. This type of sustainable agricultural production includes growing tees or shrubs around or among crops or pastureland.
   a) No-till farming  
   b) Agroforestry  
   c) Crop rotations  
   d) Riparian buffer zones

9. Agricultural pollution from fertilizer use would be classified as this type of pollution.
   a) Point-source pollution  
   b) Natural pollution  
   c) Turbidity pollution  
   d) Non-point source pollution

10. This type of pollution is the top cause of water quality impairment across the United States.
    a) Nutrient pollution  
    b) Point-source pollution  
    c) Oil spills  
    d) Factory emissions

11. What is the use of plants to absorb pollutants in the environment called?
    a) Abiotic remediation  
    b) Phytoremediation  
    c) Hypoxia  
    d) Bioreactors

12. Which of the following is NOT one of the 4 R’s in nutrient management?
    a) The right source  
    b) The right time  
    c) The right rate  
    d) The right crop

13. This term describes when the farmer does not till the soil at all, but plants seeds directly into undisturbed soil.
    a) No-till  
    b) Conservation tillage  
    c) Conventional tillage  
    d) Riparian tillage
14. This term describes the degree to which water loses its transparency due to the presence of suspended particles.

   a) Discharge  
b) Flow  
c) Turbidity  
d) Dissolved Oxygen

15. This type of tillage minimizes the frequency or intensity of tillage and leaves some crop residue from the previous year’s crop on top of the soil.

   a) No-till  
b) Conservation tillage  
c) Conventional tillage  
d) Riparian tillage

16. This program encourages agricultural producers to improve conservation systems by undertaking additional conservation activities and improving, maintaining, and managing existing conservation activities.

   a) Conservation Stewardship Program  
b) Consistent Sustainability Project  
c) Conservation Re-establish Program  
d) Agricultural Corps Program

17. Which of the following is NOT an example of a sustainable agricultural practice?

   a) Using riparian buffer zones in waterways  
b) Using efficient irrigation practices  
c) Using crop rotations when possible  
d) Using conventional tillage in areas that have steep hills

18. True or False: Planting soybeans one year and then corn the next year on the same plot of land would be considered a crop rotation.

   a) True  
b) False

19. Which of the following pillars of sustainable development refers to the long term profitability for the farmer or rancher?

   a) Economic growth  
b) Social equality  
c) Urban development  
d) Environmental protection
20. Which of the following 4 R’s of sustainable and efficient nutrient management would be described by the appropriate application amount?

a) The right source
b) The right time
c) The right rate
d) The right crop
Agricultural Stewardship Module Assessment

(Posttest)

**General Directions:** Welcome to the Agricultural Stewardship Module Postest. This is not a timed assessment and you may be graded on this assessment. You should mark an answer for each question. If you are unsure, try to answer the best you can with the information given. Only mark one answer for each question.

To start the assessment, please create and record you unique ID number in the box below. Your unique ID number is your school's abbreviation and your six-digit birth date. For example, a student attending Saint Johns High School (SJHS) born on July 31st, 2003 (07/31/03) would have the ID number "SJHS073103". Please record your ID number below.

**Student ID: ____________________________

Questions

1. Using this along waterways can prevent soil erosion, fertilizer runoff, and can offer habitat for wildlife in agricultural areas.
   
   a) Buffer zone  
   b) Conservation tillage  
   c) Organic practices  
   d) Integrated pest management

2. Which of the following is NOT one of three pillars to sustainable development?
   
   a) Economic growth  
   b) Social equality  
   c) Urban development  
   d) Environmental protection
3. This type of sustainable agricultural production includes growing tees or shrubs around or among crops or pastureland.

a) No-till farming
b) Agroforestry
c) Crop rotations
d) Riparian buffer zones

4. This unsustainable farming practice occurred in the 1930’s and had negative environmental, social, and economic effects.

a) Poor fertilizing use
b) Poor irrigation use
c) Poor tillage use
d) Poor pesticide use

5. Which of the following 4 R’s of sustainable and efficient nutrient management would be described by the appropriate application amount?

a) The right source
b) The right time
c) The right rate
d) The right crop

6. Which of the following sustainability practices would have the most impact on conserving soil?

a) Managing weeds with insects
b) Using cover crops
c) Converting manure to methane
d) Removing invasive species

7. Which of the following is NOT a component of sustainable agriculture?

a) Increasing profitability
b) Increasing soil erosion
c) Increasing productivity
d) Conservation of natural resources

8. Agricultural pollution from fertilizer use would be classified as this type of pollution.

a) Point-source pollution
b) Natural pollution
c) Turbidity pollution
d) Non-point source pollution
9. This type of pollution is the top cause of water quality impairment across the United States.
   a) Nutrient pollution
   b) Point-source pollution
   c) Oil spills
   d) Factory emissions

10. What is the use of plants to absorb pollutants in the environment called?
   a) Abiotic remediation
   b) Phytoremediation
   c) Hypoxia
   d) Bioreactors

11. Which of the following terms describe the capacity of an ecosystem to endure? In ecology the word describes how biological systems remain diverse and productive over time.
   a) Environmental Enhancement
   b) Conservation
   c) Sustainability
   d) Stewardship

12. This program encourages agricultural producers to improve conservation systems by undertaking additional conservation activities and improving, maintaining, and managing existing conservation activities.
   a) Conservation Stewardship Program
   b) Consistent Sustainability Project
   c) Conservation Re-establish Program
   d) Agricultural Corps Program

13. Which of the following is NOT one of the 4 R’s in nutrient management?
   a) The right source
   b) The right time
   c) The right rate
   d) The right crop
14. This term describes when the farmer does not till the soil at all, but plants seeds directly into undisturbed soil.
   a) No-till
   b) Conservation tillage
   c) Conventional tillage
   d) Riparian tillage

15. This term describes the degree to which water loses its transparency due to the presence of suspended particles.
   a) Discharge
   b) Flow
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   d) Dissolved Oxygen

16. Which pillar of sustainable development refers to a good quality of life for the farmer and the community?
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17. This type of tillage minimizes the frequency or intensity of tillage and leaves some crop residue from the previous year’s crop on top of the soil.
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**Agricultural Stewardship Module Assessment Key**

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## APPENDIX P
### CORRELATIONS FOR IBI AND DI GROUPS

#### Correlations between variables for group receiving IBI as treatment

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LIST OF REFERENCES


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BIOGRAPHICAL SKETCH

Blake C. Colclasure grew up in Mahomet, IL. His initial exposure to agriculture was through his first job, detasseling corn. His passion for agricultural education was sparked during his freshman year of high school by his agriculture teacher, Mrs. Lindi Kocher. At Mahomet-Seymour High School, Blake became an active member of FFA, competing in Career Development Events and serving as an FFA officer.

Following in his brother’s footsteps, Blake attended Parkland Community College. He received his associates of science in agriculture and transferred to the University of Illinois. At the U of I, Blake majored in Agriculture and Environmental Science Communication and Education, with a focus in agriculture teacher certification. Shortly after completing his bachelor degree, Blake started a school-based agricultural education program in Steeleville, Illinois.

At Steeleville High School, Blake became known by his students as Mr. Colclasure or coach. In addition to growing a new agricultural education program and establishing an FFA chapter, Blake coached high school basketball, track, and cross country. In three short years, student enrollment in the new agriculture program grew to serve nearly 75% of the school’s students. During his time teaching, Blake earned a master’s degree from the University of Illinois in Environmental Sciences and Natural Resources.

Blake came to the University of Florida in the fall of 2015 to complete a Ph.D. in Agricultural Education and Communication. He accepted a graduate teaching and research assistantship within the Department of Agricultural Education and Communication, where he taught and assisted with various agricultural education courses in the department. Blake’s commitment to high quality teaching was evident. He
received the North American Colleges and Teachers of Agriculture Graduate Student Teaching Award in June 2018. In addition to teaching, Blake was an active member of the Agricultural Education and Communication Graduate Student Association and Alpha Tau Alpha. Furthermore, while at the University of Florida, Blake enjoyed designing and delivering professional development workshops to practicing agriculture and science teachers across Florida. Blake graduated with his Ph.D. from the University of Florida in the summer of 2018.